TREPANATION

History, Discovery, Theory

Edited by

ROBERT ARNOTT

Centre for the History of Medicine, The Medical School, University of Birmingham, UK

STANLEY FINGER

Department of Psychology, Washington University, St. Louis, Missouri, USA

C.U.M. SMITH

Aston University, Birmingham, UK

With the Support of

BOLESLAV LICHTERMAN

Postgraduate Medical Academy, Moscow, Russia

RUPERT BREITWIESER

Institute for Ancient History, University of Salzburg, Austria

SWETS & ZEITLINGER PUBLISHERS

LISSE ABINGDON EXTON (PA) TOKYO

Also available as a printed book
see title verso for ISBN details

TREPANATION

TREPANATION
History, Discovery, Theory

Edited by

ROBERT ARNOTT

Centre for the History of Medicine, The Medical School, University of Birmingham, UK

STANLEY FINGER

Department of Psychology, Washington University, St. Louis, Missouri, USA

C.U.M. SMITH

Aston University, Birmingham, UK

With the Support of

BOLESLAV LICHTERMAN

Postgraduate Medical Academy, Moscow, Russia

RUPERT BREITWIESER

Institute for Ancient History, University of Salzburg, Austria

SWETS & ZEITLINGER
PUBLISHERS

LISSE ABINGDON EXTON (PA) TOKYO

This edition published in the Taylor & Francis e-Library, 2005.

"To purchase your own copy of this or any of Taylor & Francis or Routledge's collection of thousands of eBooks please go to www.eBookstore.tandf.co.uk."

Library of Congress Cataloging-in-Publication Data

Applied for

Copyright © 2003 Swets & Zeitlinger B.V., Lisse, The Netherlands

All rights reserved. No part of this publication or the information contained herein may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, by photocopying, recording or otherwise, without written prior permission from the publishers.

Although all care is taken to ensure the integrity and quality of this publication and the information herein, no responsibility is assumed by the publishers nor the author for any damage to property or persons as a result of operation or use of this publication and/or the information contained herein.

Published by: Swets & Zeitlinger Publishers
www.szp.swets.nl

ISBN 0-203-97094-2 Master e-book ISBN

ISBN 90 265 1923 0 (Print Edition)

Contents

Part 3: Trepanation in Africa, Asia and The Americas

Part 4: Trepanation in Western Medicine

Part 5: Global Perspectives and Future Research

"I have the honour to present to the Academy an ancient Peruvian skull on which trepanning was performed during the lifetime of the individual"

Paul Broca, 1867

Preface

After examining the pre-Columbian skull sent to him by United States diplomat to Peru, E. G. Squier, in 1867, French surgeon-anthropologist Paul Broca astounded the world of science and medicine by suggesting that the cranial opening was the result of some form of prehistoric surgery. Moreover, the Inca on whom the procedure had been performed had survived the ordeal by a few weeks.

This was not the first reported example of a man-made opening of a skull, nor was it by any means the earliest. But it was the first case of trepanation to be correctly identified, interpreted, and accepted, and as such it made people think about why the skulls of living people were opened in the distant past.

Clearly, the Squier skull marked the start of serious study and intense fascination with trepanation. Within a few decades, scholarly (and sometimes not so scholarly) contributions were beginning to fill the journals. This growth has continued to accelerate and researchers today are by any standard exceedingly prolific. In 1975 Guido Majno remarked that the number of papers on the subject of cranial trepanation probably exceeds the number of specimens known throughout the world! Today, even with more skulls unearthed, we would be pressed to think of the multiple.

Despite the exponential growth of research on this subject, something important has been lacking. Simply put, there is little cohesion. The study of cranial trepanation has, over the years, gone in many different directions, and the leading scholars now actively involved represent many regions, disciplines, and approaches. These diverse researchers, historians, and theorists, however, have rarely come together, never mind engaging in a large group discussion to consider common problems and future directions for the field. The need for more interaction, more cooperation, and a fruitful exchange of ideas was apparent to all of the editors of this volume. The "time had come", we all agreed, for research on cranial trepanation to be taken forward.

This volume arises out of the first International Colloquium on Cranial Trepanation in Human History, which was held at the University of Birmingham (UK) between the 7th and the 9th of April, 2000. The idea for this much-needed colloquium was conceived by Robert Arnott of the Department of Ancient History and Archaeology (now of the Centre for the History of Medicine) of the University of Birmingham. It was officially supported by the International Society for the History of the Neurosciences, the Institute of Ancient History of the University of Salzburg (Austria), and the Russian Postgraduate Medical Academy (Moscow).

The conference was truly an international gathering, as had been hoped for by the organizers, bringing together 89 scholars from 16 countries across four continents. Before Birmingham, many of these scholars had not only never met each other, but in some cases had never even heard of each other's work. Taking the podium with slides too numerous to count were archaeologists, anthropologists (physical and social), pathologists, anatomists, surgeons, historians of medicine, and others with their own specializations. The material they described (all papers were in English) ranged chronologically from the Epipaleolithic Ukraine to eighteenth-century Germany. Geographically they not only covered the rich terrains of Eastern and Western Europe and the

New World, but also recent finds from Polynesia and even Mongolia.

Many participants addressed the features of crania and theorized about the pathological conditions that might have led to the surgery. But there were also discussions about the evolution of instruments and thoughtful reassessments of specimens studied in the past and the methodologies used. The doyen of British paleopathology, Don Brothwell, fittingly closed the symposium by telling those in the audience where, from his perspective, new efforts should be directed.

Because there had not been a book providing an extensive, up-to-date overview or synthesis of our understanding of cranial trepanation in human history, it was decided early on that the material presented at the Birmingham conference should be edited and published under one cover. Our intent was not only to serve laboratory and field scientists, but to provide a balanced volume on cranial trepanation for any professional or layman who might have an interest in this fascinating subject.

The opening chapters in this volume deal with how trepanned skulls were initially found, and the theories that some of the most fertile minds of nineteenth-century science and medicine (e.g., Squier, Broca, Pruniéres, Horsley) had about the operation. After a discussion about the pathology of trepanation, attention is drawn to discoveries made in various European countries (e.g., Great Britain, Denmark, Portugal, Austria, Russia). Subsequent sections of the book deal with the revelations stemming from new and older discoveries made in Egypt, Asia, and throughout the vast territory of the Americas.

Once this global tour is completed, the history of trepanation in Western medicine is addressed. Chapters in this section deal with Galen, who trepanned skulls in ancient Rome, Lorenz Heister, a German physician called upon to trepan patients in the eighteenth century, and the history of cranial saws and related instruments. Some global perspectives and overviews are provided in the next section of this volume, and these are followed by Brothwell's fitting epilogue on future directions for researchers in this field.

Among the ideas that came out of this multidisciplinary meeting was a need to build a common terminology. One of the areas discussed was the fundamental point of whether "trepanation" or "trephination" should be used. Medical and etymological dictionaries were consulted, but they provided little definitive help; many English dictionaries, in fact, preferred "trephination" to the probably more commonly used word "trepanation".

Della Cook (2000) has explored the background of the two competing words and, with the support of the Oxford English Dictionary (1971 edition), points out that "trepan" was first used in about 1,400 AD to describe a crown saw employed as a surgical instrument. The word, we read, derives from the Greek *trepanon*, a borer.

The first use of the newer word "trephine" is often thought to be by John Woodall, sometime Master of the Company of Barber-Surgeons of London (Woodall, 1639). Stedman's dictionary (1982, p. 1478) provides an etymology for "trephine". We are told that it is "… contrived fr[om] L. tres fines, three ends; probably suggested by trepan.". Woodall actually wrote: "The Trefine is an instrument of mine owne composing although it may be said to be a derivative or Epitomy of or from the Trepan upon it (a tribus finibus) from the three ends thereof.". Hence, although Woodall did not invent the instrument, he certainly described it and is probably most responsible for passing the word trephine into common English usage (Grmek, 1975; Cook, 2000).

The question we were forced to ask ourselves was "Does it matter whether "trepan" and "trepanation" or "trephine" and "trephination" are used? Perhaps it does not. There are many papers published using both forms of the word, and no meaning is lost. Nor is there any possibility of misunderstanding. From this perspective, although perhaps not to the purist, the usage of "trepanation" and "trephination" is a quaint language diversity that probably can be indulged. Nevertheless, most of the contributors to this volume do show a preference for "trepanation", which is older and perhaps has become the more generic form of the word.

So, where are we now and what are some of the more important conclusions reached by the authors of the many chapters in this volume? First of all, the data show that trepanation was surprisingly more widespread than many people had previously believed. In addition, although Neolithic trepanation in France and pre-Columbian trepanation in Peru have received most of the press, the roots of trepanation seem to extend further back into antiquity than is often realized.

As for the specific reasons for birth and success of trepanation, they may be many. The general belief is that, as Squier, Broca, Pruniéres, and Horsley suggested during the second half of the 1800s, it was probably a therapeutic intervention. This, of course, is not to deny that the practice could also have had religious overtones or served some social purpose. But the consensus is that it probably evolved as a means to treat head injuries or perhaps diseases that people of the distant past might have associated with supernatural forces.

Today, there are still many areas in the trepanation domain that need further work, including validating currently accepted theories for trepanation in the distant past. Chronology and dating are two additional issues that call for further refinements and improvements. Still another perplexing matter is the thorny problem of how trepanation seemingly diffused from one society to another.

Happily, a start has now been made. As witnessed at the Birmingham conference, and as will be seen in the chapters of this volume, there is now a great resolve to carry out further interdisciplinary research. New projects in the field and in the laboratory, and new theoretical and historical work, will undoubtedly take us in unforeseen directions. Without question, when researchers interested in trepanation meet again - and they will - they will certainly have much more to talk about. It is gratifying to think that some of it will have been stimulated by what transpired in the auditorium and afterward in Birmingham.

Finally, no international conference can be organised, never mind a successful conference, without a dedicated team of supporters. The organizers of the Birmingham conference and the editors of this book wish to thank Siân Williams and the rest of the team on the ground at the University of Birmingham, which included Tikshna Mandal and a band of enthusiastic student helpers, for their help. The meeting could not have happened without them or the generous help and support of the Head of the Department of Ancient History and Archaeology, Professor John Hunter.

We also wish to acknowledge the following organizations for their financial support and help: The University of Birmingham, Birmingham City Council, Forth Medical Limited, and the Bioanthropology Foundation. Thanks also go to Arnout Jacobs and Laura Martin of our publisher, Swets and Zeitlinger, for their efforts and gentlemanly reminders (to one of us!) to deliver all the manuscripts, as promised, by autumn of 2001.

All of the people mentioned here, but most of all the talented, dedicated, and scholarly contributors to this volume, made the book you see in front of you both possible and, in our estimation, worthwhile. We hope it stimulates your imagination as much as it did ours, and that it is a harbinger of exciting things to come.

Robert Arnott
Stanley Finger
C.U.M. Smith

References

—— (1982): *Illustrated Stedman's Medical Dictionary*, 24th Edition, Baltimore, Williams and Wilkins.
Cook DC (2000): Trepanation or trephination? The orthography of palaeopathology. *Paleopath Newsletter 109*: 9-12.
Majno G (1975): *The Healing Hand: Man and Wound in the Ancient World*, Cambridge, MA, Harvard University Press.
Woodall J (1639): *The Surgeons Mate for Military and Domestique Surgery*, London, Rob. Young for Nicholas Bourne.

Part 1: Trepanation: Discovery and Palaeopathology

"*We practiced during the neolithic epoch a surgical operation that consisted of opening the cranium . . .*"

Paul Broca, 1876

Chapter 1

Ephraim George Squier's Peruvian Skull and the Discovery of Cranial Trepanation

HIRAN R. FERNANDO AND STANLEY FINGER
Department of Psychology, Washington University, St. Louis, Missouri, USA

Abstract

During the 1860s, Ephraim George Squier obtained the frontal and facial portions of an old Peruvian skull with an odd, rectangular opening on the top. Convinced that the opening was made by human hands on a living person prior to the European conquest, Squier presented the skull to members of the New York Academy of Medicine and then to Paul Broca in Paris. Although some ancient trepanned skulls had been found prior to this time in Europe and Peru, the earlier specimens had not been interpreted correctly, and hence generated little excitement. In contrast, there was no doubt about the man-made openings or the general time period of the Squier specimen. In this context, we provide biographical information on Squier, his own story of how he obtained the skull, the notes describing its reception at the New York Academy of Medicine, a complete English translation of Broca's 1867 report on the skull, and some additional comments made in 1877 by Squier and Nott on why trepanation might have been performed by the Incas.

Keywords: Squier, Broca, Nott, Peru, fracture, Inca, Pre-Columbian trepanation, Cuzco

Introduction

No specimen has figured more prominently in the history of cranial trepanation than the Inca skull shown in Figure 1. Obtained in the Cuzco region of Peru, and dated between 1,400 and 1,530 AD, the incomplete skull (posterior and interior portions are missing) was brought to the United States in 1865 by Ephraim George Squier (1821–1888). It is presently a part of the physical anthropology collection of the American Museum of Natural History in New York City.

Squier's Peruvian specimen caused an immediate sensation in the United States and in Europe. Nothing quite like it had been seen before, and prior to this time nobody had seriously entertained the idea that cranial surgery could have been performed by "primitives" or "savages" prior to the European conquest. Unlike previously discovered trepanned skulls, which had routinely been dismissed or misinterpreted, this was a "pre-Columbian" specimen with cross-hatched cuts that could only have been sculpted by the hands of man, and not by gnawing animals, weapons of war, or the forces of nature itself.[1] Moreover, the skull belonged to an individual who seemed to have survived the surgery by about two weeks – the opening did not appear to have been made after the time of death.

Brief mention on how Squier obtained this skull, how it was received at the New York Academy of Medicine, and what Paul Broca (1824–1880), the leading anthropolo-

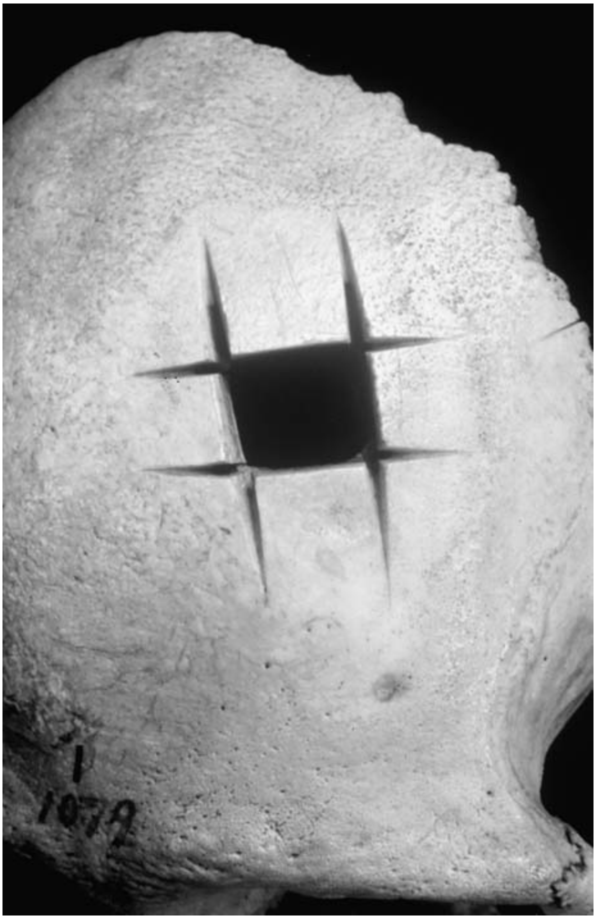


Figure 1. The Inca skull obtained by Squier with its rectangular trepan opening.

gist of the day, thought about it, can be found in many review articles and chapters that begin with a paragraph or two on the history of trepanation. Yet given the landmark status of this cranium, it is surprising that little has been written about Squier, the man behind the skull, and also that the original early documents about his specimen have not been collected for presentation in one readily accessible place.

With this in mind, we shall now present: 1. biographical information about Squier, 2. Squier's story of how he came across the Inca skull, 3. the minutes from 1865 meeting of the New York Academy of Medicine, where the skull made its North American debut, 4. a complete translation of Broca's 1867 report on seeing it, and 5. some additional thoughts by Squier and Josiah Nott (1804–1873) on why skulls might have been trepanned long ago in South America.

Ephraim George Squier

Ephraim George Squier was born on 17 June, 1821, in the town of Bethlehem, Albany County, New York (for biographical information, see anonymous, 1850; Finger and Fernando, 2001; Seitz, 1911; F. Squier, 1939). He proudly traced his lineage back to Samuel Squier, friend, auditor, and lieutenant of Oliver Cromwell (1599–1658), whose son emigrated to Boston. His own father was a Methodist Episcopal clergyman of limited finances, who resided in Connecticut.

As a youngster, Squier attended rural schools and educated himself, while also working on the family farm during summer vacations. He became a teacher and then qualified as a civil engineer. When engineering became unprofitable as a result of the Panic of 1837 and the recession that followed, he moved to Albany, New York and turned to journalism. He became a writer for local newspapers (e.g., *The Literary Pearl* in 1840–41, *Lady's Cabinet Magazine* in 1841–42) and started *The Poets' Magazine* in 1842.

Squier now began to involve himself in politics. His favorite subject was prison reform, and he wrote many articles in *The New York State Mechanic* to promote this cause. Once a successful outcome was achieved, this periodical, which was established solely to improve prison conditions, was terminated.

Squier's first book dealt with the people of China and was stimulated by the British occupation of Canton. It bore the title *The Chinese as they Are* and appeared in 1843. A year later, he established the *Whig Daily Journal* in Hartford, Connecticut, and used this periodical to support Henry Clay (1777–1852), a Whig, for the presidency. When Martin Van Buren (1782–1862) defeated Clay (who had won the State of Connecticut) and became president, Squier moved again, this time to Chillicothe, Ohio. There, in 1845, he became editor of the Scioto *Gazette* (the oldest paper west of the Allegheny Mountains). A year later he was elected Clerk of the Ohio House of Representatives.

The ancient Indian mounds in Ohio attracted Squier's attention and sparked what would become an enduring interest in ancient cultures. In 1847 he published a small book on the mounds, and a year later gave up his other responsibilities to devote more time to his archeology. It was with local physician and amateur archeologist Edward Hamilton Davis (1811–1888) that Squier wrote *Ancient Monuments of the Mississippi Valley.* This impressive work of over 300 pages appeared in 1848. It was followed one year later by *Aboriginal Monuments of the State of New York.* This time, however, Squier was the sole author.

Figure 2 shows Squier as he looked in 1849. With regard to his personality, he was then described as cheerful, self-reliant, "facile and agreeable" in speaking and writing, and contemptuous of "exterior and superficial distinctions" (Anon., 1850, p. 347).

Zachary Taylor (1784–1850), a political Whig, became the twelfth president of the United States in 1848. On 2 April, 1849, Squier was rewarded for his efforts in Taylor's campaign. Thanks to the help of some of his friends, he was given the position "Chargé-d'Affaires of the United States to the Republics of Central America." This position, the first diplomatic appointment made by Taylor, not only allowed Squier to travel as a diplomat and represent his country, but also afforded him the opportunity to study the history of Central America and its many cultures first hand.

Squier served his government in Nicaragua, Honduras, San Salvador, and neighboring

Figure 2. Ephraim George Squier (1821–1888) as he appeared in 1849. (From F. Squier, 1939.)

countries until 13 September, 1850, and was praised in Washington for his expertise on Central America. He also managed to write many articles about the region, its people, history, and its commercial importance for the United States. His hefty, two-volume *Travels in Central America* appeared in 1852, *Notes on Central America* in 1855, and *Waikna; Or Adventures on the Mosquito Shore* made its debut in 1855. The latter was his only work of fiction and the only one in which he used a pseudonym (Samuel A. Bard). Five years later he published *Nicaragua: Its People, Scenery, Monuments, Resources, Condition, and Proposed Canal*.

While the American Civil War was raging, President Abraham Lincoln (1809–1865) gave Squier the position of "Member Mixed Commission under Claims Convention of Jan. 12, 1863, between United States and Peru." Squier subsequently served in Peru between 17 July, 1863 and 27 November, 1863. Once his diplomatic assignment was completed, Squier began to gather additional material for yet another book. He would later write:

> It was on the conclusion of my duties as Commissioner that I commenced my explorations in Peru; explorations directed mainly to the elucidation of its aboriginal monuments, the only positive and reliable witness of the true condition of its ancient inhabitants. My travels and investigations occupied me actively for more than a year and a half. During that time I prob-

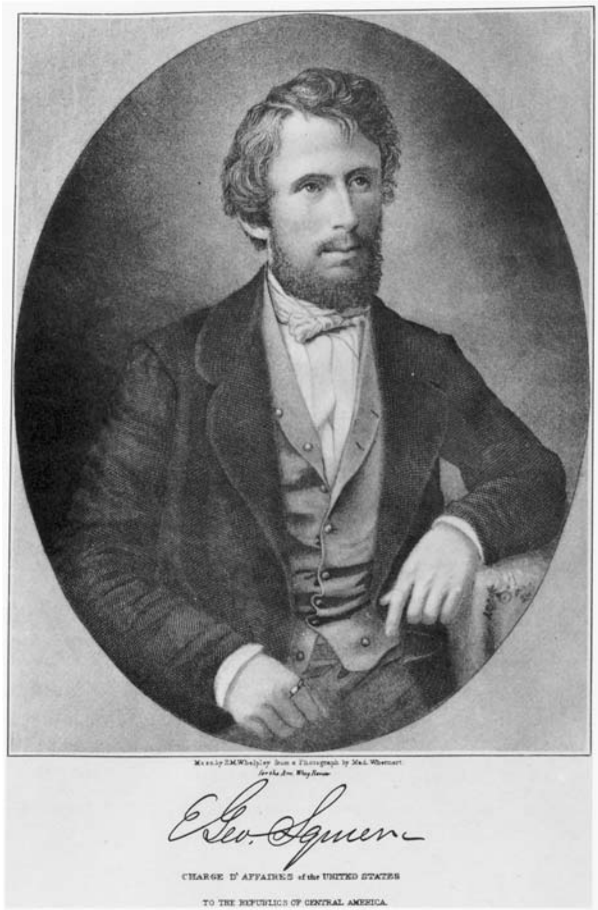


Figure 3. E. G. Squier in the late 1860s. (From F. Squier, 1939.)

> ably went over more ground than any of my predecessors in the same field. (Squier, 1877, p. 3).

Being a diplomat, writer, historian, scientist, and man of culture, Squier was invited to visit the home of a wealthy woman in Cuzco. It was at her home that he encountered the now-famous Inca skull with the rectangular trepan opening. He described the skull and provided an illustration of it in *Peru: Incidents of Travel and Exploration in the Land of the Incas,* his 599-page book of 1877 (there was also a German edition in 1883).

In 1869 Squier became Consul for Honduras. Figure 3 shows a portrait of Squire from this period of his life. His remaining years, when not travelling, were spent in New York, where, among other things, he wrote *Honduras, Descriptive, Historical and Statistical,* which was published in 1870.

Squier apparently suffered a mental breakdown during the 1870s, following his divorce from "Minnie" (F. Squier, 1939). Nevertheless, he was still able to publish *Hondu-*

ras and British Honduras in 1880 and edit Frank Leslie's highly successful *Illustrated Weekly* until 1881. He died in Brooklyn on 17 April, 1888. Fifty-one years later, an annotated list of his known books and articles was published (F. Squier, 1939).

In addition to his distinguished diplomatic record and extensive accomplishments as a writer,[2] Squier had served as president of the Anthropological Institute of New York and was an active or honorary member of many scientific societies. The latter included the American Ethnological Society, the Academy of Natural Sciences of Philadelphia, the American Association for the Advancement of Science, the Historical Societies of New York and Massachusetts, the Archaeological Institute of London, the Society of Antiquities of France, and the Royal Society of Antiquities of Denmark. He also held several honorary degrees, the first coming from Princeton College in 1848.

Alexander von Humboldt (1769–1859), the doyen of German science with whom he communicated in writing, could well have written Squier's archeological epitaph. In his words: "With Dr. Morton's *Crania Americana*, the work of Mr. Squier constitutes the most valuable contribution ever made to the archaeology and ethnology of America" (Anonymous, 1850, p. 350).

Squier on How He Encountered the Inca Skull

In his lengthy monograph on Peru, Squier wrote the following about his discovery of the trepanned skull and its significance:

> Seven-eighths of the population of Cuzco are pure Indians … . The white and foreign population is small, made up chiefly of government officials, a few wealthy *haciendados*, who live a great part of the time on their estates, and a dozen or so *comerciantes*, who would be called shop-keepers in any other country. . . . Some of the old families live in considerable style, and their houses are fitted with real elegance. . . .
>
> I may refer particularly to the residence of the late Señora Zentino, a lady who lived on the Plaza of San Francisco, whose attention to strangers was proverbial, and who established an honorable reputation as the collector of the finest and most valuable museum of antiquities in Peru. This house would be called a palace even in Venice, if not in architecture, certainly in extent. In the spaciousness of its apartments, and their rich and varied contents and decorations, it would creditably compare with some of the finest on the Grand Canal. The señora gave some very amusing accounts of Castelnau and other travellers, and especially of a Frenchman named Lorenzo Saint Criq, who, under the name of "Paul Marcoy," published, after a lapse of many years, a description of Cuzco and other parts of Peru. An adequate description of the museum would occupy a volume, and I content myself with engravings of some pieces of pottery selected from many hundreds, illustrating the skill of the ancients in the plastic arts, and their appreciation of humor.
>
> In some respects, the most important relic in Señora Zentino's collection is the frontal bone of a skull, from the Inca cemetery in the valley of Yucay, which exhibits a clear case of trepanning before death. The señora was kind enough to give it to me for investigation, and it has been submitted to the criticism of the best surgeons of the United States and Europe, and regarded by all as the most remarkable evidence of a knowledge of surgery among the aborigines yet discovered on this continent; for trepanning is one of the most difficult surgical processes. The cutting through the bone was not performed with a saw, but evidently with a

> burin, or tool like that used by engravers on wood and metal. The opening is fifty-eight hundredths of an inch wide and seventy hundredths long. (Squier, 1877, pp. 455–457).

In addition, at the start of Appendix A, we find:

"The trepanned skull mentioned on page 457 was taken from an Inca cemetery in the valley of Yucay, within one mile of the "Baths of the Incas. There is no doubt of its ante-Colombian date." (p. 577)

The New York Academy of Medicine

Squier took the trepanned skull to New York, where Dr. August K. Gardner (1821–1876) displayed it at the New York Academy of Medicine. The brief committee report in the *Bulletin of the New York Academy of Medicine* from 6 December, 1865, reads:

> Dr. Gardner also exhibited the calvarium of one of the Inca tribe of South America, which, according to reliable accounts from Mr. Squier, the American minister, who had much interested himself in the collection of such relics, dated back anterior to the time of Columbus. The skull showed that during the patient's life an operation for trephining had been performed, a square-shaped piece of bone having been removed from the frontal bone, by what would appear to have been a gouging instrument. At one portion of the opening there seemed to be evidence of the attempt on the part of nature to form new bone, to repair the injury done by the operation. (p. 530)

Evidently, there was some disagreement over the last statement, namely that the bone showed signs of healing. This difference of opinion is apparent from next sentence, which reads: "Dr. Post stated that he did not see any of the evidence of the reparative process sufficiently marked to decide positively that the operation was not performed after death." (p. 530)

The written minutes conclude by noting that Gardner nevertheless felt certain that there was some healing, which was in accord with the position taken by Squier: "Dr. Gardner remarked that the appearances to which he referred were more easily discernible during the daytime than by gas-light." (p. 530)

The meeting was then adjourned.

Broca and the Skull

It is not surprising that the skull was soon shown to Paul Broca, who had recently achieved great fame for his research on the language and cortical localization. He had also founded the *Société d'Anthropologie de Paris* in 1859, the first formal organization of its type. Regarded by some as a founder of modern anthropology, Broca not only had a strong interest in human prehistory and the family of man, but he was also a practicing surgeon, a dominant figure in the world of medicine, and a fair-minded person whose opinions were very highly valued.[3]

There is no question that Squier thought of Broca as a great authority on skulls. For his part, Broca also thought highly of Squier. When presenting the skull to his colleagues in Paris in 1867, Broca referred to Squier as "the most renowned, archeologist in America" (Broca, 1867a, p. 404).

Broca's opinions about the skull appeared in two places in 1867. In the *Bulletins de la Société d'Anthropologie* it bore the title *Cas singulier de trepanation chez les Incas*. In the *Bulletin de l'Academie de Médecine,* the title was *Trepanation Chez les Incas*. The two articles are identical in all but one respect, the opening words. In the former, they are: "Mr. Broca has presented to the Society an ancient Peruvian skull... ", whereas in the latter we find "I have the honor to present to the Academy an ancient Peruvian skull."

Because Broca's comments on the Inca skull have not been translated into English in their entirety (Squier, in 1877, translated sections of Broca's report in his Appendix A), we here present a complete translation of Broca's paper from 1867, using the opening words from the *Bulletin de l'Académie de Médecine.*

> I have the honor to present to the Academy an ancient Peruvian skull on which trepanning was performed during the lifetime of the subject, following a procedure entirely different from that which is used in European surgery.
>
> Trepanning is one of the oldest surgeries; it is mentioned by Hippocrates, who considers it to be a routine operation but seems unaware of its origin. Similar to today, [ancient Greek] trepanning was carried out by means of a crown shaped saw, driven by a rotational movement. Nothing indicates that the Greeks or their ancestors ever practiced this operation any differently.
>
> In the Peruvian cranium, trepanning was performed not by means of a circular section, but with a squared section, limited by four rectilinear incisions.
>
> Documents known up to now had not established the existence of a routine surgery among indigenous Americans before European settlement. The artifact now presented thus has revealed a completely unexpected fact and it is necessary, above all, to demonstrate its authenticity. The name of the scientist who discovered it, and who agreed to entrust it to me, provides us, in this respect, with all the guarantees desirable. Mr. Squier is the most renowned archeologist in America. He is a specialist in Peruvian antiquities, and his high level of competence cannot be questioned. Here is a translation of the note he gave me:
>
> "This cranium was exhumed from an Inca cemetery in the valley of Yucay, twenty-four miles to the east of Cuzco (Peru). This cemetery is located one mile outside the "Inca Baths," a favorite stay and countryside residence for the royal family. There is no possible doubt that this cranium dates to the pre-Colombian era. The obviousness of sound authenticity is complete."
>
> The walls of the skull are very thick, and they present characteristics that could only belong to an Indian of Peru.
>
> I shall now proceed to show that the trepanning was practiced during life.
>
> On the lateral portion of the right frontal bone there is a large white spot, quite regular, almost round, or rather slightly elliptical, 42 millimeters wide and 47 long. The outlines of this spot are not by any means sinuous. The surface is smooth and presents the appearance of entirely normal bone. Around this, to the edges, the coloration of the bone is notably darker; it is riddled with a great number of small holes caused by dilation of the small osseous canals. The line of demarcation between the smooth and the cribriform surfaces is abrupt; it is quite certain that the smooth surface had been denuded of its periosteum several days before death. In effect, this is how denudations of the cranium react. In the denuded points, the superficial

layer of the external table, deprived of vessels, and similarly deprived of life, undergoes no change and preserves its normal structure; while the surrounding parts, undergoing the effects of traumatic inflammation, become the seat of osteitis.

After considering the development of these perforations of the external table of the denuded surface it seems to me impossible to admit that the subject could have survived the denudations less than seven or eight days. Monsieur Nélaton, who carefully examined the specimen, thinks he may have survived fifteen days.

The trepanning was performed in the centre of the denuded part; but the four incisions, which circumscribe the removed portion, extend at their extremities to the very limits of the denudation. From this, it is certain that the separation of the periosteum was produced by the surgeon who performed the operation, for the denudation, more regular than it could be as the result of an accident, presents exactly, neither more nor less, the dimensions and form necessitated by the operation which has been performed on the bone.

The operation consists of four linear incisions in parallel pairs. Two are vertical; the other two are horizontal. At their intersection there is the square opening, or rather a rectangle, 15 millimeters long and 17 wide. The rectangular portion of the bone included within the lines was entirely removed down to the dura mater, and the result is a loss of bone, whose absolute extent corresponds very closely to that produced by our own circular trephines of ordinary size.

In the middle part, the four incisions in the bone occupy its entire thickness, which at this point is 6 millimeters; beyond the limits of the removed portion they become more and more superficial and terminate in a slight depression on the surface of the bone at the limits of the denudation.

The width of the incisions is about 2 millimeters in the middle and superficial part. This width diminishes in the deeper parts, so that the bottoms of the cuts become linear: it diminishes in the same way in approximation to the extremities of the incisions.

It is interesting to determine the nature of the instrument used in this operation. A shield-shaped saw, analogous to that which is used by anatomists, could produce effects not very different from those which I have described. Mr. Squier, to whom I initially made these suggestions, showed me a full scale drawing of a shield-shaped instrument, and its outline would coincide exactly with the base of our four incisions. On the one hand the instrument is not serrated; on the other hand, while studying the edges of the incisions, one would conclude that they were made by a pointed instrument, a large graver, for example, or simply the tip of a knife. What still confirms this opinion is that, on the other side at the surface of the bone, there appear several linear stripes that detach themselves at very acute angles from the ends of the three incisions. They are obviously due to slippage of the instrument at the beginning of the operation, before the furrow became deep enough to prevent such deviations.

In accord with this, it is apparent that each incision required much time – especially if one believes that the Peruvians knew of neither steel nor iron, and that their best metal was bronze.

There is evidently no resemblance between this mode of trepanning and Indo-European surgery, which has been known for a long time. This is not, however, the first time that we have shown how different the first sources of industry, the sciences, and the arts were between America and the Old World.

In concluding, I call attention to one last question. For what motive was the trepanning performed? There is no fracture or fissure of either external or internal table. We notice, it is true, on the internal table several very delicate linear cracks. But these present all the ordinary characters of those produced by time, which are found in the majority of old crania. There was, then, no fracture; and the surgeon who performed the operation could consequently only be governed by functional troubles when diagnosing the existence of an intra-cranial lesion. Was this diagnosis correct? Did the operation succeed in evacuating a fluid poured into the

> cranium? I am far from affirming this, but am tempted to believe it. In effect, the internal table around the opening is the seat of a very different alteration from that which existed on the external table around the denudation. It is the seat of little porosities in patches, which attest to the existence of osteitis. But this does not seem to have been the result of the trepanning, because it is not at all regularly distributed around the opening. It is entirely missing above the opening, it is minimal below, a little better marked on the outside, and is only really well pronounced about a centimeter and a half on the inner side of the internal border of the opening. These peculiarities and several others, which would take too long to detail, are well explained, if we suppose that there had been for some days before the operation an effusion of blood under the dura mater.
>
> What astonishes me is not the boldness of the operation, as ignorance is often the mother of boldness. To trepan on an apparent fracture at the bottom of a wound is a sufficiently simple conception and does not necessitate the existence of advanced surgical arts. But here the trepanning was performed on a point where there was no fracture, and probably not even a wound, so that the surgical act was preceded by a diagnosis. Whether this diagnosis was correct, as is probable, or false, we are in either case authorized to conclude that there was in Peru, before the European era, a surgery already very advanced – and this entirely new notion is not without interest for American anthropology. (pp. 403–408)

At the end of the same report in the *Bulletins de la Société d'Anthropologie* we find: "Mr. Leguay: By carefully examining the incisions, their form, their aspect, and the inequalities they present, I think, like Mr. Broca, that they were made using a metal burin [graver]." (p. 408)

Nott and Squier on the Reason for Trepanation

The Peruvian skull had caused such a sensation in France that when, ten years later, Squier published *Peru: Incidents of Travel and Exploration in the Land of the Incas* (1877), he included, as notes Appendix A, two additional commentaries on why the operation on the skull might have been performed.

One note was from Josiah Clark Nott (1804–1873), an American authority on skulls (Horseman, 1987), and the other note was Squier's own. Nott believed that the operation on Squier's Peruvian skull was necessitated by a puncture wound. Squier, having examined Peruvian spear and arrow heads first hand, agreed that a sharp, pointed instrument could have provided a sound medical reason for trepanation in Peru.

Nott, shown in Figure 4, was a physician from Alabama who went to school in South Carolina and Philadelphia but also studied in Paris. He was a recognized ethnologist and a man who wrote extensively on skull features. He was guided by a firm belief in White racial superiority, and he contended that the Bible did not adequately deal with racial diversity. Nott shared these views with Samuel George Morton (1799–1851), the skull collector and author of *Crania Americana* (1839) and *Crania Aegyptiaca* (1844), with whom he became close friends. Today Nott is best remembered for writing *Types of Mankind* (1854) and *Indigenous Races of the Earth* (1868) with George Robins Glidden (1809–1857), an Egyptologist with similar racial views who was also interested in the study of skulls.[4]

Note 1 (source not given), from Nott, reads as follows:

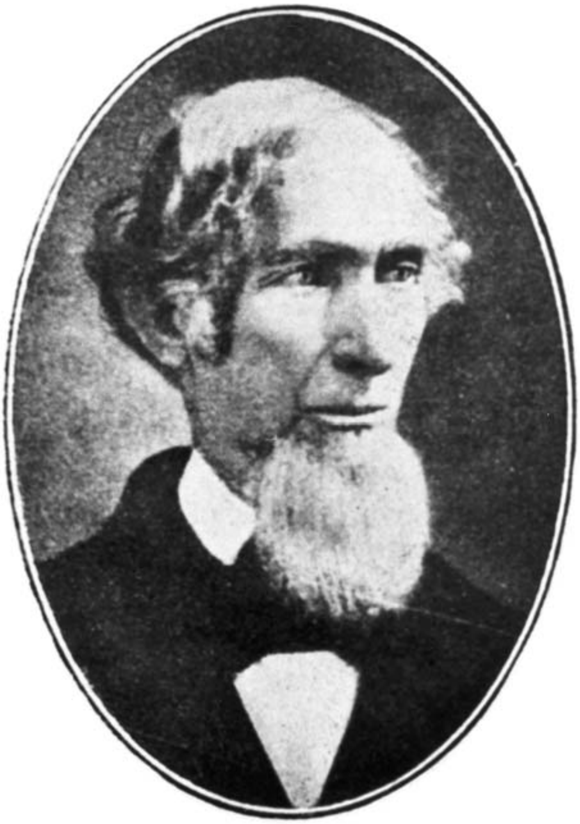


Figure 4. Josiah Clark Nott (1804–1873).

> After examining carefully this interesting skull, and reading the able opinion of M. Broca, an idea occurred to me, which may afford an explanation of the nature of the injury that led to the operation, and the reasons for which it was performed. According to the account of M. Broca, there is no satisfactory reason for the performance of so bold an operation. He has made no allusion to the probability of a *punctured wound,* one made with a small sharp-pointed instrument. Very small perforations of a skull are sometimes made by a bayonet, dirk, etc., without fracture. They, however, often cause extravasation of blood within the cranium, violent inflammation, suppuration, delirium, coma, etc. A punctured wound, followed by such symptoms, would clearly indicate trepanning to a surgeon of our day. The operation, too, would remove the whole of the injured bone, and leave no trace behind of fracture or other bone injury.
>
> Such, to my mind, is the rational explanation of the kind of injury inflicted, and of the symptoms, which justified the operation. (p. 579)

In Note 2, Squier concurs:

> The spear, lance, and arrow-heads of the ancient Peruvians were generally of bronze, sharply

> pointed. I have in my collection a bronze lance-head, with a socket at one end for the reception of a staff or handle. At this point it is round, measuring a trifle over half an inch in diameter. The socket extends inwards five and a half inches, and from the point where it terminates the solid portion of the lance gradually assumes a square form, and tapers regularly to a point. The whole length of this lance-head is twenty-three inches. What may be called spear-heads are heavier, thicker, and not so long. The arrow-heads are of similar form with the lance-heads, usually about five inches long; also fitted with a socket for receiving the shaft of the arrow. Among the ruins of Grand Chimu, where, according to tradition, was fought the final decisive battle between the Chimus (Yuncas) and the Incas, I found a vast number of skeletons, the skulls of most of which showed evidence of violence. Some were crushed in, as if from the blows of a club; others were cleft, as if by the stroke of a battle-axe, and others perforated, as if by lances or arrows, exhibiting a small square hole corresponding precisely with what would probably be made by the weapons I have described. In fact, I found a skull thus perforated, with a bronze arrow still sticking in it. The orifice was a clear one, with no radiating fissures. I regret that this interesting specimen was lost, with other valuable relics, on its way to the United States. These facts, it appears to me, tend to sustain the hypothesis of Dr. Nott in regard to the wound or injury leading to the operation of trepanning in the skull from Yucay. (pp. 579–580)

Epilogue

The Squier skull was not the first South America specimen to show a trepan opening. A trepanned skull had been depicted in 1839 by Morton in *Crania Americana.* The significance of the opening, however, was not recognized at the time. Morton, who had been President of the Academy of Natural Sciences in Philadelphia, thought the hole had been made by a blunt instrument, possibly the back of a war axe, during a battle. He did not realize that the opening in his specimen had probably been made surgically to treat this individual, rather than to take his life.

Morton's specimen was really treated no differently that the even earlier European finds. In effect, none of the pre-Squier specimens had attracted much attention, mainly because they had been grossly misinterpreted. Unlike these skulls, many of which had oval openings that might not have suggested surgery, the cross-hatched cuts on the Squier skull could only have been made by human hands. This distinctive feature of the Peruvian skull, plus evidence that the individual survived his surgery for a week or two, permitted the specimen to stand out above the others. Here, for the first time, was a striking example of "primitive" surgery – and it forced people to think differently about medical treatment in non-Western cultures in the past.

Nevertheless, the Squier skull raised more questions than could be answered in the 1860s and 1870s, or even today. Although it has been suggested that the early Peruvians treated cranial fractures by trepanning (Jørgensen, 1988; Popham, 1954; Rifkinson-Mann, 1988; Stewart, 1957; Verano, 1997), traumatic head injuries may not have been the only reason, or even the primary reason, for the operation. In addition, contemporary scholars still can do little more than speculate about just how much the Incas or their predecessors knew about the relationship between the brain and behavior.

In closing, it is interesting to consider, if only briefly, what happened to Squier and

Broca in the years after Squier's trepanned Peruvian skull took the scientific community by storm.

Looking first at Squier, the skull clearly added to his fame as an expert on early American cultures and artifacts. But although his name became associated with the celebrated skull, he did not write a book or a major paper on trepanation after he presented his material in his 1877 monograph on Peru. (Nott, whose comments on the skull were given in the book, died four years before this book was even published.)

As for Broca, the skull marked a great moment and a turning point in his illustrious career. One year after he presented the Peruvian skull in Paris, trepanned skulls and fragments dating from the Neolithic Period (c. 3,000 –2,000 BC) began to be found on French soil by his friend and associate P.-Barthélemy Prunières. Although Prunières (1874a,b) at first misinterpreted his specimens (he thought the openings were made after death to allow the skulls to serve as ceremonial drinking cups), Broca (1874a,b) recognized the trepanned skulls for what they were and worked diligently in the 1870s to understand how trepanation was performed and why. In this context, he published a plethora of papers and notes, and even a book on trepanation, for which he was well recognized by the scientific community (Broca, 1875a,b, 1876a-i, 1877a-c). Broca's theories on Neolithic trepanation had great impact. Although it is now recognized that his ideas require modification (e.g., he wrongly believed that in Neolithic France children were the usual subjects), what he had to say is still cited today (see Finger and Clower, this volume).

Whether Broca would have had the mindset to recognize the European skulls with skull breaks as examples of prehistoric trepanation had he not first seen the Squier specimen will never be known. But clearly, the Peruvian specimen that Squier sent him in 1867 had a dramatic impact on his thinking and, for that matter, on how scientists and historians around the world would think about new discoveries in human prehistory.

Acknowledgements

The authors would like to thank Dominique Holden and Dr. William Clower for their help with the French translations and Dr. John Verano for his perceptive comments on an earlier draft of this manuscript.

Notes

1. For example, a trepanned skull was found in 1685 by Bernard de Montfauchon in Cocherel, France, but its significance had not been recognized. Another trepanned skull was found at Nogent-les-Vierges and presented to the Société des Antiquaires by Alexandre François Barbie du Bocage in 1821. It was recognized that this skull came from an individual who survived a craniotomy by more than a decade, but the specimen was not thought to be very old.
2. Seitz (1911) provides a bibliography of almost 100 of Squier's books and papers. Some of Squier's works proved so enduring that they were reprinted well over a hundred years after they were written. For example, *The Serpent Symbol and the Worship of Reciprocal Principles of Nature in America* of 1851 was reprinted in 1975, and "Observations on the Archaeology

and Ethnology of Nicaragua," which first appeared as an article, was reprinted as a book in 1990.

3. The best biography on Broca remains that of Schiller (1979), who devotes considerable space to Broca's infatuation with ancient and modern skulls. See the contribution by Finger and Clower in the present collection of papers for a more detailed look at how Broca became involved with even older trepanned skulls from France (soon after seeing the Squier skull), and the evolution of his ideas about why trepanation was performed in antiquity.
4. Nott believed that Blacks were inferior to Whites and that this could be proved by examining brain size, skull shape, the nerves, and other physical features. He greatly respected Morton, the senior man in the field with an immense collection of skulls, and caught his attention, as well as the support of Glidden, during the 1840s. These three Americans were well aware of Squier's writings on ancient cultures and monuments in the New World and they used Squier's material to support their own theories.

References

Anonymous. (1862–66). Committee reports of December 6, 1865. *Bull NY Acad Med 2*: 530.

Anonymous. (1850). (No title: Biographical material and a description of E. G. Squier following a report by Squier on American foreign relations.) *Am Whig Rev 6* (n.s.): 345–352.

Bard SA [pseudonym of EG Squier] (1855): *Waikna; or, Adventures on the Mosquito Shore*. New York, Harper & Brothers.

Broca P (1867a): Cas singulier de trépanation chez les Incas. *Bull Soc Anthrop 2* (2nd ser.): 403–408.

Broca P. (1867b): Trépanation chez les Incas. *Bull Acad Méd (Paris) 32*: 866–872.

Broca P (1874a): Discussion. *Bull Soc Anthrop 9* (2nd ser.): 189–205.

Broca P (1874b): Sur les trépanations préhistoriques. *Bull Soc Anthrop 9* (2nd ser.): 542–557.

Broca P (1875a): Sur la perforation congénitale et symétrique des deux pariétaux. *Bull Soc Anthrop 10* (2nd ser.); 192–199.

Broca P (1875b): Sur les trous pariétaux et sur la perforation congénitale double et symétrique des pariétaux. *Bull Soc Anthrop 10* (2nd ser.): 326–336.

Broca P (1876a): Diagnostic d'un abscès situé au niveau de la région du langage: trépanation de cet abscès. *Rev Anthrop 5*: 244–248.

Broca P (1876b): Sur la trépanation du crâne et les amulettes crâniennes à l'époque Néolithique. Congrès International d'Anthropologie et d'Archéologique Préhistoriques (Session à Budapest). *Rev Anthrop 5*: 101–196.

Broca P (1876c): Sur les trépanations préhistoriques. *Bull Soc Anthrop 11* (2nd ser.): 431–440.

Broca P (1876d): Sur l'âge des sujets soumis à la trépanation chirurgicale néolithique. *Bull Soc Anthrop 11* (2nd ser.): 572–576.

Broca P (1876e): Sur les trépanations préhistoriques. *Bull Soc Anthrop 11* (2nd ser.): 236–251.

Broca P (1876f): Discussion. *Bull Soc Anthrop 11* (2nd ser.): 279–285.

Broca P (1876g): Prétendues amulettes crâniennes. *Bull Soc Anthrop 11* (2nd ser.): 461–463.

Broca P (1876h): Trépanations préhistoriques; crânes trépanés à l'aide d'un éclat de verre. *Bull Soc Anthrop 11* (2nd ser.): 512–513.

Broca P (1876i): Amulettes crâniennes et trépanation préhistorique. *Rev Anthrop 5*: 106–107.

Broca P (1877a): De la trépanation du crâne, pratiquée sur un chien vivant, par la méthode néolithique. *Bull Soc Anthrop 12* (2nd ser.): 400.

Broca P (1877b): Trépanation de crâne par le procédé préhistorique. *Bull Soc Anthrop 12* (2nd ser.): 477–478.

Broca P (1877c): Sur la trépanation du crâne et les amulettes crâniennes à l'époque néolithique. *Bull Acad Méd (Paris) 6*: 710–714.

Finger S, Fernando HR (2001): E. George Squier and the discovery of cranial trepanation: A landmark in the history of surgery and ancient medicine. *J Hist Med Allied Sci 56*: 353–381.

Horseman R (1987): *Josiah Nott of Mobile: Southerner, Physician, and Racial Theorist*. Baton Rouge, LA, Louisiana State University Press.

Jørgensen JB (1988): Trepanation as a therapeutic measure in ancient (pre-Inka) Peru. *Acta Neurochirurg 93*: 3–5.

Morton SG (1839): *Crania Americana: Or a Comparative View of the Skulls of the Various Aboriginal Nations of North and South America.* Philadelphia, PA, Simpson, Marshall & Co.

Morton SG (1839): *Crania Aegyptiaca: Observations on Egyptian Ethnology, derived from Anatomy, History, and the Monuments,* Trans Am Phil Soc *9*: 93–159.

Nott JC, Gliddon GR (1854): *Types of Mankind.* Philadelphia, PA, Lippincott.

Nott JC, Gliddon GR (1868): *Indigenous Races of the Earth.* Philadelphia, PA: Lippincott.

Popham RE (1954): Trepanation as a rational procedure in primitive surgery. *Univ Toronto Med J 31*: 204–211.

Prunières PB (1868): Fouilles éxecutées dans les dolmens de la Lozère. *Bull Soc Anthrop 3* (2nd ser.): 317–320.

Prunières PB (1874a): Sur les crânes artificiellement perforés à l'époque des dolmens. *Bull Soc Anthrop 9* (2nd ser.): 185–205.

Prunières PB (1874b): Sur les crânes perforés et les rondelles crâniennes de l'époque néolithique. *Comp Rend Assoc Fran Avan Sci 3*: 597–635.

Rifkinson-Mann S (1988): Cranial surgery in ancient Peru. *Neurosurgery 23*: 411–416.

Schiller F (1979): *Paul Broca*. Berkeley, CA, University of California Press.

Seitz DC (1911): *Letters from Francis Parkman to E.G. Squier.* Cedar Rapids, IA, Torch Press.

Squier EG (1843): *The Chinese as they Are; Their Moral and Social Character.* Albany, NY, George Jones.

Squier EG (1847): *Observations on the Aboriginal Mounds of the Mississippi Valley*. New York, Bartlett & Welford.

Squier EG (1848): *Aboriginal Monuments of the State of New York*. City of Washington, Smithsonian Institution.

Squier EG (1851): *The Serpent Symbol and the Worship of Reciprocal Principles of Nature in America*. New York, George P. Putnam. (Reprinted in 1975 by Kraus Reprint Co., Millwood New York).

Squier EG (1852): *Travels in Central America, Particularly in Nicaragua, etc*. London, Longman & Co.

Squier EG (1853): Observations on the Archaeology and Ethnology of Nicaragua. *Trans Am Ethno Soc 3*: 83–158. (Reprinted in 1990 by Labyrinthos, Culver City, CO.)

Squier EG (1855): *Notes on Central America; Particularly the States of Honduras and San Salvador.* New York, Harper & Brothers.
Squier EG (1860): *Nicaragua: Its People, Scenery, Monuments, Resources, Condition, and Proposed Canal.* New York, Harper & Brothers.
Squier EG (1870): *Honduras, Descriptive, Historical, and Statistical*. New York, Holt & Williams.
Squier, EG (1877): *Peru: Incidents of Travel and Exploration in the Land of the Incas.* New York, Harper & Brothers.
Squier EG (1880): *Honduras and British Honduras*. New York, Charles Scribner's Sons.
Squier EG, Davis EH (1848): *Ancient Monuments of the Mississippi Valley*. City of Washington, Smithsonian Institution.
Squier F (1939): *A Collection of Books by Ephraim George Squier*. New York, Frank Squier Paper Co.
Stewart TD (1958): Stone Age skull surgery: A general review with emphasis on the New World. *Ann Rep Smithsonian Inst*: 469–491.
Verano JW (1997): La trepanación tratamiento terapéutico para fracturas
craneales en el antiguo Perú. *Estud Anthrop Biol 8*: 65–81.

Chapter 2

On the Birth of Trepanation: the Thoughts of Paul Broca and Victor Horsley

STANLEY FINGER[1,*] AND WILLIAM T. CLOWER[2]
[1]*Department of Psychology, Washington University, St. Louis, Missouri, USA*
[2]*Research Service (151 S), VA Medical Center, 800 Irving Avenue, Syracuse, New York, USA*

Abstract

Paul Broca and Victor Horsley were both intrigued by trepanned skulls, especially those showing that the operation was performed on the living. Broca was involved with the first case of trepanning widely recognized as such (from Peru) and with many Neolithic skulls found on French soil. His theory from the 1870s, which held that the cranial holes allowed the demons causing convulsions in infants to escape, reflects both his anthropological and medical background. Horsley, in contrast, approached trepanning as an expert on the primate motor cortex and as a surgeon who had just successfully treated Jacksonian epilepsy. In contrast to Broca, he postulated that trepanning originated as a way to treat pain and epilepsy caused by skull fractures. Although Broca and Horsley had different ideas, the two men tied trepanning to convulsions and both helped to create the exciting *Zeitgeist* that led others to explore, ponder, and write about ancient trepanned skulls.

Keywords: Trepanning, Trepanation, Broca, Horsley, Epilepsy, Convulsive Disorders, Motor Cortex, Jacksonian Seizures, Demonology, Neurosurgery, Cortical Localization

Introduction

Trepanation has stirred the interest of brain surgeons, neurologists, psychologists, and anthropologists since it was first realized in the 1860s and 1870s that ancient human hands made holes in the skulls of the living. That there has been, and still is, so much interest in trepanning is not surprising.

First, trepanation can be looked upon as indirect evidence that people living approximately 4,000–5,000 years ago during the late Neolithic Period or New Stone Age (which is associated with polished stone tools, community life, farming, and the domestication of cattle) in France, and perhaps even more than 10,000 years ago elsewhere, may have already associated the contents of the skull with the mind and behavior.[1] Second, the

* Also associated with the program in Neuroscience and the program in Philosophy-Neuroscience-Psychology.

history of trepanning from ancient to modern times sheds light on how conceptions of the brain in health and disease have changed over time.[2] And third, the literature on trepanning helps historians to understand how some outstanding scientists and physicians worked and thought, paving the way for better biographies and more accurate portrayals of these individuals.

Two neuroscience icons from the second half of the nineteenth century who were intrigued by ancient trepanned skulls were Paul Broca and Victor Horsley. For Broca, studying ancient skulls was long-lasting interest that contributed significantly to his greatness as an anthropologist. For Horsley, it was a brief and passing fancy, but one reflective of the *Zeitgeist* in the 1880s. What drew these men to talk and write about the ancient practice of trepanning, and their thoughts about the origins of this surgery, will now be examined.

Paul Broca

Broca's Background and Squier's Peruvian Skull

Paul Broca (1824–1880; Fig. 1) was born in Sainte-Foy-la-Grande, a town east of Bordeaux (for biographical and scientific information, see Schiller, 1979). He attended medical school in Paris, graduated in 1848, and remained in the French capital for the rest of his life. Highly respected for his keen intellect and ability to see things from many perspectives, his contributions spanned an impressive array of disciplines, including neurology, neuroanatomy, comparative anatomy, human evolution and diversity, pathology, statistics, oncology, and therapeutics. He was instrumental in merging laboratory science with medicine, in revolutionizing thinking about the cerebral cortex, and in the founding of modern anthropology.

Broca, who published over 500 scientific articles, began his distinguished scientific career in the 1850s. His early work dealt with cancer, muscular dystrophy, and rickets. During the next decade, he became much better known; first for the discovery of the language area that now bears his name (in 1861), and then for suggesting that the left hemisphere plays the leading role in speech (in 1865).

In 1865 Broca was elected President of the Paris Surgical Society and in 1868 became Professor of Clinical Surgery. In this domain, he introduced cranial cerebral topography, a technique which uses skull and scalp landmarks to localize underlying parts of the brain (Broca, 1868). Broca used his new method to trepan the skull and drain an abscess in patient whose speech had become impaired after a closed head injury (Broca, 1876a; Pozzi, 1880). Even though brain tissue was not removed, some authors regard Broca's case as the first brain surgery to be based on the theory of cortical localization of function (see Stone, 1991).

At the same time that he was making these seminal contributions to the neurosciences, Broca was deeply involved with human prehistory and physical anthropology. But just like everyone else before the mid-1860s, he had no reason to think that the skulls of living people were trepanned prior to the time of the ancient Greeks. The situation changed dramatically for him and subsequently for scientists around the world in 1867, after he

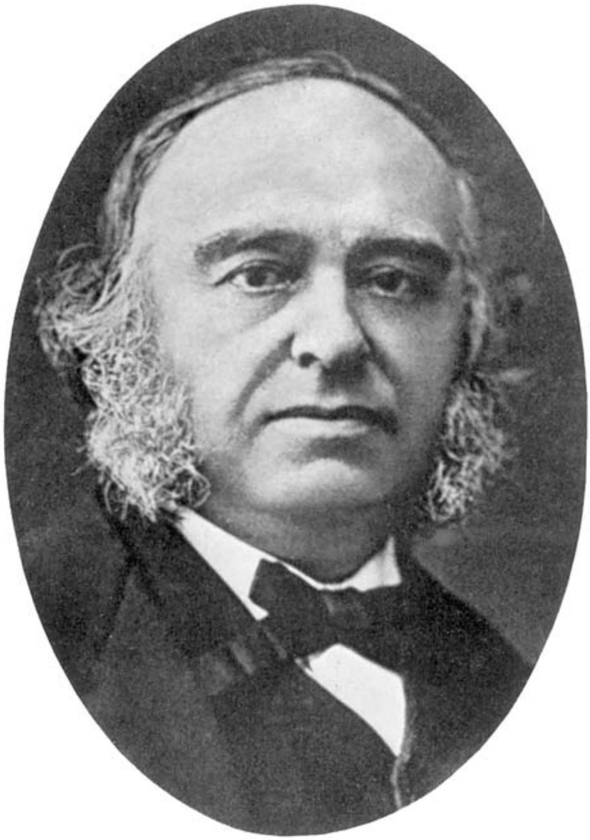


Figure 1. Paul Broca (1824–1880).

was shown an old Peruvian skull with cross-hatched cuts (Fig. 2).

This skull had come from an Inca cemetery in the valley of Yucay and belonged to a wealthy woman in Cuzco who enjoyed collecting and filling her home with fine antiques and artifacts. It was in 1865 that Ephraim George Squier, an archeologist, writer, and diplomat, first encountered this perforated skull. Squier had originally been sent to Peru by the United States government to settle some conflicting international claims. Once his job was completed, he began to travel around Peru to collect material for a book about this South American country's geography, people, and past.

In his monograph, which appeared in 1877, Squier described the skull with its 15 x 17 mm rectangular opening as "a clear case of trepanning before death," the opening having been made "with a burin, or tool like that used by engravers on wood and metal" (pp. 456–457). He considered it the most important relic in the woman's collection, and added: "The señora was kind enough to give it to me for investigation, and it has been submitted to the criticism of the best surgeons of the United States and Europe, and regarded by all as the most remarkable evidence of a knowledge of surgery among the aborigines yet discovered on this continent" (p. 456).[3]

Figure 2. The Peruvian skull with a cross-hatch opening that was obtained by Ephraim George Squier. Squier took it to New York and then to France, where Paul Broca concluded that the opening was made before the European conquest on an Inca who survived the surgery by one or two weeks (from Squier, 1877).

Indeed, the skull was shown to members of the New York Academy of Medicine in the winter of 1865 by Dr. A. K. Gardner. The notes from the meeting read:

> The skull showed that during the patient's life an operation for trephining had been performed . . . by what would appear to be a gouging instrument. At one portion of the opening there seemed to be evidences of the attempt on the part of nature to form new bone, to repair the injury done by the operation. (Committee reports of the NY Academy of Medicine, 1865, p. 530)

Nevertheless, not everyone was in agreement. In the minutes we also find: "Dr. Post stated that he did not see any of the evidences of the reparative process sufficiently marked to decide positively that the operation was not performed after death" (p. 530). Thus, although some observers looked upon the skull as a clear case of pre-Columbian trepanning, others remained skeptical.

Because there was not uniform agreement about the skull, and perhaps also because Squier also wanted to enhance his own fame, he now decided to solicit Broca's opinion.

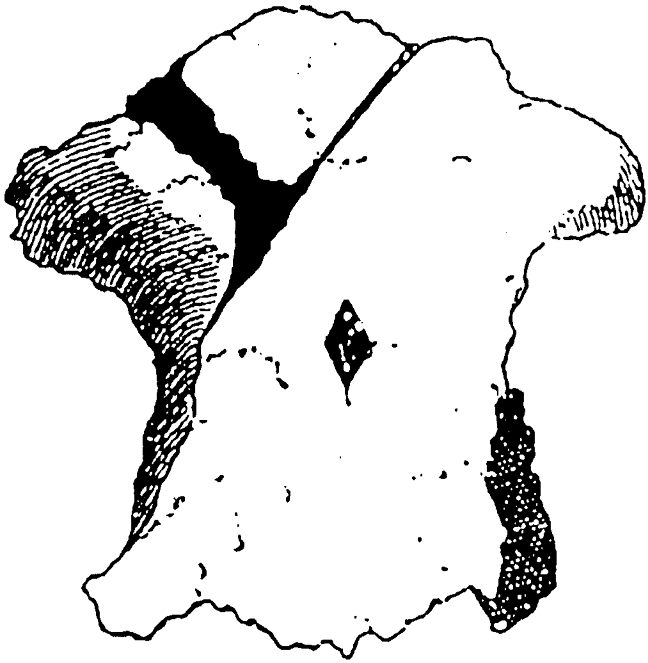


Figure 3. An "irregular" amulet from the Prunières collection with a hole for suspending it from a cord (see Broca, 1877a, p. 200).

Broca had not only founded the Société d'Anthropologie de Paris in 1859, but was considered by many to be the leading anthropologist in the world, as well as an established authority on the brain and its pathology.

Careful examination of the Peruvian skull left no doubt in Broca's mind that "advanced surgery" had been performed in the New World before the European conquest (Broca, 1867a,b). As he explained to the members of his Société d'Anthropologie, the features of the circle of bone around the opening that were denuded of its periosteum proved that the surgery was performed while the individual was still alive. The sharp edges around the hole and signs of inflammation suggested that death probably occurred a week or two later.

But why, wondered Broca, was such an operation performed? What was the motive? One possibility was that cranial bone was removed to treat a fracture. Josiah Nott, a leading American researcher of skulls, favored this idea, as did Squier, who had seen skulls from Peru that had been penetrated with sharp-pointed weapons (e.g., lances and arrows; see Squier, 1877). Nevertheless, there were problems with the fracture theory, the most significant of which was that there were no unusual cracks or lines anywhere on the skull to suggest injury.

Hence, Broca considered a related medical possibility – namely that the operation might have been performed after a closed head injury to relieve a build-up of blood and intracranial pressure:

> Did the operation succeed in evacuating a fluid poured into the cranium? I am far from affirming this, but I am tempted to believe it. […] These peculiarities and several others […] are well explained, if we suppose that there had been for some days before the operation an effusion of blood under the dura mater.
> (Broca, 1867a, p. 407; Translated in Squier, 1877, pp. 578–579)

Broca continued:

> To trepan on an apparent fracture at the bottom of the wound is a sufficiently simple conception […]; but here the trepan was performed on a point where there was no fracture, or probably even no wound, so that the surgical act was preceded by a diagnosis. […] We are… authorized to conclude that there was in Peru, before the European epoch, an advanced surgery.
> (Broca, 1867a, p. 408; Translated in Squier, 1877, p. 579)

Broca's comments about the Peruvian skull had important ramifications. One was that it enticed European anthropologists to search for unusual skulls from the past in their own backyards. To Broca's delight, hundreds of old, perforated crania were soon discovered on French soil. New Stone Age discoveries were also made in Spain, Portugal, Germany, Czechoslovakia, Scotland, Denmark, Sweden, Austria, Poland, Italy, and Russia (Horne, 1894; Lucas-Championnière, 1878; Munro, 1897). The French finds were by no means unique, although France proved to be exceptionally fertile soil for Broca and his fellow skull hunters.[4]

Squier's Peruvian skull, which is now thought to date from 1,400–1,530 AD, as well as the new discoveries from Europe, also forced scientists to re-examine and reconsider some skulls that had been collected years earlier. It was now realized that there were excellent examples of trepanned skulls already on the shelves. One was found in 1685 by Bernard de Montfauchon in Cocherel, France, but its significance had gone unrecognized in the past. Another was found at Nogent-les-Vierges and presented in 1821 to the Société des Antiquaires by Alexandre François Barbie du Bocage. It had been recognized that this skull came from an individual who survived a craniotomy by about a dozen years, but until now the specimen was not thought to be very old. Other trepanned skulls had been erroneously dismissed or downplayed because they were thought to show natural defects (e.g., infectious processes, tumors), openings made by animals, or perforations due to accidents or battle wounds (see Broca, 1876b).

The Discovery of Neolithic Trepanned Skulls

Broca examined many ancient skulls from France, most of which are now estimated to be late Neolithic, or approximately 5,000–5,500 years old. He visited burial sites and unearthed some cranial pieces himself, but he largely studied the findings presented to him by others, especially those of P.-Barthélemy Prunières, his friend and associate.

Prunières excavated the megalithic granite "dolmens" (from the Breton language, meaning "stone table") in central France. In 1868, while working in the dolmens of Lozère, he discovered the first of many skulls with large openings. His initial thought was that these openings had been made in some skulls to transform them into drinking cups for rituals.

He also found rounded, polished, and beveled pieces of skull bones within or near these specimens. Because many were oval shaped, Prunières (1874a, p. 189) called the fragments “rondelles” and postulated that they were probably worn on strings or carried in other ways as charms or amulets (Fig. 3; see Broca, 1876c,d, and Munro, 1897, for more on the amulets). Prunières gave a notable report on his material in 1873, and two important papers on the stone burial chamber material followed a year later.

For Broca, Prunières’ most significant finding was a skull with three elliptical cut-out areas along the parietal wall, the middle one of which seemed to have been smoothed or polished (Fig. 4). Prunières (1874b) suggested that the smooth part of this skull had been manually polished in order for it to be applied to the lips for drinking. In the discussion following Prunières’ presentation and elsewhere, however, Broca (1874a,b) offered a very different explanation for why the central cut out region was smooth, whereas the other two regions were not. He postulated that that the openings had been made by scraping with a sharp stone, such as a piece of flint or obsidian, and that the smoothed surface was the result of an extended period of healing. Put somewhat differently, some of the cranium had been removed many years before this individual died.

Broca now explained that the operation had probably been performed very early in life. From this premise he postulated that it could have served as a part of a group or religious initiation rite. He pointed out that priestly ceremonies and grizzly initiations involving blood and surgery are well documented by modern anthropologists, and therefore completely plausible among the savages of the distant past.

During the mid-1870s, Broca (1875a,b, 1876a-i, 1877a-c), gave many more talks and published a stream of papers on trepanation. One of his goals was to convince more people that the holes in the skulls were not due to accidents or combat injuries. A second was to show that the surgery was largely or exclusively performed on children. A third was to associate the surgery with some sort of therapy or cure. And a fourth goal was to tie the procedure, its consequences, and the associated rondelles together with plausible ideas about the religious beliefs of Neolithic man. To quote:

> I propose to establish the two following facts. 1) We practiced in the Neolithic epoch a surgical operation that consisted of opening the cranium to treat certain internal maladies. This operation was made almost exclusively, maybe even exclusively on infants (*surgical trepanation*). 2) The crania of the individuals who survived this trepanation were considered to enjoy particular properties of a mystical order, and when these individuals died we often cut out from their cranial walls the ovals, or fragments, which served as amulets, and that these were cut by preference from the borders of the healed trepanation opening *(posthumous trepanation)*. (Broca 1876b, p. 111)

The Data

Broca began by firmly establishing the time period in which he was working. Among other things, he studied the flints, polished stones, and pottery he collected on his initial trip with Prunières in 1872 to the Caverne de l’Homme-Mort (Broca, 1873). From these artifacts, as well as from evidence of cremation and trepanation, he concluded that the skeletal fragments were indeed from the New Stone Age or Neolithic era (Broca, 1876f,g; see also the opinion of M. de Baye in Broca, 1876f, p. 285). Based on findings from several

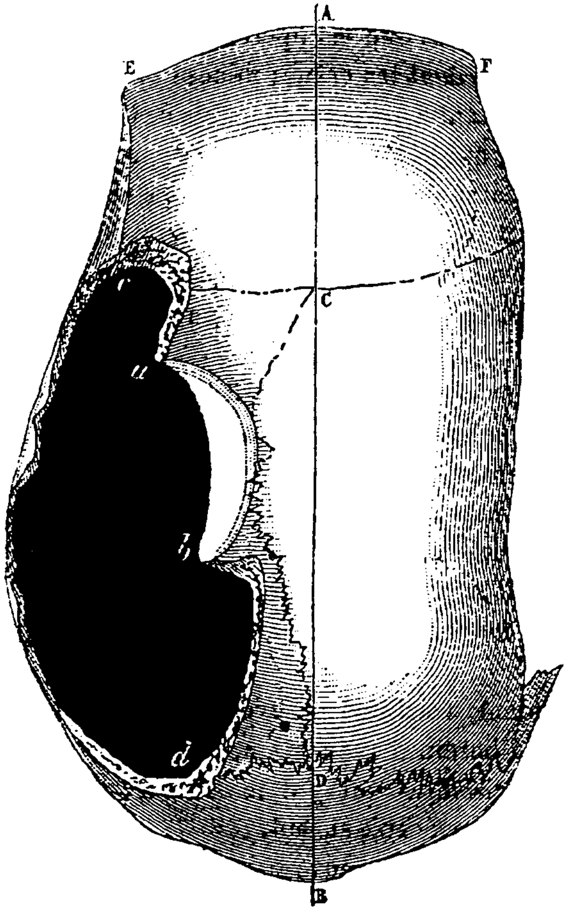


Figure 4. A trepanned Neolithic skull found in a dolmen in France by Prunières. Broca concluded that this skull was trepanned both before and after death (see Broca, 1876b, p. 136).

sites, he maintained that the practice probably extended through the whole of the Neolithic age, but not to earlier or later periods. He attributed this primarily to different religious beliefs and customs, including extensive cremation during the later Bronze Age.

He next established that at least some of the cranial openings resulted from trepanation. Broca had wrestled with this issue since 1873, when he saw a perforated skull with a hole in the right parietal bone "larger than a 5 franc piece" that might have been due to an aggressive blow (Broca, 1873, cranium #8, p. 18; also see Broca 1874a). He was also suspicious of some skulls with symmetrical openings, which he thought might have been caused by congenital malformations (Broca 1875a,b).

Yet even after conservatively removing the skulls seen as possible "false positives," there still were many skulls that met his criteria for trepanation during life. The consistent characteristics of the holes in the remaining skulls provided the most convincing evidence that the openings were created intentionally – as he put it, made by the patient hand of "a methodical operator, not a furious enemy" (Broca 1874a, p.197). These openings typically were elliptical, with borders that narrowed as they extended from the external to the internal layers of bone. Although skulls were also found with irregular openings, the similarities among the smooth openings were striking.

With this much established, he next distinguished between two forms of trepanation. One was "surgical trepanation," the type performed on the living. The other was "posthumous trepanation," which was performed after death. The difference between the two could be seen in the shape and orientation of the openings, as well as the extent of healing around the borders. In some cases, the same skull showed both types of man-made openings.

Broca now turned to the locations of the openings on the skulls. At first, they seemed to be random or unsystematically placed. But with larger samples it became clear that bone was never taken from a place that would alter or distort one's personal appearance or identity in life or after death, i.e., the forehead or facial region. This observation reinforced Broca's position that these openings were not due to injuries or to surgeries designed to treat head wounds, since wounds would have been produced with considerable frequency over the facial area. More likely, he thought, the operations were done on the living to correct certain "internal maladies." The fact that there was no strong gender bias was also supportive of this idea.

To bolster his position that the young were involved, Broca reiterated that the bone must have had sufficient time to heal in order to appear as smooth as it did in many specimens. He also reassessed the skull found by Prunières with three arcs removed from its left side. Inspection of the coronal and lambdoid sutures, which were more or less fused, indicated that this person that had lived to an old age. As for the midline sagittal suture, it deviated significantly from normal in the direction of the surgical trepan hole (see Fig. 4). This unusual suture pattern was viewed by Broca as absolute proof that this sculpted hole had been made when the subject was quite young.

Broca maintained that there are several advantages to operating when the afflicted person is young. First, the young skull is softer and easier to penetrate, and second, it will heal more rapidly. To drive home his initial point, he even conducted some experiments to show just how quickly immature skulls could be penetrated with "primitive" flint or glass scrapers (Broca, 1876h). He found he could scrape a hole in the skull from a deceased two-year-old child in just 4 minutes, whereas it took 50 minutes to open the thicker skull of an adult (he had to rest his hands because of fatigue and pain). Broca's (1877a,b) craniotomy experiments on dogs further showed that it was relatively easy to avoid damaging the dura mater, which would have markedly increased the probability fatal infections and decrease survival.

There were still more conclusions to draw from the three elliptical cut out regions of the skull found by Prunières. Although the central arc had healed, the other two arcs showed no signs of healing and so were determined to be posthumous. Here was a beautiful example of one surgical and two posthumous trepanations in the same skull. Moreover, an oval amulet from another skull was found in the earth that had filled the skull.

Thus, one cranial specimen alone made all the points Broca had hoped to make: 1. based on the deviated sagittal suture line, the trepanation must have occurred very early in life; 2. this person survived to old age, as evidenced by the fact that the sutures were either fused or almost fused; 3. because an amulet had been placed inside a skull that had been operated upon early in life, the individual must have had special significance; 4. the goal of posthumous trepanation was the fabrication of cranial amulets; and 5. the rondelles taken from sacred people probably played a protective role, conferring good luck. As Broca (1876b, p. 152) himself put it:

> It is therefore natural to think that these individuals were considered in their tribe as having a character of a sanctity, and it is this idea that represents the spirit of what I would present. . . .The cranium that the spirit had inhabited, the opening through which the spirit exited, was marked by a supernatural seal; and the relics that were provided came to have the property of good luck, of averting the evil spirits, and in particular of preserving the individual and their families of terrible evil from which the trepanned subject had luckily escaped. (Broca 1876b, pp. 162, 168)

Of Demonology and Convulsions

Prunières and Broca agreed that there was a therapeutic component to trepanation, but disagreed about the specific malady or the theory behind it. Prunières now maintained that surgical trepanation could have originated to treat cranial fractures or depressed bone pieces (Prunières, 1874b; Broca, 1876e). Splinters of bone could cause bizarre behavioral states, including convulsions and delirium. These signs and symptoms would disappear following a removal of the fractured area. In any case, the problems would have been recognized as arising from the bone itself. Thus, Prunières held that the Neolithic surgeon followed something like an observation-based science to determine what to do. Over time, he surmised, the procedure could have been extended to involve the insane, the mentally deficient, or even convulsive patients without fractures.

Broca disagreed with most of this. None of the skulls he found acceptable showed any evidence of associated fractures. Further, he did not believe that Neolithic people had any understanding of the physiological functions of the brain or, for that matter, anything like a sophisticated medical surgery. “I think for my part that they were inspired, not by observation, but by superstition” (Broca 1876b, p. 164). Nevertheless, surgical trepanation could not be due just to superstition. The operation must have had a therapeutic component, “a goal with an immediate utility, and since a large number of families decided to operate on their infants, it could only be to avoid a danger, which could otherwise be more or less imaginary” (Broca 1876b, p. 162). With such thoughts in mind, Broca focused on infantile convulsions.

Broca knew that trepanation had been a treatment for spontaneous epilepsy in the past. In addition, he learned that trepanation was still being performed in some parts of the world to exorcise demons thought to cause seizures and other dreaded diseases. Here he cited the Kabyle Berbers of North Africa, some Oceanic societies, and even the mountaineers of Montenegro (see Lucas-Championnière, 1912, for commentary by another intrigued Paris surgeon on the practice of trepanation in North Africa and elsewhere). He hypothesized that Stone Age humans probably reasoned much like modern primitives. “That which engenders superstition, … are the inexplicable maladies, that the causes underlying are attributed to the influences of the divine or diabolic” (Broca 1876b, p.166).

In a lengthy paper given in Budapest, Broca (1876b) cited Jean Taxil, a physician from Arles who lived early in the seventeenth century. Taxil wrote an entire chapter linking epilepsy to demon possession (Taxil 1603, pp.149–159). A deeply religious man, he wrote that it was not possible to find a demoniac who was not an epileptic (see Temkin, 1971). Clearly, thought Broca, the unconscious and powerful movements of epilepsy could create the image of a tormented, imprisoned spirit with superhuman strength. Taxil went on to explain that if one could make a door in the skull, the powerful demon would have a means of escaping his prison and the afflicted would be healed.

Taxil also believed that human cranial bones possessed special curative powers, even for epilepsy. He recommended many different forms of human cranial bones, including shavings, powders, and cinders. They could be applied to the coronal suture, taken as potions and pills, or suspended around the neck in a small sac. For centuries, flasks labeled *Ossa wormiana* graced the shelves of pharmacies, and they were filled with suture bones for treating epilepsy. The idea that Neolithic people wore charms made of skull bones from selected individuals to ward off the spirits causing convulsive disorders, and possibly even used these charms as articles of commerce, was entirely consistent with what Taxil had written.

To Broca's further delight, Taxil had even commented on epilepsy in the young. In his opinion, it was very common in children. This fit with Broca's idea that Neolithic trepanation was probably performed to treat seizure disorders in children. Broca recognized, however, that Taxil was using the term "epilepsy" very loosely. To Taxil and others of his day, it was an umbrella term, one that included true epilepsy and a myriad of other convulsive disorders. Unlike Taxil, Broca believed that true epilepsy was a relatively rare occurrence before age 10. From this premise, he concluded that epilepsy, as it was being defined in the 1870s, was not likely to have been responsible for many of the childhood Stone Age surgeries. He further reasoned that if young children did suffer from real epilepsy, trepanning would not have helped them anyway (Broca, 1874b, 1876b, 1877c). As for meningitis, which can also cause convulsions, few subjects would have survived it.

Thus, by elimination, Broca found himself left with children suffering from "simple" convulsions. Included in this basket term would be the non-recurring convulsions that may accompany minor trauma, teething, and fevers, as well as isolated idiopathic convulsions from causes that could not be identified.[5] These children would have been the ideal candidates for the procedure, because of the numbers involved and because they would have gotten better anyway. The illusion of success, which Broca thought was needed for the procedure to prosper as it did, would have been achieved.

Broca thus combined medical and historical knowledge with what he as an anthropologist knew about the primitive mind to interpret his Neolithic data. Although he disagreed with Prunières on the extent to which Neolithic trepanation was born of rational medicine or superstition, as well as on the age factor, both men thought a medical condition had fostered a procedure to alleviate an individual's apparent distress.

During the mid-1880s, as we shall now see, Victor Horsley, a pioneer of modern brain surgery, would select Prunières' fracture orientation over the demonology and disease ideas favored by Broca. His support of the fracture idea, however, would have a

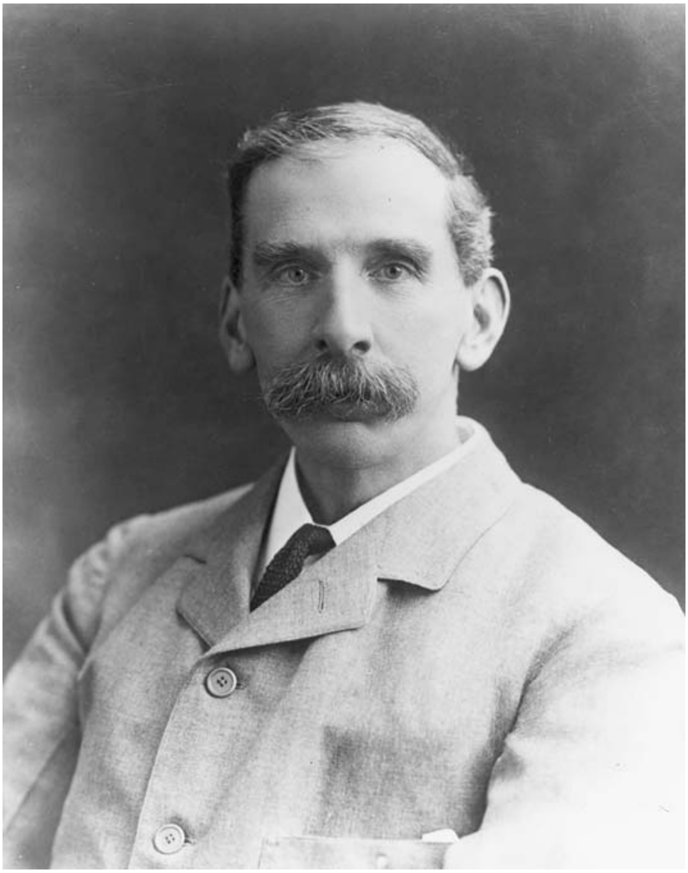


Figure 5. Victor Horsley (1857–1916).

new, more modern twist. It would emerge from exciting new discoveries about cortical localization of function and a new way of thinking about and treating motor epilepsy.

Victor Horsley

Background

Victor Horsley (1857–1916; Fig. 5), who mastered the trephine and helped put brain surgery on its modern footing, was born in Kensington (London) in 1857 (Bond, 1939; Paget, 1919; Lyons, 1966, 1967). Bright, energetic, daring, and optimistic as a child, Horsley retained these qualities into adulthood, although he also garnered a reputation for being brash and uncompromising.

Horsley made up his mind to be a surgeon at an early age. He matriculated at the University of London in 1874 and entered the medical school of University College in

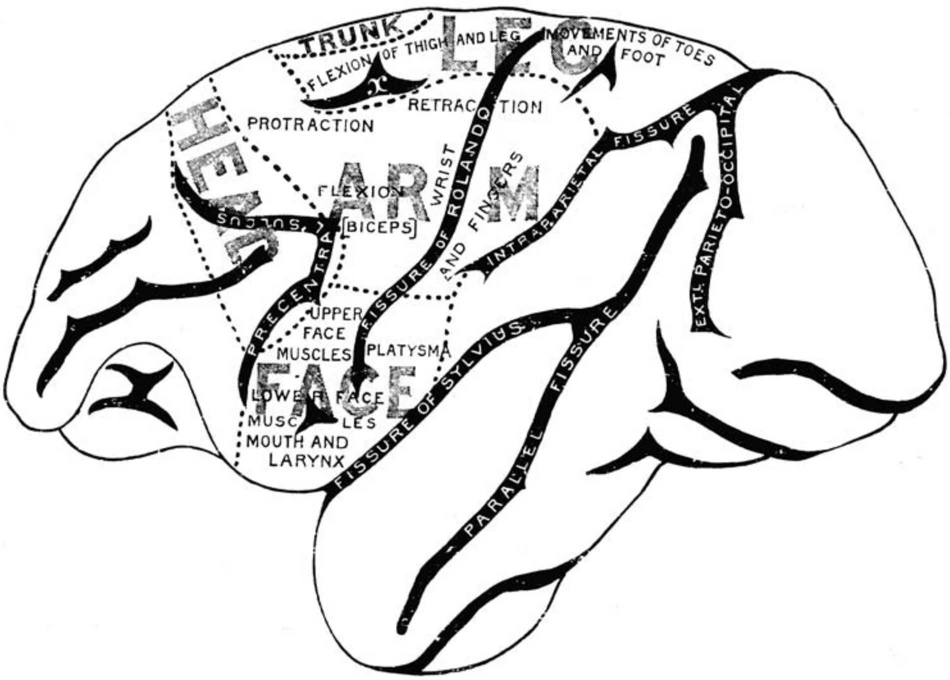


Figure 6. The motor region of the brain as defined by Horsley and Schäfer in 1888. More modern maps of the motor cortex in primates limit it to the precentral gyrus.

1875. There he fell under the influences of Burdon Sanderson and Edward Schäfer, two world-class physiologists who promoted careful experiments on animals as the best way to advance modern medicine. Horsley won many awards as a student and received his Bachelor of Medicine and Bachelor of Surgery degrees with a gold medal in 1881. After graduating, Horsley obtained coveted appointments at University College Hospital and the Brown Institution (for veterinary medicine research). In 1886 he added the post of Surgeon to the National Hospital for the Paralysed and Epileptic, Queens Square, to his credentials.

Horsley believed in the principles of asepsis made public by Lister in 1867, and he became adept at performing difficult new surgeries on animals, including thyroid and pituitary ablations. Importantly, he also used aseptic surgical procedures to study cortical localization of function in monkeys, both at the Brown Institution and at University College Hospital. He was especially drawn to "the so-called motor cortex" (Fig. 6), which he looked upon as sensory as well as motor, and he published a series of important papers on this structure during the mid-1880s (e.g., Beevor and Horsley, 1887, 1888; Horsley, 1887a; Horsley and Schäfer, 1885, 1888).

Considerably more fame came to Horsley in the domain of brain and spinal cord surgery on humans, where he applied what he had learned from his projects on monkeys to sick and injured human patients.[6] As he put it: "experiments on the brains of animals closely allied to man has proved most fertile in the production of facts upon which very active treatment has been safely based" (Horsley, 1887, p. 344). Among his notable surgical achievements are the removal of an extramedullary spinal cord tumor, nerve sections for painful facial tics, surgeries for craniostenosis, attempts to surgically alleviate involuntary movement disorders, intracranial surgeries for subcortical tumors, trigeminal, and the development of a stereotactic frame for subcortical surgery (with R. H. Clarke). It was still another of his monumental surgical contributions, his ability to cure epilepsy by ablating diseased parts of the cerebral cortex, however, that led him to theorize about trepanned skulls.

Surgery for Epilepsy

Trepanning patients as a treatment for convulsions, especially those caused by head injuries, was practiced by ancient Greeks and Roman surgeons (Temkin, 1971). During the European Renaissance, craniotomies continued to be performed for epilepsy, especially of traumatic origin, although the purpose of the operation was still to remove broken bone or a buildup of fluid or "evil" air – not to remove diseased brain tissue. In the 1600s, for example, Duretus cured a boy of his epilepsy by removing some broken bone pressing on his brain. Along the same lines, but in 1828, Benjamin Dudley, a Kentucky physician, successfully trephined five subjects for epilepsy of traumatic origin.[7]

Nevertheless, most of Dudley's better-known nineteenth-century contemporaries in the major hospitals of Europe avoided the trephine, especially for "internal" disorders. Their reasons were many. First, existing anesthetics were crude and dangerous. Second, they were yet not guided by cortical localization, so they had no idea where to search for hidden problems when there were no external signs on the skull. Third, deadly infections routinely followed these operations in the pre-Lister era. And fourth, before John Hughlings Jackson's insights of the 1870s, nobody was thinking about epilepsy as a cortical disorder, much less one that could be treated by removing an irritative focus on the surface of the brain (Jackson, 1870, 1873).

On 25 May, 1886, Horsley began to operate on his first three patients with epilepsy (Horsley, 1886). Among his colleagues at the National Hospital who aided with the diagnoses, were at his side during the surgery, or helped in other ways with his initial patients, were John Hughlings Jackson, David Ferrier, Thomas Buzzard, and Charles Beevor. Unlike previous surgeries for epilepsy, Horsley's operations were intended to removed diseased brain tissue. They were based on Jackson's work showing that epilepsy can originate at the cortical level, and on what he had learned about cortical localization in primates over the years. Also contributing to the new environment were better anesthetics (he tried nitrous oxide and ether on himself) and carbolic acid sprays, soaks, and rinses, to minimize the chances of infection.

Horsley's first patient was James B., a twenty-two-year-old man from Scotland who was under the care of Jackson and Ferrier. He had sustained a depressed skull fracture fifteen years earlier. He then showed intermittent Jacksonian seizures starting in his right leg. Now his life was threatened by *status epilepticus*. Horsley's skillful use of the trephine revealed a vascularized scar in the superior frontal sulcus, and removal of the scar and some surrounding cortex led to a resolution of his seizure disorder.[8]

Although Horsley's third case of epilepsy also had earlier skull trauma, his second case, Thomas W., was more notable because he suffered from a tuberculoma under the dura that was localized solely on the basis of signs and symptoms. This man was another of Jackson's patients, and he had been exhibiting "fits" beginning in his left thumb and forefinger. Jackson suspected a tumor and advised surgery. Thanks largely to his own research with Schäfer and Beevor on thumb and finger movements elicited by cortical stimulation in monkeys, Horsley knew precisely where to apply his trephine. Like his other two cases, Thomas W. survived his surgery and was cured of his epilepsy.

Horsley presented these three cases at a meeting of the British Medical Association in 1886, after which he was personally congratulated by Charcot and Jackson. A London physician by the name of Gibbon commented: "The fact that the cases on which he had operated upon had been . . . rescued from what might be justly termed 'a living death,' and cured without a single hitch in a brilliant operation, was a sure guarantee that this splendid and successful surgery would be perpetuated" (Horsley, 1886, p. 675). The idea of discovering a successful new procedure for curing epilepsy and then perpetuating it, as well as perhaps even using it for related problems, was precisely what Horsley himself would now write about – not just with an eye on the future but as he pondered the trepanned skulls unearthed in Neolithic France.

Horsley on Neolithic Trepanation

Horsley never picked up a shovel to dig for prehistoric skulls, but he did love history and his hobbies included archeology and photography. Hence, at the same time that he was studying the primate motor cortex and beginning to operate on patients with Jacksonian epilepsy, he took the opportunity to examine and photograph the Neolithic crania housed in the Broca Museum in Paris.[9] What emerged in Horsley's fertile mind was a theory extending what Prunières had to say about treating depressed skull fractures surgically. His new variation of the theory stemmed from his conclusion that the cranial holes made during the Neolithic Period were not randomly placed, even after deleting the face or forehead from the equation. He had drawn a composite map of the holes, and found that they were centered on the vertex of the head, more or less above the motor cortex as it was then envisioned (Horsley, 1887b, 1888). In Horsley's own words:

> By means of this composite arrangement it was demonstrated beyond question, that in almost all the known instances of this practice the opening in the skull was made over that portion of the surface of the brain which is known to be more especially the seat of representation of movement. This region of the brain, moreover, is the seat of origin of that special form of convulsions which is known as Jacksonian epilepsy, and which so frequently follows injuries to the skull and brain.
> (Horsley, 1888, p. 101)

Indeed, this was the part of the brain that Horsley knew more about than just about everyone else. It had been, and still was, the subject of some of his most important stimulation and ablation experiments on monkeys (Beevor and Horsley, 1887, 1888; Horsley, 1887a; Horsley and Schäfer, 1885, 1888). In addition, he had just shown the medical world that it is likely to be damaged or compromised in cases of Jacksonian epilepsy, and that motor seizures could be stopped by ablating damaged parts of it.

Thus, from first-hand experience, Horsley knew that a depressed fracture above this region would almost certainly have caused considerable pain and quite probably epilepsy. With this as his premise, he suggested that the tender cicatrix might first have been removed to control the pain, only to find that removing the bone fragments and splinters also eliminated or severely diminished the epilepsy, which had to have been looked on as a bizarre and dreaded disorder. "Consequently the operation would gain a certain reputation for the cure of convulsions generally, and as such might have been frequently practiced among savages to whom pain is of slight consequence" (Horsley, 1888, p. 102).

In 1886 and 1887 Horsley presented his motor cortex theory to the Royal Institution, the Harveian Society, and the Anthropological Institute of Great Britain and Ireland. Although Horsley never followed up on his ideas in a manner comparable to that of Broca, who wrote more on trepanation than he did on language and the brain, Stephen Paget (1919), one of Horsley's biographers, had this to say about him:

> Never were lecturer and subject more happily suited to each other . . . the fact that trephining was practiced far and wide in the Stone Age found its proper exponent in him, who was both surgeon and antiquarian. The skulls in Paris had been waiting for him ever since they were trephined; and he set everybody talking about them. (p. 124)

Nevertheless, being devoid of demonology, Horsley's surgical theory was met with considerable skepticism from the anthropologists whose territory he had clearly invaded. In the discussion that followed his presentation to the Anthropological Institute, one listener stood up and defended Broca's theory that the openings were made to facilitate the exit of evil spirits causing distress. She in turn was supported by Professor Leith, who remarked:

> No cases afforded the savage mind more striking proof of demoniacal influence or the efficacy of magical cure than epilepsy. It seemed, therefore, highly probable that the process of trephining had been employed by primitive man in order to expel the demon who possessed the patient, especially in cases of epilepsy.
> (Horsley, 1888, p. 105)

The biggest problem, said society president Sir Francis Galton, was that even though Horsley's story was bolstered by new and exciting findings coming forth from the brain sciences, his theory "implied more intelligence than savages usually shewed." Hence "they were apt to proceed in a very off hand, ruthless, and unintelligent manner, following their fancies and superstition rather than experience" (see Horsley, 1888, p. 106).

Horsley took these criticisms in stride, showing none of the combativeness for which he was famous. He then thanked the society "for the kindly manner in which it had received and discussed his views" (1888, p. 106). After all, as was put it in the first sentence of the published synopsis of his address:

> The object the author had in view was to obtain the criticism of the Anthropological Institute upon certain views which he had formed from a surgical standpoint, of the operative procedure of trephining as practiced by the people of the polished stone epoch, and the reasons which led to its performance.
> (Horsley, 1888, p. 100)

Commentary

The theory that trepanation might originally have been performed on the living for seizure disorders gained broader acceptance Horsley gave his talks and saw his ideas published in the summaries of these meetings. Nevertheless, there was never good agreement about whose orientation was the better one, Broca's or Horsley's. Some favored Broca's, with its emphasis on the role of the supernatural in disease states, whereas others sided with Horsley, whose stress was on the painful and bizarre consequences of cranial fractures without recourse to demons or the supernatural (see Clower and Finger, 2001; Finger and Clower, 2001).

Sir William Osler, one of the most respected men of medicine at the turn of the century, clearly favored Broca's view when he gave his Silliman Lectures at Yale University in 1913. According to Osler (1923, p. 8): "The operation was done for epilepsy, infantile convulsions, headache, and various cerebral diseases believed to be caused by confined demons, to whom the hole gave a ready method of escape."

Others displaying a pro-Broca orientation speculated similarly:

> Making the hole in the skull of such a person may have been considered a sacred operation because the hole would permit the escape of the imprisoned spirit, devil, demon, or other supernatural being. If the individual survived the operation, perhaps he was the object of veneration. (Wakefield and Dellinger, 1939, p. 167)

But to many people then and now, the weakest part of Broca's theory was his emphasis on the surgery being performed in early childhood. Late in 1879, just one year before Broca died, he was interviewed by a British anthropologist, who examined the skulls in the Anthropological Museum with him. Miss Buckland politely noted:

> One circumstance in connection with this seems rather difficult to explain: it is that among all of the trepanned skulls hitherto discovered there has not been one of a child found. Now as it is certain that some, and probably a large proportion of those operated upon died from its effects, we should naturally expect to find at least a few children's skulls thus treated. (Buckland, 1882, pp. 9–10).

Broca responded that children's skulls are not as durable as those of adults, especially if mutilated. Buckland knew this was true, but she was not entirely swayed by what Broca had to say in defense of his theory. She also observed that the skull which showed the aberrant suture growth indicative of surgery early in life was the exception, not the rule. As far as she was concerned, and she was not alone, Broca needed more such skulls or, even better, some skulls of youngsters, to prove that the usual subjects were in fact children.

As for Horsley's more general thesis, that traumatic injury was the initial reason for the surgery, here too one can find more than a few supporters (see Gross, 1999, for some comments on headaches following head wounds). But as proved to be the case when it came to the specifics of Broca's theory, there were perceptive faultfinders here as well.

In Horsley's case, a particularly pertinent question was whether the holes were really located over the motor cortex. One critic of this contention was Lambert Rogers, a general surgeon. He had visited the Broca museum in 1929 to see if the cranial holes were really above the motor area, which by now was synonymous with the precentral gyrus. Based on newer maps of the brain, he found himself unable to corroborate what Horsley had originally maintained about the wounds causing motor epilepsy. In his words: "The openings appeared too irregularly placed in regard to the motor cortex and to be placed indiscriminately over the vault of the skull" (Rogers, 1930, p. 498).[10]

Today it is generally agreed that the best empirical support for the more generic fracture theory comes from Peru, not from Neolithic Europe. Moodie (1929), who is often cited for his research on a large number of Peruvian trepanned skulls, wrote:

> Trephining or trepanation may have been a military measure, following injuries received in battle. The great majority of trephined skulls discussed here were from the locality, Cinco Cerros, supposed to have been an ancient fort. . . . Many of the trephinings studied show parts of fractures, showing that depressed fractures were a frequent cause of trephining. (p. 727)

Other authors have also commented on the depressed fractures found on many of the Peruvian skulls. Unlike the French Stone Age skulls, the ratio of males to females is about 4:1, about half show frontal area damage, and there are significantly more holes on left side of the head (Rifkinson-Mann, 1988; Stewart, 1957). These statistics suggest that trepanation was readily practiced as a way to treat traumatic injuries from right-handed adversaries, such as those caused by stones and clubs, in the war zones of Peru (Horrax, 1952; Jørgensen, 1988; Popham, 1954).

Epilogue

As we look back to the cranial discoveries that were made in the second half of the nineteenth century and the ideas that they spawned, we must remember that Broca was seeing Neolithic trepanation through the eyes of a mid-nineteenth-century French anthropologist and man of medicine, and not as a tribal witness to what might have been a special or demanding event. As for Horsley, his sharp eyes and mind were those of a "new" brain scientist and enthusiastic English brain and spinal cord surgeon. He was the man who had just cured epilepsy at the operating table and he was a bold individual who enjoyed presenting new ideas, even if they were controversial. Without question, both Horsley and Broca were bound to their cultures and products of their times.

Speculations about how our distant ancestors were thinking about illness, injury, and the brain can persist for many reasons. One is that they have indirect support,[11] and another is that they may seem logical and intriguing. Still a third reason is that some ideas take on a life of their own when the names of great scientists are associated with them. But not to be overlooked is the fact that some of the more general ideas, though not necessarily the specifics, may also persist because they can be impossible to disprove.

Notes

1. Trepanned skulls thought to be greater than 8,000 years old have been described by Ferembach (1962), Kurth and Rohrer-Ertle (1981), Lillie (1998), and others. These skulls have been classified as Mesolithic.
2. For example, the physicians of classical Greece often left simple, non-depressed skull fractures (open head injuries) alone, but frequently opened the skull after closed head injuries (see Hippocrates, 1952). They reasoned that a blow to the skull could cause blood and other humors to stagnate in the head and form harmful dark pus. If there were a fracture, there would be an exit for the accumulating humors, but craniotomies were performed if the skull did not break to allow the excess humors to drain (Bakay, 1985; Majno, 1975).
3. A trepanned skull from South America had been depicted years earlier in a book by Morton on American crania. This work was dated 1839, but the significance of the skull was not properly recognized at the time. Morton thought the hole had been made by a blunt instrument, possibly the back of a war axe. Unlike most trepanned skulls, which have smooth, round openings that might not have suggested surgery, the cross-hatched cuts on the Squier skull could only have been made by human hands.
4. In addition to the European skulls, many drilled, scraped, and gouged skulls began to be unearthed from the high Andes Mountains of Peru and Bolivia, and to a lesser extent from other countries in the Americas. Among the most notable of these skulls were two found in Peru, one displaying five separate openings and another with seven holes showing healing (MacCurdy, 1923; Oakley, et al., 1959; Parry, 1928). Especially in some Peruvian burial sites, the surgery had a high frequency of occurrence and overall survival rates have been estimated to be in the range of 50–60%. But in contrast to the Old World discoveries, the Inca and pre-Inca skulls are less than 2,500 years old.
5. It has been argued that the term "epilepsy" should be restricted to recurrent and persisting seizures (Szepetowski et al. 1997). In this context, Pellock (1989) estimated that that there are 2–5 times more isolated, simple seizure disorders in childhood than there are cases of true infantile epilepsy. To quote from Szepetowski et al. (1997), who described the genetics of some of these childhood seizure disorders:

   > Whereas epilepsy is generally considered as a chronic disturbance of chronic brain function, convulsive disorders of infancy and childhood, a relatively large percentage of which are idiopathic, may reflect a developmental process. . . . Three distinct entities are classified among the idiopathic forms with onset in the first year of life; benign neonatal convulsions, benign familial convulsions, and benign myoclonic epilepsy in infancy. In addition, nonfebrile convulsions, with the first seizure at age 3–12 mo., have been described. . . . These convulsions have a favorable outcome, and the term "benign infantile familial convulsions" has been proposed. (p. 890)

6. Along with William Macewen (1879, 1881, 1888) and Rickman Godlee (Bennett and Godlee, 1884, 1885), Horsley was successful in giving brain surgery its modern look; one based on laboratory experiments, cortical localization, and aseptic procedures. It was because of his enthusiasm for brain and spinal cord surgery, his ability to devote the majority of his time to it, and the scope of his work – from the operations performed to the development of the Horsley-Clarke stereotactic frame – that he, and not Macewen or Godlee, is often referred to as the "father of neurological surgery" (see Horrax, 1952; Lyon's, 1967). (The term "neurosurgery" was coined by Harvey Cushing in 1905.)

   In recognition of his neurosurgical achievements, Horsley was knighted in 1902. But his impulsivity, combativeness, and inability to see the world from different angles, made him mortal enemies in the medical establishment and somewhat unpredictable to his friends. Horsley died in sweltering Amara (Mesopotamia) in July of 1916, possibly of heatstroke. He was serving his country as a colonel whose main goal was to improve the hospital conditions confronting wounded British soldiers in the Middle East.

7. Benjamin Winslow Dudley believed he had better success with the trepan than Bell, Pott, and other famous European surgeons because he was working in the "healthy and invigorating" Mississippi Valley of the United States, and not in a crowded European city hospital with bad air. In his 1828 report, he described five cases of trephining, all of whom sustained earlier blows to the head that guided him to a buildup of blood or fluid. Like others who dared to operate on the brain in this era, he was not willing to venture forth when there were no cranial signs to guide him. With regard to a six-year-old child who developed epilepsy after being kicked by a horse, Dudley wrote: "I have not operated on this case, because I am unable, from external appearances, to point out the source of the mischief" (1828, p. 21). (For more about Dudley and his surgical accomplishments, see Jensen and Stone, 1997.)
8. Upon completion of this successful operation, Jackson, who was usually staid and aloof, turned to Ferrier and whispered "awful, perfectly awful." Ferrier was shocked. He did not understand what mistake Jackson could have caught. But the normally shy and reserved Jackson then went on: "Here's the first operation of this kind that we have ever had at the Hospital: the patient is a Scotsman. We had the chance of getting a joke into his head, and we failed to take advantage of it" (Paget, 1919, p. 120.)
9. After his death in 1880, Broca's collection of trepanned skulls and skull fragments was divided up. Some specimens were given to Laboratoire d'Anthropologie of the Musée de l'Homme in Paris, whereas others were given to certain members of his Société d'Anthropologie. It is not known where all of the latter specimens presently reside.
10. Interestingly, Horsley was one of the first researchers to come to the conclusion that the "so-called motor cortex" probably does not include the parietal lobe. He discovered that only feeble movements could be obtained by applying light current to the postcentral gyrus of primates and therefore thought the precentral gyrus considerably more important (see review by Horsley, 1909; Finger, 1994, p. 199). Sherrington's detailed work with Grünbaum (later Leyton), however, is better remembered for establishing the currently accepted boundaries of the motor cortex (e.g., Grünbaum and Sherrington, 1901, 1903; Leyton and Sherrington, 1917; Finger, 2000).
11. For example, some indirect support for the medical use of trepanation comes from tribes that practiced trepanation well into the twentieth century (Ackernecht, 1947; Lisowski, 1967; Margetts, 1967; O'Connor and Walker, 1967; Rawlings and Rossitch, 1994). The operation was done among the natives of the South Pacific Islands to treat fractures, epilepsy, insanity, and headache, and it was performed for headache with or without cranial fractures in Kenya and Tanganyika. Severe headaches and fractures after head injuries were also treated by trepanning in Uganda, Nigeria, Chad, Somalia, Libya, and among the Zulu of South Africa. Notably missing from the newer anthropological studies is convincing evidence that trepanning was done in a non-medical context, such as for religious, magical, or cultural reasons alone.

References

Anon. (1862–66). Committee reports of December 6, 1865. *Bull NY Acad Med 2*: 530.

Ackernecht EH (1947): Primitive surgery. *Am Anthropol 49*: 25–45.

Bakay L (1985): *An Early History of Craniotomy.* Springfield, IL, Charles C Thomas.

Beevor CE, Horsley V (1887): A minute analysis (experimental) of the various movements produced by stimulating in the monkey different regions of the cerebral centre for the upper limb, as defined by Professor Ferrier. *Phil Trans R Soc 178*: 153–167.

Beevor CE, Horsley V (1888): A further minute analysis by electrical stimulation of the so-called motor region of the cortex cerebri in the monkey. *Phil Trans R Soc 179*: 205–256.

Bennett AH, Godlee R (1884): Excision of a tumour from the brain. *Lancet 2*: 1090–1091.

Bennett AH, Godlee R (1885): Case of cerebral tumour. *Brit Med J 1*: 988–999.

Bond CJ (1939): *Recollections of Student Life and Later Days.* London, H. K. Lewis & Co.
Broca P (1861): Remarques sur le siège de la faculté du langage articulé; suivies d'une observation d'aphémie (perte de la parole). *Bull Soc Anat 36*: 330–357, 398–407.
Broca P (1865): Sur le siège de la faculté du langage articulé dans l'hémisphère gauche du cerveau. *Bull Soc Anthrop 6*: 377–393.
Broca P (1867a): Cas singulier de trépanation chez les Incas. *Bull Soc Anthrop 2* (2nd ser.): 403–408.
Broca P. (1867b): Trépanation chez les Incas. *Bull Acad Méd (Paris) 32*: 866–872.
Broca P (1868): Sur le stéréographe, nouvel instrument craniographique. *Bull Soc Anthrop 3* (2nd ser.): 99–126.
Broca P (1873): Sur les cranes de la caverne de l'Homme-Mort (Lozère). *Rev Anthrop 2*: 1–53.
Broca P (1874a): Discussion. *Bull Soc Anthrop 9* (2nd ser.): 189–205.
Broca P (1874b): Sur les trépanations préhistoriques. *Bull Soc Anthrop 9* (2nd ser.): 542–557.
Broca P (1875a): Sur la perforation congénitale et symétrique des deux pariétaux. *Bull Soc Anthrop 10* (2nd ser.): 192–199.
Broca P (1875b): Sur les trous pariétaux et sur la perforation congénitale double et symétrique des pariétaux. *Bull Soc Anthrop 10* (2nd ser.): 326–336.
Broca P (1876a): Diagnostic d'un abscès situé au niveau de la région du langage: trépanation de cet abscès. *Rev Anthrop 5*: 244–248.
Broca P (1876b): Sur la trépanation du crâne et les amulettes crâniennes a l'époque Néolithique. Congrès International d'Anthropologie et d'Archéologique Préhistoriques (Session à Budapest). *Rev Anthrop 5*: 101–196.
Broca P (1876c): Sur les trépanations préhistoriques. *Bull Soc Anthrop 11* (2nd ser.): 431–440.
Broca P (1876d): Sur l'âge des sujets soumis à la trépanation chirurgicale néolithique. *Bull Soc Anthrop 11* (2nd ser.): 572–576.
Broca P (1876e): Sur les trépanations préhistoriques. *Bull Soc Anthrop 11* (2nd ser.): 236–251.
Broca P (1876f): Discussion. *Bull Soc Anthrop 11* (2nd ser.): 279–285.
Broca P (1876g): Prétendues amulettes crâniennes. *Bull Soc Anthrop 11* (2nd ser.): 461–463.
Broca P (1876h): Trépanations préhistoriques; crânes trépanés à l'aide d'un éclat de verre. *Bull Soc Anthrop 11* (2nd ser.): 512–513.
Broca P (1876i): Amulettes crâniennes et trépanation préhistorique. *Rev Anthrop 5*: 106–107.
Broca P (1877a): De la trépanation du crâne, pratiquée sur un chien vivant, par la méthode néolithique. *Bull Soc Anthrop 12* (2nd ser.): 400.
Broca P (1877b): Trépanation de crâne par le procédé préhistorique. *Bull Soc Anthrop 12* (2nd ser.): 477–478.
Broca P (1877c): Sur la trépanation du crâne et les amulettes crâniennes à l'époque néolithique. *Bull Acad Méd (Paris) 6*: 710–714.
Buckland AW (1882): Surgery and superstition in Neolithic times. *J Anthrop Inst G Brit Ire 11*: 7–21.
Clower WT, Finger S (2001): Discovering trepanation: The contribution of Paul Broca. *Neurosurg 49*: 1417–1425.
Dudley BW (1828): Observations on injuries of the head. *Transyl J Med 1*: 9–40.

Ferembach D (1962): *La Necropole Epipaleolithique de Taforalt (Maroc Oriental), Etude de Squelettes Humains,* Rabat, Centre Nationale de la Recherche Scientific.

Finger S (1994): *Origins of Neuroscience: A History of Explorations into Brain Function,* New York, Oxford University Press.

Finger S (2000): *Minds Behind the Brain: A History of the Pioneers and their Discoveries,* New York, Oxford University Press.

Finger S, Clower WT (2001): Victor Horsley on "Trephing in Pre-historic Times". *Neurosurg 48*: 911–918.

Gross CG (1999): A hole in the head. *Neuroscientist 5*: 263–269.

Grünbaum ASF, Sherrington CS (1901): Observations on the physiology of the cerebral cortex of some of the higher apes. *Proc R Soc Lond 69*: 206–209.

Grünbaum ASF, Sherrington CS (1903): Observations on the physiology of the cerebral cortex of the anthropoid apes. *Proc R Soc Lond 72*: 152–155.

Hippocrates (1952): *On Injuries of the Head.* In: *Hippocrates and Galen. Great Books of the Western World* (*Vol. 10*). Chicago, William Benton. pp. 63–70.

Horne JF (1894): *Trephining in Its Ancient and Modern Aspect.* London, John Bale & Sons.

Horrax G (1952): *Neurosurgery: An Historical Sketch.* Springfield, IL, Charles C Thomas.

Horsley V (1886): Brain surgery. *Brit Med J 2*: 670–675.

Horsley V (1887a): A note on the means of topographical diagnosis of focal disease affecting the so-called motor region of the cerebral cortex. *Am J Med Sci 96*: 342–369.

Horsley V (1887b): Brain surgery in the Stone Age. *Brit Med J 1*: 582–587. (Abstract of his address at the Royal Institution.)

Horsley V (1888): Trephining in the Neolithic period. *J Anthropol Inst G Brit Ire 17*: 100–106.

Horsley V (1909): The function of the so-called motor area of the brain. *Brit Med J 2*: 125–132.

Horsley V, Schäfer AE (1885): Experimental researches in cerebral physiology: On the muscular contractions which are evoked by excitation of the motor tract. *Proc R Soc Lond 39*: 404–409.

Horsley V, Schäfer AE (1888): A record of experiments upon the functions of the cerebral cortex. *Phil Trans R Soc Lond 179* (ser. B): 1–45..

Jackson JH (1870): A study of convulsions. *Trans St. Andrews Med Grad Assoc 3*: 162–204.

Jackson JH (1873): On the anatomical, physiological, and pathological investigation of the epilepsies. *West Riding Lunatic Asylum Med Rep 3*: 315–319.

Jensen RL, Stone JL (1997): Benjamin Winslow Dudley and early American trephination for posttraumatic epilepsy. *Neurosurgery 41*: 263–268.

Jørgensen JB (1988): Trepanation as a therapeutic measure in ancient (pre-Inka) Peru. *Acta Neurochir 93*: 3–5.

Kurth G, Rohrer-Ertle O (1981): On the anthropology of the Mesolithic to Chalcolithic human remains from the Tell es-Sultan in Jericho, Jordan. In: Kenyon KM ed., *Excavations in Jericho.* London, British school of Archeology in Jerusalem, pp. 407–500.

Leyton ASF, Sherrington CS (1917): Observations on the excitable cortex of the chimpanzee, orang-utan and gorilla. *Q J Exp Physiol 11*: 135–222.

Lillie. MC (1998): Cranial surgery dates back to the Mesolithic. *Nature 391*: 854.

Lisowski, FP (1967): Prehistoric and early historic trepanation. In: Brothwell DR, Sandison, AT eds., *Disease in Antiquity.* Springfield, IL, Charles C Thomas, pp. 651–672.

Lucas-Championnière JMM (1878): *Etude Historique et Clinique sur la Trépanation du Crâne,* Paris, V. A. Delahaye et Cie.

Lucas-Championnière JMM (1912): *Les Origines de la Trépanation Décompressive: Trépanation Néolithique, Trépanation Pré-Colombienne, Trépanation des Kabyles, Trépanation Traditionnelle.* Paris, G. Steinheil.

Lyons JB (1966): *The Citizen Surgeon: A Biography of Sir Victor Horsley.* London, Peter Dawnay.

Lyons JB (1967): Sir Victor Horsley. *Brit Med J 2*: 361–373.

MacCurdy G (1923): Human skeletal remains from the highlands of Peru. *Am J Phys Anthrop 6*: 217–329.

Macewen W (1879): Tumour of the dura mater removed during life in a person affected with epilepsy. *Glasgow Med J 12*: 210- 213.

Macewen W (1881): Intra-cranial lesions, illustrating some points in connexion with localisation of cerebral affections and the advantages of antiseptic trephining. *Lancet 2*: 541–543.

Macewen W (1888): An address on the surgery of the brain and spinal cord. *Brit Med J 2*: 302–309.

Majno G (1975): *The Healing Hand.* Cambridge, MA, Harvard University Press.

Margetts EL (1967): Trepanation of the skull by the medicine-men of primitive cultures, with particular reference to present-say native East African practices. In: Brothwell DR, Sandison AT eds., *Disease in Antiquity.* Springfield, IL, Charles C Thomas, pp. 673–701.

Moodie RL (1929): Studies in paleopathology. XVIII: Surgery in pre-Columbian Peru. *Ann Med Hist 11*: 698–728.

Morton SG (1839): *Crania Americana: Or a Comparative View of the Skulls of the Various Aboriginal Nations of North and South America.* Philadelphia, PA, Simpson, Marshall & Co.

Munro R (1897): *Prehistoric Problems.* Edinburgh, William Blackwood and Sons.

Oakley KP, Brooke WMA, Akester AR, Brothwell DR (1959): Contributions on trepanning or trephination in ancient and modern times. *Man 59* (Art. 133): 92–96.

O'Connor DC, Walker AE (1967): Prologue. In: Walker AE ed., *A History of Neurological Surgery.* New York, Hafner, pp. 1–22.

Osler W (1923): *The Evolution of Modern Medicin: A Series of Lectures Delivered at Yale University on the Silliman Foundation in April, 1913.* New Haven CT, Yale University Press.

Paget S (1919): *Sir Victor Horsley: A Study of his Life and his Work.* London, Constable & Co.

Parry TW (1928): Holes in the skulls of prehistoric man and their significance. *Archaeol J 85*: 1–12.

Pellock JM (1989): Preface. *Ped Clin N Am* 36: ix.

Popham RE (1954): Trepanation as a rational procedure in primitive surgery. *Univ Toronto Med J 31*: 204–211.

Pozzi S (1880): Paul Broca. *Rev Anthrop 2*: 577–608.

Prunières PB (1868): Fouilles éxecutées dans les dolmens de la Lozère. *Bull Soc Anthrop 3* (2nd ser.): 317–320.

Prunières PB (1874a): Sur les crânes artificiellement perforés à l'époque des dolmens. *Bull Soc Anthrop 9* (2nd ser.): 185–205.

Prunières PB (1874b): Sur les crânes perforés et les rondelles crâniennes de l'époque néolithique. *Comp Rend Assoc Fran Avan Sci 3*: 597–635.

Rawlings CE III, Rossitch E (1994): The history of trepanation in Africa with a discussion of its current status and continuing practice. *Surg Neurol 41*: 507–513.

Rifkinson-Mann S (1988): Cranial surgery in ancient Peru. *Neurosurgery 23*: 411–416.

Rogers L (1930); The history of craniotomy: An account of the methods which have been practiced and the instruments used for opening the human skull during life. *Ann Med Hist 2* (new ser.): 495–514.

Schiller F (1979): *Paul Broca: Founder of French Anthropology, Explorer of the Brain.* Berkeley, University of California Press.

Squier EG (1877): *Peru: Incidents of Travel and Exploration in the Land of the Incas*. New York, Harper and Brothers.

Stewart TD (1958): Stone Age skull surgery: A general review with emphasis on the New World. *Ann Rep Smithsonian Inst:* 469–491.

Stone JL (1991): Paul Broca and the first craniotomy based on cerebral localization. *J Neurosurg 75*: 154–159.

Szepetowski P, Rochette J, Berquin P, Piussan C, Lathrop GM, Monaco AP (1997): Familial Infantile convulsions and paroxysmal choreoathetosis: A new neurological syndrome linked to the pericentromeric region of human chromosome 16. *Am J Human Genet 61*: 889–898.

Taxil J (1602): *Traicté de l'Epilepsie, Maladie Vulgairement Appelée au Pays de Provence la Goutette aux Petits Enfans.* Lyon, Robert Renaud.

Temkin O (1971): *The Falling Sickness (2*nd *ed.).* Baltimore, MD, Johns Hopkins University Press.

Wakefield EG, Dellinger SC (1939): Possible reasons for trephining the skull in the past. *Ciba Symp 1*: 166–169.

Chapter 3

The Pathology of Trepanation: Differential Diagnosis, Healing and Dry Bone Appearance in Modern Cases

A. NERLICH , O. PESCHEL , A. ZINK[1] AND F. W. RÖSING*,[3]
[1]*Pathologisches Institut, Ludwig-Maximilians-Universität München, München, Germany;*
[2]*Institut für Rechtsmedizin , Ludwig-Maximilians-Universität München, München, Germany;*
[3]*Institut für Humangenetik und Anthropologie, Universität Ulm, Ulm, Germany*

Abstract

Today, trepanation is a surgical routine procedure, particularly used after severe trauma and in cases of intracranial neoplasms. In historic periods, trepanation seems to have been used for both medical and religious or mythical reasons. This is the consequence of primordial and more holistic *weltbild* concepts that damage to the body at the same time is a damage to the soul. In order to identify trepanned skulls properly and to distinguish this condition from other perforating skull defects (congenital and developmental defects, pathological lesions, trauma sequels and pseudopathologic postmortem defects) its exact dry bone appearance and the differential healing indicators are of decisive importance.

This chapter will demonstrate major macromorphological features of trepanation with particular reference to the bone surface appearance. Hence, the appearance of trepanations during the subsequent healing process will be presented on dry bone specimens from 11 modern cases with known or partially known history. These trepanations are individuals which have survived from a few minutes up to 34 years.

Using this approach we will provide evidence that trepanation defects do not show osseous healing before a postdefect period of more than 70 days. This “healing” process is characterized by a smoothing of the trepanation margins and a loss of the typical layering of the skull bone (internal and external tabula with diploe). Despite this remodelling none of the defects showed complete closure of any defect – even when the trepanned fragment had been replaced during surgery. Furthermore, plaque-like appositional calcifications had to be noted which were attached to the trepanation defects.

These cases demonstrate the possibility of elucidating the presumed osseous remodelling process of trepanations imposing general considerations of healing processes of the skull bones. Our observations also demonstrate a clearly different skull healing pattern and speed, as com-

* Adress for correspondence: Prof. Dr. Friedrich W. Rösing, Institut für Humangenetik und Anthropologie, Universitätsklinikum Ulm, D–89070 Ulm, Germany, Phone: 0731 500 25230, Mobile: 0170 294 0068, Fax: 0731 500 25239, e-mail: erbbio@medizin.uni-ulm.de

pared to long bone fractures; this might be due to the missing mechanical stress to a skull bone disruption.

Keywords: Trepanation, pathology, differential diagnosis

Introduction

Trepanation has been practiced in many primordial cultures dating as far back as the Neolithic Age in Europe, and has been detected world-wide in anthropological and palaeopathological material. After the first scientific notice (Broca, 1867), cases from every well-documented period and region are known today (Aufderheide, 1985; Bennike, 1985; Stevens, 1991). This kind of rather difficult operation was well-mastered in Europe, particularly during the Neolithic period. Survival rates were very good as suggested by the many known healed specimens, as compared to the very unhealed cases, although a comprehensive and solid quantiative and nosological study is missing so far. Naturally the indication of trepanation cannot be inferred directily for scriptless times. Yet the number of healed skull injuries not directly associated with the trephination shows that there must have been medical reasons. Another indirect source for inferences of reasons are extra-European descriptions; the classic and well-known east African case of the "hat-on-hat-off-man" (Margetts, 1967) is a key example: in original cultures, i.e. non-European and non-modern ones, the obvious corporal damage has often been seen to be associated with, or sometimes dominated by, some kind of spiritual evil. Then the head must be opened to set free that black spirit, not only to perform a medical treatment.

At present, trepanation of the skull is performed as a routine surgical procedure, particularly after severe trauma, intracranial bleeding or in cases of cerebral and meningeal neoplasms. The removal of inappropriate neoplastic tissue, bleeding residues or trauma fragments is thereby performed. Otherwise, trepanation is performed in order to "enlarge" the skull volume. During this procedure, a part of the skull bone is removed.This may be replaced after completion of the operation. In other instances, however, the fragment is not replaced and the bone defect may remain "open" for a long period of time. The healing procedure is characterized by distinct morphological changes which are associated with stages of bone healing and which may provide information about the time course and eventual differential diagnoses of trepanation.

In this paper, we describe major macromorphological features of trepanation with particular reference to the bone surface appearance in dependence of surgery and the time period between trepanation and pathological removal of the affected skull bone(s). These removed samples were subjected to maceration in order to provide a reference material for the detailed interpretation of dry bone morphology of trepanned skulls from historic periods. Hence, the consequences of trepanation during the subsequent healing process will be presented on dry bone specimens of modern cases with known or partially known history.

Materials and Methods

Sample Preparation

The present study was conducted on dry bone samples obtained from individuals who had suffered intravital trepanation for medical reasons in recent times. All cases had died minutes to several years after trepanation due to various causes, and consequently medico-legal autopsies, again for various reasons, had been performed. During these autopsies the affected skulls/ skull bones were removed for diagnostic reasons and were subjected to maceration. Adhering residual soft tissues were carefully removed by excision. Thereafter, the bones were cleaned with tap water and were either left untreated until the soft tissue remains had disappeared or were immersed in warm water containing 0.1% H_2O_2. The morphology of the resulting dry bone specimens was carefully recorded and photodocumented.

Short Description Of The Cases

The following 11 cases were examined in this study:

Case 1: Calotte of a male aged 50, epidural hematoma after falling; acute trepanation of approximately 9 x 11cm, patient died during surgery (see Fig. 1).

Case 2: Calotte of a female aged 41 years with signs of an acute subarachnoidal bleeding, acute trepanation with removal of a 7 x 5.5 cm large fragment of the right fore head, death within several hours after beginning of the bleeding.

Case 3: Calotte of a 35 year-old male suffering from meningioma. Surgical tumor removal was attempted through a 9 x 6 cm large parietal trepanation defect. The patient died within 6 days after surgery due to acute aspiration pneumonia.

Case 4: Calotte of a 33 year-old male; acute onset subarachnoidal bleeding; despite immediate trepanation (6 cm in diameter) the patient died within seven days of a failure of central regulation.

Case 5: Calotte of a 86 year-old female with acute subarachnoideal bleeding 10 days prior to death. A few hours after onset of clinical symptoms the brain was opened and surgery was attempted in order to stop bleeding. Despite successful stoppage of the bleeding through a 7.5 cm trepanation defect, the individual died 10 days later of severe bilateral necrotizing pneumonia.

Case 6: Calotte of a small and gracile male aged 76, hit as a pedestrian by car, survived for 74 days, several thin fracture lines (see Fig. 2).

Case 7: Calotte of a 24 year-old male who was suffering from extensive glioblastoma; therefore osteoclastic trepanation of a 9 x 7 cm large fragment of the right frontal skull bone 1 year prior to death; replacement of the trepanned fragment and fixation with metal clips. Death due to tumor recurrence.

Case 8: Calotte of a female aged 74, fell from bridge into shallow waters, impression

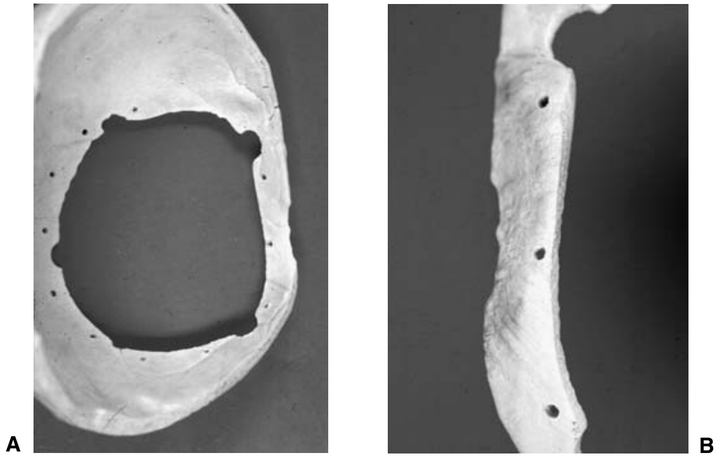


Figure 1. Modern case of trepanation (Case 1). The removal of a major segment of the skull bone results in a major defect. Note the drilling holes which are used for an eventual refixation of the trepanned fragment (A). (B) A close-up photo reveals no structural change of the acute defect margins.

Figure 2. Skull from a male with extensive skull trauma. Although the fracture lines of the previous skull lesion are easily visible, this skull shows after 76 days of healing, an almost complete reunification of the fracture fragments (Case 6).

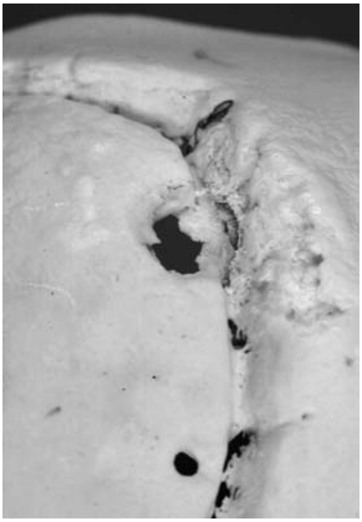


Figure 3. Modern case of trepanation (Case 8). The replaced trepanation fragment shows in this case partial reunification. However, despite the long healing period of four years, the fragment margins are still partly open.

Figure 4. Trepanation defect of a male six years after neurosurgical intervention (Case 10). Even though in this case the replaced fragment shows some healing, some gaps still remain.

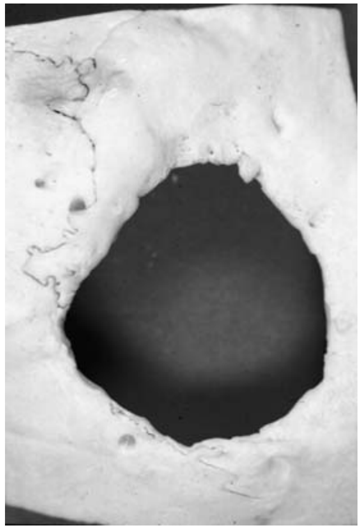


Figure 5. Trepanation defect after 34 years (Case 11). In this individual, the trepanation defect had been left open for this long period of time. Although the defect margins are rounded and smoothened, there is no evidence for a tendency to closure of the defect.

fracture at right frontal, small scrab from salvage tools; left frontal with trepanation ca. 4 years before (see Fig. 3).

Case 9: Calotte of a male aged 48, trepanation of left parietal, 6cm, accident with skull trauma 6 years before.

Case 10: Skull of a male aged 74, trepanation six years before during neurosurgical removal of meningioma; approx. 12 x 10.5 cm (see Fig. 4).

Case 11: Partial parietal of a male aged 37, died after drug abuse; trepanation 34 years before, after motorcycle accident (see Fig. 5).

Observations

There were significant differences in the morphology of the trepanation margins between the various cases and with the different times elapsed since each operation. Despite these major differences in the morphology of the defect margins, further variability has to be taken into account due to variances in the extent of those defects and in the therapeutic treatments performed. Nevertheless, our present study provides significant information to indicate that the "healing" / remodelling process of trepanation defects undergoes distinct time-dependent changes.

We observed no osseous reaction in those trepanned skulls surviving only for a few hours to days (Cases 1–5). In those cases, the margins of the trepanation defects were sharp-edged and there was no sign of new bone formation or osteoclastic resorption of marginal bone edges. There were no differences in this morphology, either for small or large defects, nor for those defects that had been treated by replacement of the trepanation fragment or left open.

In contrast, the skull of an individual surviving the trauma for 76 days showed a good healing of the fractured skull fragments (Case 6; Fig. 2). In this case, however, no complete osteoclastic trepanation had been performed, but the fractured skull fragments had been replaced after surgery. This exact reposition (replacement) of the fracture fragments obviously had produced an excellent condition for inducing a bony reunion of the fragmented skull. The fracture lines, however, were still very much visible and the fracture line edges were somewhat prominent. In the next case (Case 7), the trepanation had been survived by approximately one year. In this case which is of a rather frequent type of trepanation, the defect margins showed minor "healing" and some remodelling with slight focal new bone formation and focal osteoclasia resulting in smoothing of the trepanation defect´s margins. Despite this long interval, the replaced fragment had not reunited with the surrounding skull bone except for those areas where metal clips had been attached to the trepanned fragment.

In the further cases which had survived their trepanation by more than four years (up to 34 years; Cases 8–11), more or less extensive signs of "healing" could be noted. In those cases, where the removed fragment had been replaced, an extensive reunion of the fragment and the surrounding skull bone was seen. Despite these long periods of time, however, even in this group there were still several cases where this reunion was incomplete. A "malunion" was not only seen in areas where residual sewing material was present, which may have impeded (hampered) healing and remodelling, but also in other areas. Despite this focal malunion, the defect margins were considerably altered with major smoothing and rounding of the defect margins.

As a further finding, there were plaque-like calcifications attached to the intracranial side of the defect zone or the replaced fragment in several long-term samples. In those cases, where the trepanation defects had not been refilled, the hole had remained open. Here again, the defect margins were smooth and rounded and the diploic structure was lost at the marginal zones. This was particularly seen in the oldest sample, where the trauma had been survived for 34 years, starting in childhood.

Discussion

Trepanation has obviously been practiced in a whole variety of ancient and extra-European groups (populations). Thus, trepanation defects have been identified in skulls from European, South and North American, Asian and African populations dating back to the Neolithic Age (Brothwell and Sandison, 1967). Prioreschi (1991) estimated that the frequency of Neolithic trepanations ranged between 6 and 10% of skulls. The reasons remain obscure, but it is assumed that this occurred for religious or mythical reasons. Moreover, it is supposed that in historic and prehistoric times, trepanations was used to relieve intracranial pressure conditions, such as that following skull trauma (Kaufman et al., 1997). Pre-modern trepanation is currently still performed on native tribes of East Africa and

Polynesia (Campillo, 1984; Meschig and Schadewaldt, 1981) and the type of bone morphology of these recent trepanations closely resembles those seen in ancient skulls. Nevertheless, there exist several perforative lesions of the skull that may mimic trepanation defects. Therefore it is of particular interest to identify the pattern of trepanation defects in documented present-day cases and to compare them with other defect types. Furthermore, the course of remodelling may provide information about the time period of survival. It was therefore the aim of this study to investigate a series of present-day cases to identify the features of trepanation healing in the course of known time periods.

Although our series of trepanned skulls was limited, and the trepanation conditions were variable with respect to the size of the defect and the treatment, several consistent observations could be made:

1. Despite very long periods of time (up to 34 years in our series), the trepanation defects do not show complete obliteration, even when the trepanned fragment is replaced properly. Additionally, there is no evidence that the defects show any tendency to decrease by marginal bone proliferation, as we did not see any significant new bone formation at the defect margins. In this respect, skull defects (irrespective of their origin) obviously underlie a basically different way of remodelling when compared to (traumatic as well non-traumatic) defects of long bones. While the latter tend to reunite – such as by bridging callus formation and extensive new bone formation (see Nerlich, 1998) – such a bone formation seems to occur only minimally on the skull. This is shown by the consistently irregular margins which obviously conform to the operation traces and the largely open gaps in cases of fragment reposition. Even in those cases where the trepanned fragment had been replaced and left at the trepanation site for several years the fragment did not show complete healing. Nevertheless, some minor new bone formation may occur at trepanation defects and we have seen this particularly at those points where clips or other suture material may attach the trepanation fragment closely to the surrounding original skull.

2. The defect margins of the trepanation site finally do show some remodelling which is characterized by osteoclastic resorption. This leads to a smoothing of the initially sharp edges. Furthermore, a characteristic feature is the loss of the typical layering of the skull bone at the defect margins, in particular the loss of the diploic structure. Finally, the remodelled defect margin consists of only one compact bone layer, and the internal and external tabula can no longer be distinguished. When including other cases and general observations, it may be stated that healing originates in the outer table, which suggests a particular role of the scalp (Stevens, 1991).

3. These remodelling processes follow a definite time course. In our series, the samples with a very short survival time of few hours or even days did not show any remodelling. The first defect with signs of significant healing was that of a male individual that had not suffered from typical trepanation, but a severe skull fracture and the fracture fragments had been replaced shortly after trauma to ideal arrangement (Case 6). This case showed extensive healing. The next longest case of survival after trepanations (approximately 1 year) – revealed only slight remodelling and even older trepanation defects were not completely remodelled as indicated above (Case 7). Using our observations, we can state that the remodelling of those trepanation defects extends over a very long period of several years and that therefore defects with rounded, “smoothed” margins and a loss of

the diploic skull bone structure must have survived for at least several months, or more likely, years.

4. We did not see major differences between cases with various underlying causes for trepanation. Thus, neither the tumor cases nor those where intracerebral haemorrhage or trauma had caused trepanation differed significantly. Additionally, differences in the surgical technique, such as various suturing techniques, obviously did not alter our observations to a noticeable extent. It may, however, well be that a more homogeneous study group would provide more exact data, particularly on the time course of the remodelling.

In conclusion, our observations on the dry bone appearance of modern cases of trepanation provide valuable information on the morphology of acute and chronically remodelled cases of this condition. This detailed morphologic investigation may additionally provide information upon time course and thereby relevant information after the survival of any trepanation.

This study also provides evidence that the remodelling of skull defects is considerably different from that of other bone regions. The reason for this is unclear, but it may be assumed that it is due to different biomechanical stress upon the skull bone as compared to postcranial bones. Long standing surgical experience demands that the fracture zone should be minutely moved, notwithstanding a gross immobilisation of limb bones; consequently the first *fixateurs externes* made of carbon fiber bars considerably prolonged healing periods because they were too stiff.

Acknowledgement

This study was supported by the Deutsche Forschungsgemeinschaft (DFG NE 575/3–*3*).

References

Aufderheide AC (1985): The enigma of ancient cranial trepanation. *Minnesota Medicine 68*: 119–122.

Bennike P (1985): *Palaeopathology of Danish Skeletons. A Comparative study of Demography, Disease and Injury*. Akademisk Forlag, Copenhagen.

Broca, P (1867): Cas singulier de trépanation chez les Incas. *Bull Mém Soc d'Anthrop de Paris (2ème série) 2*: 403–408.

Brothwell DR, Sandison AT (1967): *Diseases in Antiquity: a Survey of the Diseases, Injuries and Surgery of Early Populations.* Springfield, Chicago, C.C. Thomas.

Campillo D (1984): Neurosurgical pathology in prehistory. *Acta Neurochir 70*: 275–290.

Kaufman MH, Whittaker D, McTavish J (1997): Differential diagnosis of holes in the calvarium: Application of modern clinical data to palaeopathology. *J Archeol Sci 24*: 193–218.

Meschig R, Schadewaldt H (1981): *Trepanations en Afrique Orientale*. Paris, Hexagone (Roche).

Nerlich AG (1998): Pathomorphological and pathophysiological aspcets of fracture healing and their application to historic fractures. *Homo 49*: 156–171.

Prioreschi, P (1991): Possible reasons for Neolithic skull trephining. *Biol Med 34*: 296–303.

Stevens GC (1991): *The Anatomical and Microscopical Analysis of Ancient Trephinations*. Unpublished. BSc (Med) Thesis, Dept of Anatomy, University of Leicester.

Part 2: Trepanation in Europe

"*Most European trepanations were concentrated in restricted areas and periods – notably two areas of France in the Neolithic . . . was the upsurge related to the talents of a single skilled individual, a travelling surgeon?*"

C. Roberts and J. McKinley (this volume)

Chapter 4

Review of Trepanations in British Antiquity Focusing on Funerary Context to Explain their Occurrence

CHARLOTTE ROBERTS[1] AND JACQUELINE MCKINLEY[2]
[1]Department of Archaeology, University of Durham, Durham, UK; [2]Wessex Trust, Portway House, Salisbury, UK

Abstract

This study focuses on the extant evidence for trepanations in Britain and assesses the possible reasons for their occurrence. Sixty-two trepanations are considered, ranging in date from the Neolithic (4,000-2,000 BC) to the post-Medieval (post-sixteenth century AD) periods. The post-Roman/Anglo-Saxon period provided the most numerous evidence (24 or 38.7% of the total), and in 43 cases the reason for the trepanation was not apparent. Almost two thirds of the trepanations had evidence of healing. Consideration of funerary context revealed that only the Iron Age examples, and one Anglo-Saxon individual with a trepanation buried prone in a Roman villa site, might have been the result of a special or ritual act.

Keywords: Trepanation, Britain, prehistoric, Roman, post-Roman/Anglo-Saxon, later and post-Medieval, funerary context

Introduction

Trepanation, or the surgical removal of a piece of skull "to create a communication between the cranial cavity and the environment" (Aufderheide and Rodríguez Martin, 1998, p. 31) has been described as an operation performed in many parts of the world from prehistory to the present (e.g. Furnas et al., 1985; Lisowski, 1967). The evidence suggests that both healed and unhealed examples exist. However, it is often unclear whether the unhealed trepanations were performed before death and were unsuccessful, or whether the operation was undertaken after death for some reason. Clearly, the existence of an unhealed trepanation does not necessarily mean that the operation caused the death of the individual; having only the skeleton available for study means that the potentially many causes of death will not be visible, thus making the attribution of a specific cause of death impossible in virtually all cases.

The suggested reasons for trepanations have ranged from the treatment of head injuries (e.g. Zimmerman et al., 1981) to the release of spirits causing disease (Grattan and Singer, 1952). Other than the presence of a head injury, it is impossible in the majority of cases to be certain of any reason behind trepanations identified in the skeletal remains of our ancestors, but it is possible to make suggestions. "Drilling" holes in people's heads has always attracted attention from both academics and public alike, not least when they have appeared to heal and the individual obviously survived the operation. Of course, whether their mental state was affected is debateable and it is difficult, if not impossible in most instances, to establish the existence of complications arising from the operation. Perhaps by correlating the site of the operation with the underlying brain tissue and its function may help in this respect. Clearly, these operations are performed today with success but under much more controlled circumstances with full medical and surgical support, and antibiotics to combat associated infections. In the past, the survival of these people is remarkable.

The purpose of this paper is to present the current evidence for trepanation in Britain and assess the main reasons for these trepanations using funerary context as an indicator.

Past Work on Trepanations

Publications about trepanations have ranged from descriptions of individual examples (Richards, 1995), to the methods and instruments used (Rogers, 1930), and have also included the evolution and the development of the operation (Brothwell, 1994: Piggott, 1940) and differential diagnoses (Gregg and Bass, 1984; Kaufman et al.; 1997; Stewart, 1975). In British contexts probably the most prolific writer on this operation has been Parry (1914, 1916, 1921a,b,c, 1923, 1928, 1931, 1936, 1940). Parry appeared to initiate a great interest in this subject through his work and he managed to collect together data on all extant examples of trepanation in Britain. He made fairly detailed descriptions of the site and type of trepanation performed, the evidence for healing, any signs of the reason for the operation and the funerary context where possible. In addition, in a general sense, he reviewed the possible reasons for the operation and differential diagnoses for the holes observed, plus instruments used, and he also surveyed the world evidence for trepanation.

More recently, in a review paper published in 1986, Parker et al. surveyed the evidence for British trepanations and reported on two new cases. They also briefly discussed two main reasons for trepanation: a religious phenomenon and as a curative surgical operation. At that time nine prehistoric, three Roman, eleven post-Roman and three undated examples were known, for a total of 23 trepanations. Since then, however, a number of new examples have been excavated from archaeological sites, or have been identified in skeletal collections in museums.

This paper surveys the extant evidence for trepanation at the present time and considers their temporal and geographic distribution, affected ages and sexes, position and type of trepanation, evidence for healing and reasons behind the operation, particularly focusing on funerary context as a possible factor.

Material and Methods

Materials

Parker et al. (1986) was used as a starting point for collating data on the evidence for trepanation and all the original publications from which the examples described in that article derived were consulted. These publications revealed other examples (not originally included) that were deemed worthy of consideration. In addition, more recent papers describing new cases were considered (Anderson, 1993; Boylston et al*.,* 1998; Buckley and Ó Donnabhain, 1992; Duhig, 1998; McKinley, 1992a,b; Wakely, 1996), and a request to members of the British Association of Biological Anthropologists and Osteoarchaeologists was made in order to track down cases not yet published. It is inevitable, however, that some cases published in "obscure" places and others unpublished, will have been missed.

Methods

The description for each example of trepanation was consulted and a number of variables noted: site name, county, date, grave number, sex, age at death, position of trepanation on the skull (frontal, left or right parietal, occipital or a combination), type of trepanation, evidence of healing and any suggestion why the operation was performed e.g. trauma. In addition, funerary context was considered to assess if the affected individual had been subject to different funerary rites/rituals compared to others within the cemetery group. The type of trepanation was recorded as scraped, gouged (alternatively referred to as push-plough by some authors), drilled (i.e. the result of the use of a trephine, and thus can be termed trephination), sawn, or bored and sawn.

Because it was not possible to examine the trepanations physically (although the authors had originally analysed five of the examples), the data had to be accepted at face value. For example, it is expected that many of the age estimations for the affected individuals were incorrect as, firstly, many of the adult age estimation methods had not been developed at the time some of the skeletal material had been examined, and secondly, many of the methods are suspected as giving incorrect estimations (e.g., see Molleson and Cox, 1993).

Results

Unfortunately, it was not possible to record all the variables because of the variable quality of the data presented throughout the publications. Therefore, a full set of data was not available for analysis. Appendices 1 and 2 provide the dataset.

Numbers of Trepanations

A total of 62 examples of trepanation were identified in published and unpublished sources and via communication with a number of workers in the field. This is an increase of 39

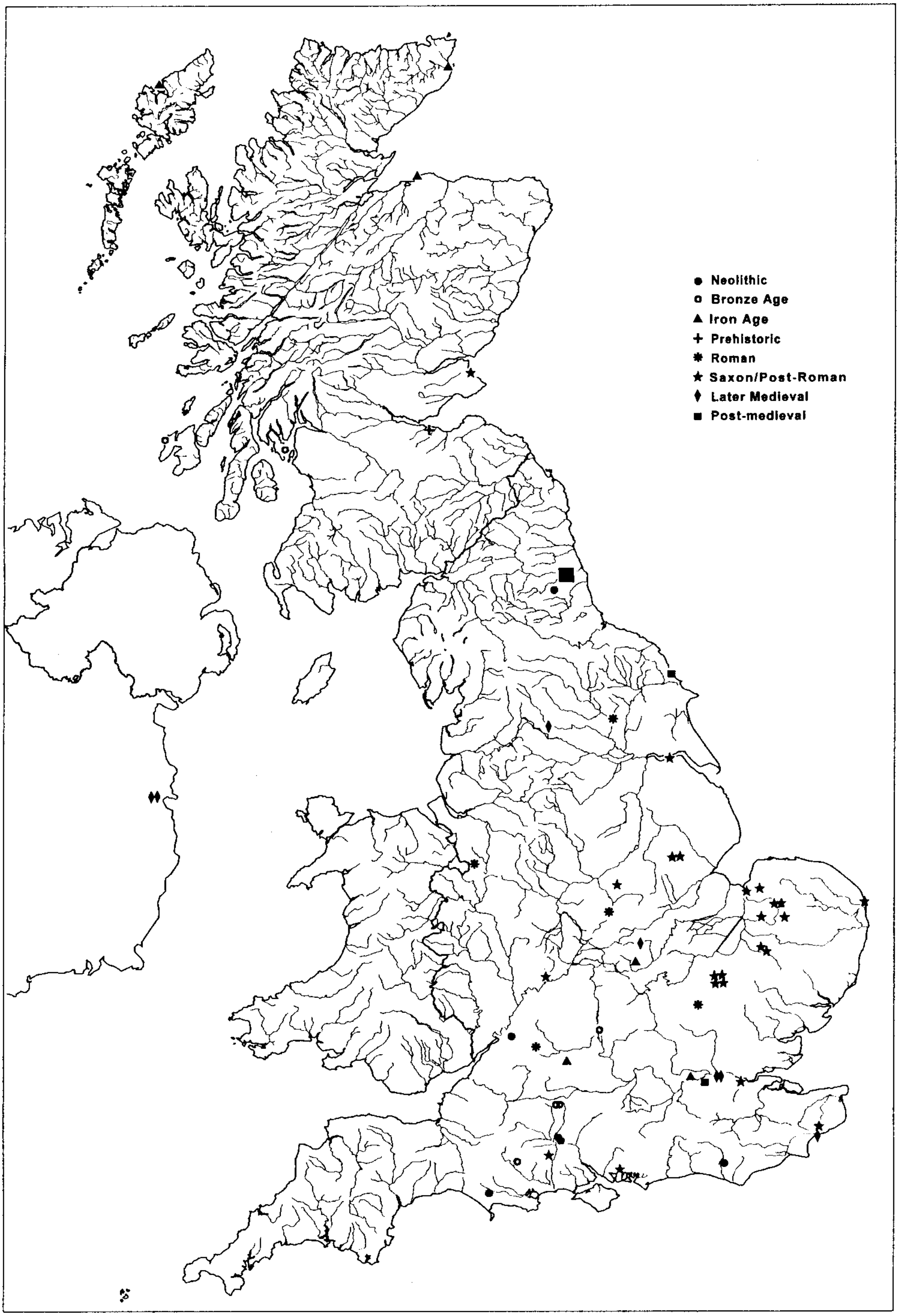


Figure 1. Distribution of trepanations.

Figure 2. Iron Age trepanation from Watchfield (with kind permission of Wessex Archaeology).

from 23 originally discussed by Parker et al. (1986). However, it is not a large percentage of the total inhumation burials excavated and analysed from the prehistoric to post-medieval periods in Britain, which has been estimated by the authors as between 45 and 50 thousand.

Temporal and Geographical Distribution (See Fig. 1)

Five examples (8.1%) derive from the Neolithic period (4,000-2,000 BC), most being recovered from locations in the south of England. Six examples (9.7%) have been found in contexts of Bronze Age date (2,600-800 BC), 75% of which came from a ca 75 mile/120km linear spread in southern England; the remaining two examples were from the west coast of Scotland within 60 miles/96km of each other. Of the eight possible (12.9%) Iron Age examples (800 BC-43 AD), half were from a limited area in central southern England (Fig. 2), and the other half were from northern Scotland (mainland and Western Isles), the latter forming the most northerly example of trepanation currently known from the British Isles. One other prehistoric trepanned skull of unknown provenance and imprecise date was recovered from Edinburgh, bringing the total number of all prehistoric trepanned skulls to 20 (32.3% of the total).

The five examples of first-fifth century AD date (Romano period), i.e. 8.1% of the known total, have been recovered from dispersed locations across England (Fig. 3).

Figure 3. Roman trepanation from Rockbourne (with kind permission of Sue Anderson; skull curated by Hampshire County Museums Service).

Figure 4. Anglo-Saxon trepanation from Oxborough.

By far the most frequent number of examples in Britain has been found in contexts of fifth-eleventh-century AD date, or the post-Roman Anglo-Saxon period (Fig. 4). Twenty-four (38.7%) of the trepanations of this date have been found, the vast majority (20 or 32.3% of the total) being from the earlier period (ca fifth-mid-eighth-century phase). Although recovered from various parts of England, with a single (late) example from Scotland (see note in App. 2), there is a noticeable concentration in eastern England from where ca 70% of the post-Roman/Saxon examples (ca 27% of the total) derive within an area of a 50 mile/80km radius, 12 (52% of the post-Roman/Anglo-Saxon, and ca 19% of total) being within a 23 mile/37km radial area. In three instances two or more cases were recovered from individual cemeteries; for example, 2.7% (4) individuals from Edix Hill, Cambridgeshire had been trepanned.

The seven (11.3%) later medieval (twelfth-sixteenth-centuries AD) examples were relatively dispersed across England, with at least two coming from Ireland (see note with App. 2). The six (9.7%) post-medieval examples were all recovered from sites in eastern England, with a concentration in the hospital cemetery at Newcastle in the north.

Geographically, all except nine of the examples, i.e. 82% of the total, have been found in England, with none, as yet, recovered from Wales. There is also a distinct concentration towards the more southern and eastern parts of the country, with no examples forthcoming from the south-west or north-west of England.

Age and Sex

Forty examples occurred in males (64.5%), eight in females (12.9%) and in 14 cases the sex of the individual was not stated (22.6%). Twelve people were classed as younger adults (20-30 years), seven as middle-aged adults (31-40 years), and 16 as older adults (41 years +). Twenty-seven individuals were classified as either "adults" (11) or no age was specified. In the latter case, therefore, there may have been non-adult individuals represented, but without more information it is impossible to say.

Reason for the Trepanation

In seven cases this information was not available. In 43 instances there was no evidence on the skull, such as a head injury, that suggested why the trepanation had been performed, and in 10 cases no comment was made regarding this variable at all.

In eight cases there was evidence on the skull which could have been the reason for the operation. Three examples were Roman (of four cases in total that reported this variable – 75%), four were post-Roman Anglo-Saxon (of 21 reporting this variable – 15%; Fig. 5, and one was later medieval in date (of eight reporting the variable – 25%). In all cases the evidence was a head injury and in all except one example the head injury had healed.

Finally, six Iron Age examples had holes that appeared to have been drilled post-mortem for the purposes of suspension.

Figure 5. Anglo-Saxon trepanation from Willoughby-on-the-Wolds.

Position of Trepanation

In eight cases this information was not available.

Prehistoric

It was possible to assess this variable in 14 cases. Three were in the frontal bone (one Neolithic, two Bronze Age), three were in the left parietal (one Bronze Age, two Iron Age) and three were in the right parietal bone (two Neolithic and one Iron Age). Five individuals had trepanation holes in a number of places on their skulls: one hole covered the frontal, parietals and occipital bone, another involved the occipital and both parietal, and in two cases both parietals were involved.

Romano-British

Two individuals were trepanned in their right parietal bone, one in both parietals, one in the occipital bone and the fifth person in the left temporal bone just above the mastoid process.

Post-Roman/Anglo-Saxon

Four people had trepans holes in their frontal bone, eight in their left parietal, five in their right parietal, one in the occipital bone, two in both parietal bones and two had holes covering the frontal and one of the parietal bones; one was trepanned in the "vault".

Later and Post-Medieval

Three individuals had trepanation holes in their frontal bone and four in their left parietal. In addition, one was specified as being in the "left side of the skull", one in the frontal and right parietal bone, one in the left parietal and occipital bone, and one in the left pterion region.

Taking the main areas of trepanation (frontal, left and right parietal bones and occipital), and viewing the data as a whole (37 cases), 10 occurred in the frontal bone (27.0%), 14 in the left parietal (37.8%), 10 in the right parietal (27.0%) and two in the occipital bone (5.4%).

Type of Trepanation

Prehistoric

Five examples were scraped (one Neolithic, two Bronze Age, one Iron Age, one "prehistoric"), four were gouged (one Neolithic, three Bronze Age), seven were drilled (one Neolithic, six Iron Age), one was unidentifiable as to type of trepanation, and for three cases the information was not given.

Roman

One example was scraped, one was gouged, two were drilled and for one no information was available.

Post-Roman/Anglo-Saxon

Eighteen were of the scraped type, one was drilled, one was unidentifiable as to type, and for three there was no information available. It has been suggested (Wells, 1974) that a number of the post-Roman/Anglo-Saxon trepanations (because they are similar in appearance and all come from Norfolk) might have been performed by the same surgeon (see later in Discussion).

Later and Post-Medieval

Three examples were scraped, five were drilled, one was unidentifiable as to type and four had no information available. Overall, of the 47 trepanations where unequivocal information was available, 27 were scraped (57.7%), five were gouged (10.6%), and 15

Figure 6. Post-Medieval trepanation from Newcastle Infirmary (with kind permission from Andrew Chamberlain, Helen Start and ARCUS).

were drilled (31.9%). Six of the drilled examples were in the medieval and post-medieval periods (Fig. 6).

Evidence of Healing

In five cases there was no suggestion as to whether the trepanation had healed or not. Of the prehistoric examples, nine cases had evidence of healing and ten had none. For the Roman period two were healed and three were not. In the post-Roman/Anglo-Saxon examples 18 were healed and three were not, whilst for the later and post-medieval periods six were healed and seven were not. Taking the data overall and pooling it for all periods, 35 trepanations (62.5%) had evidence of healing and 23 had not.

Of those that were unhealed, seven were from the prehistoric period: two Neolithic, two Bronze Age, and six Iron Age (a minimum of three were performed postmortem). Three examples derive from the Roman period, and two came from the post-Roman/ Anglo-Saxon period, with seven from the late and post-medieval periods. Of the latter, four came from the Newcastle Infirmary site. It is possible that all these unhealed examples could have been performed post-mortem for a particular (ritual?) reason. The Newcastle examples, however, may represent practice operations by budding surgeons.

Multiple Trepanations

Hunsbury (3), Fussell's Lodge (4), Edix Hill (4), Swaffham (2), Sleaford (2) and Newcastle (4), are locations that produced more than one individual with a trepanation. In

Figure 7. Watchfield: pit with trepanned skull and pig skull.

addition, Traigh Bhan, Newcastle, Hallow Hill and Watchfield produced individuals with more than one trepanation in each skull.

Funerary Context

Appendix 3 gives a summary of the funerary contexts of all the trepanned individuals. Two of the Neolithic examples represented river or coastal (Ovindean: Parry and Tildesley, 1935) skull deposits, the three others deriving from long barrow assemblages where the skulls were recovered as disarticulated and often fragmentary remains. The latter mode of deposition or "curation" was common for the period and the trepanned remains were not distinguished from others. Similarly, scores of non-trepanned skulls have been recovered as water deposits.

Three of the Bronze Age burials were from barrow cemeteries, one from a flat cemetery (Eynsham: Leeds and Musgrave, 1938), and the two Scottish examples from cist graves. All were either crouched or flexed on one side, the primary remains from one cist grave having been carefully set aside to allow the insertion of a later burial. (Traigh Bhan: Ritchie and Stevenson, 1982). All were associated with contemporary or subsequent burials made in similar locations and positions.

None of the Iron Age examples appear to have been recovered from a formal grave. All represent incomplete skulls; one from the River Thames, one from a pit fill where it lay adjacent to a pig skull (Fig. 7: McKinley, 1998) and the rest from within, or in the vicinity of, settlement sites. Although deposition of the dead in the Iron Age primarily appears to represent inhumation in either isolated graves or small grave groups in a variety of locations (Whimster, 1981), human remains of this date are frequently recovered as disarticulated fragments from middens, pits, or other localities (Hill, 1995). The "cult of the head" also appears to have been a common theme.

Four of the Roman examples derive from fairly substantial cemeteries within small towns, where the burial position was supine and extended with minor variations in arm and leg position; all except one (Baldock: McKinley, 1992a) was placed well amongst the other graves. One individual (Cirencester: McWhirr et al., 1982) had been decapitated, but then so had five others in the cemetery (1.3% of the total burials; Wells, 1982); the practice, whilst not exactly "the norm", has been noted at over 70 sites in Roman Britain (Philpott, 1991, p. 77). The fifth example (late fourth century AD) was recovered from below the floor within a building which, although not the "normal" place for burial of other than neonatal individuals, has been known to occur in the late Roman period, apparently accompanying the dissolution and shrinkage of settlements.

Of the post-Roman/Anglo-Saxon examples, all except two were recovered from cemeteries – one being from a monastery (Bawdsy: Cox, pers. comm.) – where their burial positions followed the "norm" of supine and extended with minor variations in arm and leg positions. They were undistinguished in their accompanying grave goods or locations within the cemetery groups. The only points of divergence may be the "isolated" location of the Eriswell graves (Wells, 1974), but little is known of the others within this group. Of the remaining three, details of one are unknown, the late Scottish example was recovered from a cist grave (a trait of the burials in northern Britain), leaving the prone burial in a shallow grave within the Roman villa complex (Rockbourne) as the obvious variation from the "norm".

The later and post-medieval examples were all from cemeteries or crypts (including one hospital in each period) where they were undistinguished from their neighbours in location or position.

Discussion

Sixty-two examples of trepanation were identified from British contexts dating from the prehistoric to post-medieval periods. Most occurred in males (64.5%), and for most (43 or 69.4%) there was no evidence for the reason for the trepanation. At three Iron Age sites the trepanation was undertaken post-mortem. However, in eight cases a head injury was identified (five healed). Overall, in 37 cases the position of the trepanation was identified as being in one of the frontal, left parietal, right parietal or occipital bones; 10 were in the frontal, 14 in the left parietal, 10 in the right parietal and two in the occipital.

Although a detailed study has not been carried out on the position of the trepan holes, it is worth considering the function of the parts of the brain underlying the main bones of the skull. According to Wilson (1990, p. 249) the cerebrum, which consists of the frontal, parietal, temporal and occipital lobes (underlying the frontal, parietal, occipital and temporal bones), is responsible for mental activities, sensory perception and voluntary muscle contraction. Considering the functional areas of the cerebrum (summarised in Table 1), it can be seen that there are particular areas which, if damaged, could lead to dysfunction of some kind. Hence, trepanation of the skull overlying those areas could be considered a hazard if the operator did not take care.

Perhaps the unhealed trepanations are the result of brain damage and death? Of the 18

Table 1. Functions of the areas of the cerebrum (after Wilson, 1990, pp. 249-251).

Area of cerebrum	Overlying bone	Function of area
Premotor	Frontal	Controlling influence on motor area; orderly series of movements (manual dexterity)
Speech (premotor)	Frontal	Controls movements necessary for speech
Frontal (premotor)	Frontal	Behaviour, character and emotional state
Precentral (motor)	Parietal	Contraction of voluntary muscles (L v R)
Post central (sensory)	Parietal	Pain, temperature, pressure, touch, sensation, knowledge of muscular movement and position of joints (L v R)
Parietal	Parietal	Obtaining and retaining accurate knowledge of objects
Sensory speech (parietal)	Parietal	Spoken word perceived (L v R)
Auditory (temporal)	Temporal	Receive and transmit inner ear impulses
Olfactory (temporal)	Temporal	Receipt and interpretation of impulses from nose
Taste (sensory)	Parietal	Perception of taste
Visual (occipital)	Occipital	Receipt and interpretation of eye impulses

unhealed trepanations three were of the frontal, three were in the left parietal, 11 were in the right parietal and two were in the occipital bones. Taking the healed trepanations as a whole, however, and considering their positions, 10 occurred in the frontal bone (possible effects on speech and changes in character, emotions and behaviour), 24 were in the parietal bones (possible effects on muscle contraction -possible paralysis, sensory perception, and memory and understanding), and two were found in occipital bones (possible sight problems) – see Table 1.

Of interest is that 14 of the 19 unhealed examples had been drilled, suggesting that this method was not very successful. However, some may have been performed postmortem (as seen in the Iron Age examples). Of course, this can only be conjecture because the hard evidence is not available, but by consideration of the positioning of trepanation holes, and whether they have healed or not, we may be able to shed more light on the effects of this operation on individuals in the past.

No particular patterning was seen for any period. Unhealed trepanations were seen in 23 individuals; these may have been post-mortem operations. In two cases (Crichel Down and Maiden Castle) the roundel was still in place at excavation. The majority of the trepanations were of the scraped type (27 of 47 where the information was available or 57.5%) and most (18) were from the post-Roman/Anglo-Saxon period; the drilling method occurred most in the later and post-medieval periods. Thirty-five (62.5%) of the trepanations had evidence of healing.

The vast majority of the trepanations were recovered from mortuary contexts in keeping with the normal rites prevalent at their time, and the affected individuals do not appear to have been distinguished from their contemporaries in terms of the burial rites employed. The only possible anomalous examples are the Iron Age deposits and the burial of Anglo-Saxon date made prone in the Roman villa complex.

The Iron Age skull from Watchfield (McKinley, 1998), with its large trepan and possible secondary pseudotrepan, may represent a "special/placed deposit" – a ritual offering made into pits and then deliberately backfilled. The skull was clearly deposited dry and minus the mandible – was it specifically chosen because of the presence of the trepan hole? If so, this may represent only a rare instance, since human remains have frequently been recovered as "placed deposits" in such contexts (Hill, 1995). The "trepans" in six of the other Iron Age skulls (Hunsbury, Cnip, Burghead and Hillhead) were all made post-mortem for "suspension" via between one and three holes. This may demonstrate that the trepan was carried out for neither medical nor magical reasons, but solely to illustrate some aspect of the "cult of the head", apparently prevalent at that time, the holes themselves being for practical purposes. Even with the apparent oddity of the Saxon burial in the Roman villa, one cannot state with any confidence that this individual was treated in this way in consequence of having been trepanned. Similar burials contrary to the "norm" have been found elsewhere within this period and, although they do not appear to represent some specific ritual enactment, other examples have not been found of trepanned individuals.

The most distinctive features of the British trepanations appear to be their geographical and temporal distributions. The percentage of fifth-eleventh-century skulls with trepanations (38.7% of the total) is greater than that for all the preceding periods combined (32.2%). Whilst it may be argued that considerably more burials have been recovered from Saxon than from the prehistoric periods, the numbers of excavated Iron Age – Roman burial numbers are similar and the percentages still appear significant, particularly when compared with those elsewhere in Europe, for example the large numbers of trepanned Neolithic skulls recovered from parts of France (Piggott, 1940).

There does appear to be a bias in the geographic distribution. Most examples from all periods are from the eastern side of mainland Britain, particularly towards the southern end of England. Examples are largely absent from the west side of the mainland, and those in Scotland are all from coastal locations. Although it could be argued that there is a bias reflecting archaeological activity rather than actual numbers of burials, this cannot be true of the prehistoric periods, where substantial numbers of burials across these dates have been recovered from the south-west of England, Wales and Scotland. The known distribution appears to reflect a physical proximity to the closest parts of continental Europe.

Previous workers (Piggott, 1940; Wells, 1974; Brothwell, 1995) have all stressed the "specialist skill" necessary to carry out (successful) trepanation. Piggott's (1940) review showed that most European trepanations were concentrated in restricted areas and periods – notably two areas of France in the Neolithic (8% of Neolithic skulls from the Vienne area were trepanned). He concluded that the practice represented a "fashion" or "cult", "waning in intensity" with distance from the "specialist centres". The "cultural" basis for trepanation and spread of the practice has also been supported by Brothwell (1994). The peripheral location of the British Isles from the Neolithic "specialist centres" in France could explain the paucity of specimens from Britain and the generally south-eastern location of the finds. Similarly, the limited spread and relatively high percentage of Saxon trepanations may also be seen to reflect a later upsurge in the "fashion" or "cult", the same way as it is currently fashionable to try reflexology or acupuncture i.e. it became the "alternative medicine" for the time. The close proximity of most of the cases suggests this was primarily an "Anglian" fashion – was there a similar upsurge in the continental homelands of these people in the Migration period? Was the upsurge related to the particular talents of a single skilled individual, a travelling surgeon? Certainly Calvin Wells (1974) believed the latter might have been the case, attributing the name of "Master of the Gliding Gouge". It may be significant that at least a further five examples have been added to the number within the area he believed could have formed that covered by the surgeon.

Summary and Conclusions

A number of limitations need to be considered with respect to the data surveyed in this paper. The authors have relied upon published and unpublished reports of skeletons from archaeological sites, and some of the reports are very early in date and do not contain all the required information. There are, thus, gaps in knowledge with respect to the trepanations discussed. Furthermore, the consideration of differential diagnoses for all the examples has to be assumed (as described in Kaufman et al., 1997), although clearly in all cases they were not. In addition, there are some areas of Britain where relatively few burials have been excavated, which may be a factor in the distribution patterns of the trepanations identified. There may also be instances where some of the examples are ambiguous as to whether they are actual trepanations due to the paucity of description in the original report. Furthermore, the funerary context of these trepanations often did not provide the detail necessary to make an accurate evaluation of its relevance.

The available contextual evidence does not suggest that a "magical" or "special" position was held by trepanned individuals, nor that they were subject to any differential burial rites from their contemporaries. The geographic and temporal distribution of trepanned skulls within the British assemblage does indicate influences from continental Europe and that at certain times – notably the Anglo-Saxon period – this form of intervention gained in popularity. However, the specific reason for it is unclear, possibly reflecting a "cult" or "fashion", as has been argued for earlier (Neolithic) periods of high activity.

Acknowledgements

Megan Brickley (University of Birmingham), Sue Anderson (Suffolk County Council Archaeological Service), Ian Armit (Queen's University, Belfast), Corinne Duhig (Cambridge University), Andrew Chamberlain (University of Sheffield), Mary Lewis and Anthea Boylston (University of Bradford), Margaret Cox (University of Bournemouth), Jenny Wakely (University of Leicester), and Brian Connell and Bill White (Museum of London) for providing valuable information on published and unpublished cases, and for illustrations where appropriate. Elaine Wakefield produced the photographs from Oxborough and Watchfield. Linda Colman was responsible for the distribution map and Wessex Archaeology is thanked for permission to use the plate of the Watchfield trepan.

References

Anderson S (1993): The human skeletal remains from Caister-on-Sea. In: Darling MJ, Gurney, D, eds., *Caister-on-Sea excavations by Charles Green 1951-1955*. Norwich, Norfolk Museums Service, East Anglian Archaeology 60, pp. 261-268.

Anderson S (no date): *Rockbourne Roman villa. Fact Sheet 2: The skeletons*. Southampton, Hampshire Musems.

Ashbee P (1966): The Fussell's Lodge Long Barrow Excavations 1957. *Archaeol 100*: 1-80.

Ashbee P (1978): Amesbury Barrow 51: Excavation 1960. *Wiltshire Arch Mag 70/71*: 1-60.

Armit I (forthcoming): *Anatomy of an Iron Age roundhouse: the Cnip wheelhouse excavations, Lewis.* Publisher not yet agreed.

Aufderheide AC, Rodríguez Martin C (1998): *An encyclopedia of human paleopathology*. Cambridge, University Press.

Boulter S, Robertson D, Start H (1998): *The Newcastle Infirmary at the Forth, Newcastle-upon-Tyne*. Sheffield, Arcus.

Boylston A, Wiggins R, Roberts C (1998): Human skeletal remains. In Drinkall G, Foreman M, eds., *The Anglo-Saxon cemetery at Castledyke South, Barton-on-Humber.* Sheffield, Sheffield University Excavation Reports 6, Sheffield Academic Press, pp. 221-236.

Brothwell DR (1974): Osteological Evidence of the Use of a Surgical Modiolus in a Romano-British Population: An Aspect of Primitive Technology. *J Archaeol Sci 1*: 209-211.

Brothwell DR (1994): Ancient trephining:multi-focal evolution or trans-world diffusion? *J. Paleopathology 6(3*): 129-138.

Buckley L, Ó Donnabhain B (1992): Trephination: early cranial surgery in Ireland. *Archaeology Ireland 6(4)*: 10-12.

Christie P M (1967): A Barrow-Cemetery of the Second Millennium B.C. in Wiltshire, England. *Proc Prehist Soc 33 (12)*: 336-365.

Duhig C (1998): The human skeletal analysis. In: Malim T, Hines J, eds., *The Anglo-Saxon cemetery at Edix Hill (Barrington A), Cambridgeshire.* York, Council for British Archaeology Research Report 12, pp. 154-199.

Furnas DW, Sheikh MA, Van Den Hombergh P, Froeling F, Nunda IM (1985): Traditional craniotomies of the Kisii tribe of Kenya. *Ann Plast Surg 15(6)*: 538-556.

Grattan JH, Singer C (1952): *Anglo-Saxon Magic and Medicine,* Oxford, University Press.

Gregg JB, Bass WM (1984): "Bullet hole" in an ancient South Dakota skull, or a trephination? *Plains Anthropol 29*: 321-326.

Hill JD (1995): *Ritual and Rubbish in the Iron Age of Wessex.* Oxford, British Archaeological Reports. British Series 242.

Jones M, Webster G (1968): Mediolanum-Excavations at Whitchurch. *Arch J 125*: 193-254 .

Knocker GM (1956): Early Burials and an Anglo-Saxon Cemetery at Snell's Corner, Near Horndean, Hampshire. *Proc Hampshire Fld Club Archaeol Soc XIX (2)*: 117-135.

Kaufman MH, Whittaker D, McTavish J (1997) Differential diagnosis of holes in the calvarium: application of modern clinical data to palaeopathology. *J Archaeol Sci 24*:19-18.

Leeds ET, Musgrave C (1938): Beakers of the Upper Thames District. *Oxon 3*: 31-40.

Lisowski FP (1967): Prehistoric and early historic trepanations. In: Brothwell DR, Sandison AT, eds., *Diseases in antiquity*. Illinois, Charles C. Thomas, pp. 651-672.

Lunt D, Young A (1996): Dental and anatomical reports. In: Proudfoot E, ed., Excavations at the long cist cemetery on the Hallow Hill, St Andrews, Fife 1975-7. *Proc Soc Antiq Scot 126*: 387-454 (pp. 424-431).

McKinley JI (1992a): A skull wound and possible trepanation from a Roman cemetery at Baldock, Hertfordshire. *Int J Osteoarchaeology 2*: 337-340.

McKinley JI (1992b): A probable trepanation from an early Anglo-Saxon cemetery at Oxborough, Norfolk. *Int J Osteoarchaeology 2*: 333-335.

McKinley JI (1998): *Human Remains from Watchfield, Oxfordshire.* (Unpublished Report for Wessex Archaeology.)

McWhirr A, Viner L, Wells C (1982): *Romano-British Cemeteries at Cirencester*. Cirencester, Cirencester Excavations Committee.

Meaney A (1964): *Gazetteer of Early Anglo-Saxon Burial Sites.* London, Allen and Unwin.

Molleson T, Cox M (1993): *The Spitalfields Project. Volume 2: The Anthropology. The Middling Sort.* York, Council for British Archaeology Research Report 86.

Parker S, Roberts C, Manchester K (1986): A review of British trepanations with reports on two new cases. *Ossa 12*: 141-157.

Parry TW (1914): Prehistoric man and his early efforts to combat disease. Part II. *Med Press 914 (3293)*: 66-67.

Parry TW (1916): The art of trephining among prehistoric and primitive peoples: their motive for its practice and their methods of procedure. *J Brit Arch Ass 72*: 33-

Parry TW (1921a): The prehistoric trephined skulls of Great Britain together with a detailed description of the operation probably performed in each case. *Proc Roy Soc Med 14 (10)*: 27-42.

Parry TW (1921b): Cranial trephination in prehistoric Great Britain. *Med Press 11*: 403-407.

Parry TW (1921c): Cranial trephination in prehistoric Great Britain. *Med Press 11*: 423-425.

Parry TW (1923): Trephination of the living human skull in prehistoric times. *Brit Med J 1*: 457-460.

Parry TW (1928): Holes in the skull of prehistoric man and their significance. *Arch J 35*: 91-101.

Parry TW (1931): Neolithic man and the penetration of the living human skull. *The Lancet 2*: 1388-1390.

Parry TW (1936): A case of primitive surgical holing of the cranium practised in Great Britain in Mediaeval times, with a note on the introduction of trepanning instruments. *Proc Roy Soc Med 29*: 898-902.

Parry TW (1940): A comparison between two roundels removed by surgical holing from two prehistoric skulls, lately excavated in the county of Dorset: together with a full description of the push-plough method of operation that was probably employed. *Man 46*: 33-35.

Parry TW, Tildesley ML (1935): The Ovingdean Skull. *Man 35*: 56-59.

Penn K (1998): *An Anglo-Saxon Cemetery at Oxborough, West Norfolk: Excavations in 1990.* Norwich, East Anglian Archaeology Occasional Papers No. 5.

Pitt-Rivers W (1892): *Cranbourne Chase*. Volume 4. Printed privately.

Philpott, R. (1991): *Burial Practices in Roman Britain*. A survey of grave treatment and furnishing AD 43-410. British Archaeological Reports (British Series) 219, Oxford, Tempus Reparatum.

Piggott S (1940): A trepanned skull of the Beaker period from Dorset and the practice of trepanning in prehistoric Europe. *Proc Prehist Soc 6*: 112-131.

Richards GD (1995): Brief communication: Earliest cranial surgery in North America. *Amer J Phys Anthrop 98*: 203-209.

Ritchie JNG, Stevenson JB (1982): Cists at Traigh Bhan, Islay, Argyll. *Proc Soc Antiq Scot 112*: 550-558.

Roberts CA (1993): General description of the skeletons. In: Kinsley AG, ed., *Broughton Lodge. Excavations of the late Romano-British settlement and Anglo-Saxon cemetery at Broughton Lodge, Willoughby-on-the-Wilds, Nottinghamshire 1964-1968*. Nottingham, Nottinghamshire Archaeological Monographs 4, pp. 56-58.

Rogers L (1930): The history of craniotomy: an account of the methods which have been practiced and the instruments used for opening the human skull during life. *Annals of Medical History 2 (n.s.)*: 495-514.

Stewart TD (1975): Cranial dysraphism mistaken for trephination. *Amer J Phys Anthrop 42*: 435-438.

Tildesley, M.L. (1927-28): Skull with post-mortem trepan assigned to the mid-16th century. *Proc Roy Soc Med* 21: 1016-1019.

Wakely J (1996): Skeletal analysis. In: L. Cooper, ed., A Roman cemetery in Newarke Street, Leicester. *Trans. Leicestershire Archaeol Hist Soc 70*: 33-44.
Wakely J, Duhig C (1989): A comparative microscopical study of three European trepined skulls. *Journal Palaeopath 3 (2)*: 75-87.
Warhurst A (1955): Excavations of a Jutish cemetery at Lyminge. *Arch Cant 69*: 1-40.
Webster LE, Cherry J (1972): Medieval Britain in 1971. *Med Arch 16:* 157.
Wells C (1974): Probable trephination of five early Saxon skulls. *Antiq 48*: 298-302.
Wells C (1982): The human burials. In: McWhirr A, Viner L, Wells C, eds., *Romano-British cemeteries at Cirencester.* Cirencester, Excavations Committee, pp. 135-202.
Wenham LP (1968): *The Romano-British Cemetery at Trentholme Drive, York.* London, Ministry of Public Buildings and Works Archaeological Reports No. 5.
Wheeler M (1943) Maiden Castle, Dorset. *R S A L 12*: 344-46.
Whimster R (1981): *Burial Practices In Iron Age Britain*. Oxford, British Archaeological Reports. British Series 90 (i) and (ii).
Whittle A (1994): Excavations at Millbarrow Neolithic chambered tomb, Winterbourne, Monkton, North Wiltshire. *Wiltshire Arch Mag 87*: 1-53.
Wilson DM, Hurst DG (1970): Medieval Britain in 1969 *Med Arch 14*: 161.
Wilson DM, Moorhouse S (1971): Medieval Britain in 1970. *Med Arch 15*: 130.
Wilson KJW (1990): *Ross and Wilson. Anatomy and physiology in health and illness*. Edinburgh, Churchill Livingstone.
Zimmerman MR, Trinkaus E, Lemay M, Aufderheide AC, Reyman TA, Marrocco GR, Schultes RE, Coughlin EA (1981): Trauma and trephination in a Peruvian mummy. *Amer J Phys Anthrop 55*: 497-501.

Appendix 1: Trepanations in Britain

No.	Site	Date	No.	Sex	Age years	Path.	Posit	Type	Heal
1	Bisley	Neo	?	?	?	No	1	2	No
2	Fussell's Lodge	Neo	B	M	?	No	3	?	Yes
3	Fussell's Lodge	Neo	E	M	?	No	?	?	Yes
4	Ovingdean	Neo	?	M	60	No	5	1	Yes
5	R.Wear	Neo	?	M	30	No	3	3	No
6	Amesbury	BA	51	M	20-30	No	5	2	No
7	Amesbury	BA	71	M	20-30	No	5	2	Yes
8	Crichel Down	BA	?	M	45+	No	2	2	No
9	Eynsham	BA	16	M	50	No	?	1	?
10	Mount Stuart	BA	?	F	?	?	1	1	Yes
11	Traigh Bhan	2nd M BC	Cist 1	M	17-25	No	1	?	Yes (1)
12	Burghead	IA	?	?	?	?	?	3	No
13	Cnip	IA	171	?	Older Adult	No	3	3	No
14	Hillhead	IA	?	?	?	?	?	3	No
15	Hunsbury	IA	1	M	Mid	No	5	3	No
16	Hunsbury	IA	2	?	?	?	?	3	No
17	Hunsbury	IA	3	?	?	?	?	3	No
18	R.Thames	EIA	?	M	50	?	5	1	Yes
19	Watchfield	IA	5013	M	45+	No	2	4	Yes

20	Edinburgh	?preh	?	M	50	No	2	1	Yes
21	Baldock	4^{th} AD	5779	M	Older Adult	?Yes Injury	5	?	Yes
22	Cirencester	4^{th} AD	305	M	45-55	Yes Injury	3	1	Yes
23	Newarke Street	4^{th} AD	424	M	?	Yes Injury	4	1	No
24	Whitchurch	4^{th} AD	?	M	20-30	?	3	3	No
25	Trentholme Drive	2^{nd}-4th	?	F	Adult	No	5	3	No
26	Edix Hill	AS	148	M	25-35	No	2	1	Yes
27	Edix Hill	AS	447a	M	25-35	No	3	1	Yes
28	Edix Hill	AS	451a	M	50-59	No	2	1	Yes
29	Edix Hill	AS	553	M	45+	No	5	1	Yes
30	Castledyke South	AS	PR55	M	25-35	No	5	1	No
31	Bawdsey	8-9^{th} AD	?	F	Adult Injury	Yes	4	?	Yes
32	Bidford	AS	?	M	25-35	No	2	1	?
33	Caister	8-11^{th} AD	?	F	Mid	No	2	3	Yes
34	Eriswell	6th AD	13	M	30-35	No	1	1	Yes
35	Greenhithe	AS	?	?	?Ad	No	3	1	?
36	Grimston B	AS	?	M	30-40	?	3	1	Yes
37	Horndean	AS	S22	M	Older Adult	Yes Injury	1	1	Yes
38	Icklingham	AS	?	?	?	?	2	?	Yes
39	Lyminge	AS	34	M	40	No	2	1	No
40	Maiden Castle	AS	Q1	M	25-35	Yes Injury	2	4	No
41	Oxborough	AS	9	F	Older Adult	No	2	1	Yes
42	Rockbourne	AS	2	M	35-45	No	1	?	Yes
43	Sleaford	AS	5	M	?	No	5	1	Yes
44	Sleaford	AS	12	M	?	No	3	1	Yes
45	St Andrews	7^{th}-9^{th} AD	112	M	20s	No	Vault	?	Yes (1)
46	Swaffham	6^{th} AD	A	M	30-40	No	5	1	Yes
47	Swaffham	6^{th} AD	7	M	40-55	No	3	1	Yes
48	Watton	AS	?	M	25-35	No	1	1	Yes
49	Willoughby	6^{th} AD	62/63/ 64	F	Adult	Yes Injury	2	1	Yes
50	Dublin	LateMed	?	?	Adult	Yes	5	3	No
51	Dublin	13^{th}-14^{th} AD	?	?	Adult	No	?	1	Yes
52	Hythe	1100-1600 AD	?	?	?	No	1	1	Yes
53	Ilkley	Late Med	?	F	Older Adult	No	2	1	Yes
54	London	13^{th}-14^{th} AD	?	M	Adult	No	2	?	Yes
55	London	13^{th}-14^{th} AD	?	M	Adult	Yes Injury	2	?	?
56	Rothwell	LMed	?	?	?	?	?	?	?

57	Drury Lane	18th? AD	?	?M	Adult	No	2	3	No
58	Newcastle	1753-1906	1	?M	Adult	No	1+3	3	No
59	Newcastle	1753-1906	2	?F	Adult	No	2+4	3	No
60	Newcastle	1753-1906	3	?	Y. adult	No	1	3	No
61	Newcastle y	1753-1906	217	?M	Older Adult	No	5+pte-rion	3	No
62	Scarborough	Mid- 16th AD	?	?	?	No	1	4	No

Key To Appendix 1

Position

1. Frontal
2. Left parietal
3. Right parietal
4. Occipital
5. Other

Type

1. Scrape
2. Gouge
3. Drill
4. Other

AS = Post-Roman/Anglo-Saxon
BA = Bronze Age
F = female
Heal = evidence of healing
IA = Iron Age
M = millennium
M = male
Med = medieval
Mid = middle aged adult
Neo = Neolithic
Path = pathological lesion
Posit = position on skull
Preh = prehistoric (date undefined)
R = Roman
Type = type of trepanation
? = information not available

Appendix 2: Site Name and Reference by Period (Numbers Refer to Appendix 1)

Neolithic

1. Bisley, Nr Stroud, Gloucestershire (Parry, 1914; 1921a,b, 1922; Piggott, 1940)
2. and 3. Fussells Lodge, Nr. Salisbury, Wiltshire (Ashbee, 1966)
4. Ovingdean, Nr. Brighton, Sussex (Parry, 1935; Parry and Tildesley, 1935; Piggott, 1940)
5. River Wear, Durham City, County Durham (Parry, 1921a,b, 1922)

Bronze Age
6. and 7. Amesbury, Wiltshire (Christie, 1967; Ashbee, 1978)
8. Crichel Down, Nr Blandford, Dorset (Parry, 1940; Piggott, 1940)
9. Eynsham, Nr. Oxford, Oxfordshire (Leeds and Musgrave, 1938; Piggott, 1940)
10. Mountstuart, Isle of Bute, Scotland (Parry, 1921a,b, 1922)
11. Traigh Bhan, Islay, Scotland (Ritchie and Stevenson, 1982)

Iron Age
12. Burghead, Moray, Scotland (Whimster, 1981)
13. Cnip, Lewis, Scotland (Armit, forthcoming)
14. Hillhead Broch, Caithness, Scotland (*Proceedings of the Society of Antiquaries of Scotland* 1909; Parry, 1921b, 1928; Whimster, 1981)
15, 16 and 17. Hunsbury, Northamptonshire (Pitt-Rivers, 1892, 286; Parry, 1914, 1921a,b, 1922, 1928; Whimster, 1981)
18. River Thames, Hammersmith Bridge, London (Parry, 1921a,b, 1922; Piggott, 1940)
19. Watchfield, Nr.Swindon, Oxfordshire (McKinley, 1998)

Prehistoric
20. Edinburgh, Scotland (Parry, 1921a,b, 1922, 1923; Piggott, 1940)

Romano-British
21. Baldock, Hertfordshire (McKinley, 1992a)
22. Cirencester, Gloucestershire (McWhirr et al.,1982)
23. Newarke Street, Leicester, Leicestershire (Wakely, 1996)
24. Whitchurch, Nr. Shrewsbury, Shropshire (Jones and Webster, 1968; Parker et al.,1986)
25.Trentholme Drive, York (Wenham, 1968; Brothwell, 1974)

Post-Roman/Anglo-Saxon period
26-29. Edix Hill, Barrington, Cambridgeshire (Duhig, 1998)
30. Castledyke South, Barton on Humber (Boylston et al., 1998)
31. Bawdsey, Nr. Kings Lynn (Cox, pers. comm.)
32. Bidford, Worcestershire (Brickley, pers. comm.)
33. Caister, Nr. Gt.Yarmouth (Anderson, 1993)
34. Eriswell, Suffolk (Wells, 1974)
35. Greenhithe, Nr.Gravesend, Kent (Parry, 1936; Piggott, 1940)
36. Grimston B, Nr. Kings Lynn, Norfolk (Webster and Cherry, 1972; Wells, 1974)
37. Snell's Corner, Horndean, Nr. Portsmouth (Knocker, 1956)
38. Mitchell's Hill, Icklingham, Suffolk (Meaney 1964; McKinley, pers. obs.)

39. Lyminge, Nr. Folkstone, Kent (Warhurst, 1955; Parker et al., 1986)
40. Maiden Castle, Dorset (Parry, 1940; Wheeler, 1943; Brothwell, pers. comm.)
41. Oxborough, Nr.Kings Lynn, Norfolk (McKinley, 1992b; Penn, 1998)
42. Rockbourne, Hampshire (Anderson, no date)
43. and 44.Sleaford, Lincolnshire (Parker et al., 1986)
45. Hallow Hill, St. Andrews, Scotland (Lunt and Young, 1996)
46. and 47. Swaffham, Norfolk (Wilson and Hurst, 1970; Wilson and Moorhouse, 1971; Wells, 1974)
48. Watton, Norfolk (Wells, 1974)
49. Broughton Lodge, Willoughby-on-the-Wolds, Nottinghamshire (Parker et al.,1986; Roberts, 1993)

Late medieval

50. and 51. Ship Street and Dr Steeven's Hospital, Dublin (Buckley and Ó Donnabhain, 1992)
52. Hythe, Kent (Parry, 1936)
53. Ilkley, Yorkshire (Parker et al., 1986)
54. and 55. Spitalfields Market, London (Connell, pers. comm.)
56. Rothwell, Northamptonshire (Parry, 1921a)

Post-medieval

57. Drury Lane, London (White, pers. comm.)
58, 59, 60, 61. The Infirmary, Newcastle (Boulter et al., 1998)
62. Castle Hill, Scarborough, North Yorkshire (Tildesley, 1927-1928)

NB: Details of trepans from Nendrum, Ireland (450-974 AD monastery) and the medieval cemetery at Collierstown, Co.Meath (child), both noted by Piggott (1940) could not be obtained and have, therefore, not been included in the figures presented. A recent report on a possible double trepanation in a Neolithic skull from Millbarrow, Wiltshire (Whittle, 1994) also came to light too late for inclusion. In addition, Buckley and Ó' Donnabhain (1992) note that ten trepanned skulls have been identified in Ireland but details for this paper could not be obtained.

Appendix 3: Funerary Context of Individuals Trepanned

Neolithic

Bisley:	long barrow (secondary intrusion)
Fussell's Lodge:	long barrow (2)
Ovingdean:	sea
Wear:	river

Bronze Age

Amesbury 51:	round barrow
Amesbury 71:	round barrow
Crichel Down:	round barrow
Eynsham:	Bronze Age cemetery, no grave goods but lightly cremated bones of young adult female with burial at normal site for Beaker

Mount Stuart:	cist
Traigh Bhan:	cist

Iron Age

Burghead	?
Cnip:	cist
Hillhead:	broch
Hunsbury:	outside Iron Age Camp
Thames:	river
Watchfield:	redeposited in a pit with a cow skull

Prehistoric

Edinburgh:	no provenance (museum)

Roman

Baldock:	on the edge of a cemetery
Cirencester:	cemetery (decapitated)
Newarke:	cemetery (with fourth century AD pottery)
Whitchurch:	under floor of a building
York:	cemetery

Post-Roman/Anglo-Saxon

Barrington:	cemetery
Barton on Humber:	cemetery
Bawdsey:	monastery
Bidford:	?cemetery
Caister:	cemetery
Eriswell:	isolated burial but other AS burials in area; has grave goods
Greenhithe:	?cemetery (Royal College of Surgeons)
Grimston B:	cemetery (on site of AS cemetery); has grave goods
Horndean:	cemetery; 2 teeth from earlier burial in left hand; has grave goods
Icklingham:	secondary inhumation cemetery in barrow
Lyminge:	cemetery; no grave goods (but others have)
Maiden Castle:	earthwork (ritual pit adjacent to burial)
Oxborough:	cemetery
Rockbourne:	face down in shallow grave in Roman villa complex
Sleaford 5:	cemetery
Sleaford 12:	cemetery
St. Andrews:	cist cemetery
Swaffham A:	"trench"; has grave goods
Swaffham 7:	"trench"; has grave goods
Watton:	no provenance
Willoughby-on-the-Wolds:	cemetery

Later medieval

Dublin:	cemetery
Dublin:	cemetery
Hythe:	crypt (churchyard)
Ilkley:	churchyard cemetery
London 1:	hospital
London 2:	hospital
Rothwell:	crypt (churchyard)

Post-medieval

London:	found during building works
Newcastle 1:	hospital
Newcastle 2:	hospital
Newcastle 3:	hospital
Newcastle 4:	hospital
Scarborough:	churchyard

Chapter 5

Trepanations and Pseudotrepanations: Evidence of Cranial Surgery from Prehistoric and Early Historic Ireland

BARRA Ó DONNABHÁIN
Department of Archaeology, University College, Cork, Ireland

Abstract

A total of 18 trepanations have been reported in the archaeological literature from Ireland. Most of these appear to represent past surgical intervention, but some may be pseudotrepanations and reflect taphonomic or pathological processes. Although there have been reports of trepanations from prehistoric contexts in Ireland, all of the confirmed cases date from the historic period. Whereas trepanations have been reported on all of the bones of the skull vault, the most common site is the anterior portion of the left parietal. In some cases, the surgery was associated with earlier head wounds. Scraping of the bone seems to have been the most common method of trepanation and survival rates were high. In one case where the surgeon used a cylindrical saw, the perimortem death of the patient allowed a detailed reconstruction of the surgical procedure. These examples of early surgery provide an insight into the medical knowledge systems of the Early Historic period in Ireland. They suggest that trepanation was a reasonably well-established curative procedure and was practiced with a relatively high level of expertise.

Keywords: Ireland, trepanation, prehistory, medieval, surgery, trauma

Introduction

Trepanations[1] have been reported in human skeletal remains recovered from archaeological contexts in Ireland since the 1920s (Walmsley, 1923). Although the current location of a few of the older finds is uncertain, most of the 10 possible cases reported between the 1920s and 1992 (Buckley and Ó Donnabháin, 1992) were curated and are available for re-evaluation. Since the early 1990s, the curation and analysis of human remains from all archaeological sites in the Republic of Ireland have been mandatory (Buckley et al., 1999). As a result of this development, the number of trepanations reported in the Irish archaeological literature has almost doubled and now stands at 18. Although this is partly a function of the higher levels of archaeological excavation in Ireland in recent decades, there can be little doubt that the archaeological visibility of trepanation has improved now that all human remains recovered during excavations are analysed by personnel with bioarchaeological training.

Pseudotrepanations?

While many putative examples of trepanation have been reported in the literature, it should be stressed that some of these cases may not actually represent instances of past surgical procedures. It is not always possible to determine with certainty if the feature observed in a skull is the result of surgical intervention. There are a number of taphonomic processes and pathological conditions that can produce defects that can be difficult to distinguish from healed trepanations. Weapon wounds can occasionally be confused with the effects of trepanation, especially if healed. Dysraphism, a congenital herniation of the skull, can also produce a defect that, in dry bone, can mimic a trepanation (Ortner and Putschar, 1985). This herniation often occurs at the site of the fontanelle and can lead to the incomplete fusion of the frontal and parietal bones of the skull. As a result, the defect often occurs close to bregma. It is possible that some of the cases that have been found in archaeological contexts in Ireland represent the effects of these taphonomic processes or the presence of such pathological conditions. This seems to be the case with the four examples that have been reported from contexts that were dated to the prehistoric period (i.e., prior to the fifth century AD).

The earliest putative example that has been reported was recovered from an Early Bronze Age (ca 2,000–1,600 BC) cemetery at Edmondstown, County Dublin (Buckley, in Mount and Hartnett, 1993). The skull of a young adult male has a teardrop shaped defect with a maximum length of 30 mm on the squama of the left temporal bone. Buckley concluded that the defect could be a perimortem trepanation or, perhaps more likely, that the fragment of bone could have been removed after death. The defect is located at the squamosal suture, but the parietal was not affected by whatever process that resulted in the removal of the fragment of the temporal. The cut surfaces temporal have some marks that are reminiscent of rodent gnawing. These facts combine to suggest that taphonomic processes may be the most likely cause of the defect.

Brothwell (1967; Brothwell et al., 1978) reported on an example of a pseudotrepanation of supposed Iron Age date (c. fifth century BC to fifth century AD) from Gortnacargy, County Cavan. The roughly circular defect is 25 mm in diameter and is located on the basal portion of the occipital, posterior to the right mastoid process. Given its location, this defect must reflect the post-mortem removal of bone. As the margins of the perforation are in various planes, Brothwell concluded that it represents a post-depositional feature probably caused by rodents gnawing on bone. However, the ovoid shape of the defect and its regularity suggest that the deliberate postmortem removal of a bone fragment cannot be discounted.

Rynne has argued for a date in the Iron Age for a supposed case of trepanation that was noted in one of five skeletons found at Ballinlough, County Laois (Lisowski, 1967; Rynne, 1974). His suggestion of an Iron Age date was made on the grounds that the corpses had not been buried at a Christian cemetery a few hundred metres from the site, and that an isolated human skull had been buried nearby. The latter skull, which did not have a trepanation, had been interred at some time in the past with a small collection of other human bones. The reburial of remains that had been disturbed by subsequent burial activity was commonplace in Early Modern cemeteries and it is not necessary to resort to Iron Age head cults to explain this occurrence. The fact that the burials were aligned east-west and given the absence of diagnostic artifacts, a date in the historic period does not seem unreasonable.

The skull that was described as having a trepanation had been uncovered prior to the arrival of the archaeologist at the site, so the form of its deposition and relation to other remains is unknown. It is currently not available for inspection, but photographs taken in the 1980s indicate that it was the skull of an adult male. The defect is located on the right frontal, about 10 mm posterior to bregma and close to the sagittal suture. The perforation is roughly circular with a diameter of about 20 mm and is irregularly bevelled. Erskine, the anatomist who wrote a five-line report on the skull as an appendix to Rynne's (1974) report, considered this to be a trephination (sic) and suggested that the margins of the wound had some signs of healing, but that this was obscured by post-mortem cracking.

Examination of photographs of the defect suggests that the entire margin of the perforation could have been produced by cracking and the defect has the appearance of an exit wound. Two large cracks radiate from the defect. Erskine considered these to be post mortem, but they could have been produced at the same time as the perforation. There was no obvious entry wound to account for this defect, but it is possible that it was produced by an object that was introduced into the cranium through the foramen magnum and then forced through the top of the head.

Unfortunately, the skull is not currently available for inspection to check its base for associated damage. It seems possible then that this was not a case of trepanation but rather one where a head had been mounted in some way prior to its disposal. The practice of displaying trophy heads has been documented from a number of medieval contexts in Ireland (Ó Donnabháin, 1995a,b) and it is possible that some of the people buried at Ballinlough had been treated in a manner similar to that depicted in a sixteenth century woodcut from John Derrick's *Image of Ireland* where heads of defeated Irish soldiers were carried impaled on swords by victorious English troops (Plate 1).

Rynne (1974) did mention that some of the post-cranial remains from Ballinlough had weapon wounds. Unfortunately, these bones were not curated. If the remains from the site do represent individuals killed in a violent conflict during the historic period, this may explain the location of the burials, close to but outside a cemetery. In medieval Ireland, as elsewhere, people who died in circumstances that were considered spiritually suspect were often interred in marginal locations either within or near a cemetery.

McLoughlin (1950) examined the skeletal remains of over 140 individuals from an Early Medieval (fifth to twelfth centuries AD) cemetery at Castleknock, County Dublin. The excavation was carried out in 1938 and the resulting report is an interesting though redundant example of the typological approach that dominated physical anthropological discourse in the first half of the twentieth century. The report concentrated on metrical analysis and on the determination of "racial type". Little mention was made of pathological changes, but he did note that:

> There were two cases of perforation of the parietal bone over the left lateral lacuna, a large one in the skull of a woman of about 45 and a smaller one in the skull of a man of about the same age (McLoughlin, 1950, p.1).

It is not clear from this statement if McLoughlin considered the perforations to be trepa-

Plate 1. An engraving taken from John Derrick's sixteenth century book, *Image of Ireland*, where heads of defeated Irish soldiers are carried impaled on swords by victorious English troops.

nations carried out during life. The remains from Castleknock are not currently available for inspection, though arrangements are being made to place the collection in the care of the National Museum of Ireland. As a result of this move, it may be possible to identify the two crania mentioned by McLoughlin and provide a more detailed analysis.

In two of the reported Later Medieval (twelfth to sixteenth centuries AD) cases of possible trepanation from Ireland, the defect occurs at bregma and a diagnosis of dysraphism cannot be discounted. One of these examples was a chance find from Maganey Lower, County Kildare (Prendergast, 1962) and the other was recovered during excavations of the cemetery at the site of the medieval hospital of St Stephen, Dublin (Buckley and Ó Donnabháin, 1992; Buckley, 1993). A further potentially confounding factor that inhibits diagnosis is the poor preservation of the example from Maganey Lower. These examples are typical of situations where diagnoses must remain open and other possible interpretations borne in mind. If the example from the site of St Stephen's hospital does represent a trepanation, the individual survived the procedure. The irregularity of the lesion suggests that, if it does represent a trepanation, a scraping technique was used.

A third possible case of Late Medieval date is from Moyle Abbey, County Kildare (unpublished file in the National Museum of Ireland). The defect occurs on the left side of the frontal bone of an adult who might have been male. The perforation is sub-rectangular and measures 50 mm by 25 mm. It is at the centre of a bevelled ovoid area of pared bone that measures 75 mm by 45 mm. The angle of the cut surface is on a single plane. This form of the lesion is consistent with a cutting wound where the left side of the forehead was hit with a glancing blow. However, whereas this may be a healed weapon wound, trepanation cannot be ruled out. Whatever the cause, the lesion healed and the affected individual lived for a considerable time thereafter.

Trepanation from the Church of St. Michael-Le-Pole, Dublin

The cases of skull perforations where a diagnosis of trepanation can be made with greater confidence all appear to date from the Historic period. One of these provides a salutary lesson regarding the value of the curation and analysis of archaeologically retrieved human bone. This is demonstrated by the wealth of cultural and biological information that can be gleaned from the single human bone that was curated as a result of excavations that were carried out at the site of the church of St. Michael le Pole in Dublin in 1981 (Ó Donnabháin et al., 1985; Ó Donnabháin, in press).

A number of burials were uncovered during this work. While most of the remains post-dated the construction of the twelfth-century church (the name of which probably refers to the pool adjacent to the medieval core of Dublin), this latter activity had cut through an earlier series of burials, one of which produced a radiocarbon date ranging from the late-tenth to eleventh centuries (Simpson, 2000). Unfortunately, most of the human remains were not submitted for osteological analysis and were reburied at the site. A perforation was noted on one bone that came from a disturbed context. Unfortunately, it was not possible to determine the date of the bone in question which could date from either the Early or Later Medieval periods.

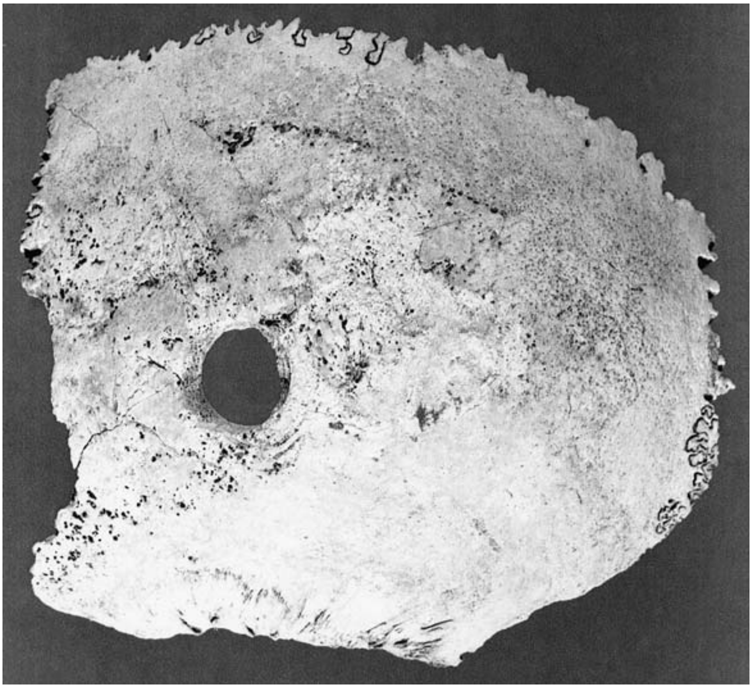


Plate 2. General view of the trepanned left parietal bone from the St. Michael le Pole site.

The bone that was recovered during the excavation consists of the greater part of a human left parietal that had been trepanned (Plate 2). The size of the bone suggests it belonged to an adult. None of the observable sutures (the bregmatic portion of the coronal suture, the sagittal suture, the lambdoidal and median portions of the lambdoidal suture and the squamosal suture) had begun to fuse. This may indicate that the individual was a younger adult. In suggesting this age estimate it must be stressed that the correlation between age at death and suture closure is relatively weak (Masset, 1989; Key et al., 1994), but it is the only indicator of age available in this case. It is not possible to determine the sex of this individual based on the morphological examination of this single bone.

The trepanation procedure had been carried out in the area immediately anterior to the parietal eminence. An oval roundel of bone was detached; the excised bone was not recovered. At the ectocranial or outer surface, the resulting perforation measures 20.9 mm anteroposteriorly and 19 mm mediolaterally. On the cerebral or inner surface, the trepanation measures 14.99 mm anteroposteriorly and 17.1 mm mediolaterally. The margin of the trepanned cavity is slightly bevelled in both its anterior and posterior aspects, whereas it is almost vertical medially and laterally. The margins of the perforation are located 27 mm from the coronal suture (the latter is broken post mortem), 85.5 mm from the lambdoidal suture, 60 mm from the sagittal suture, and 48.7 mm from the inferior border of the squamosal suture. There is some post-mortem cracking of the bone be-

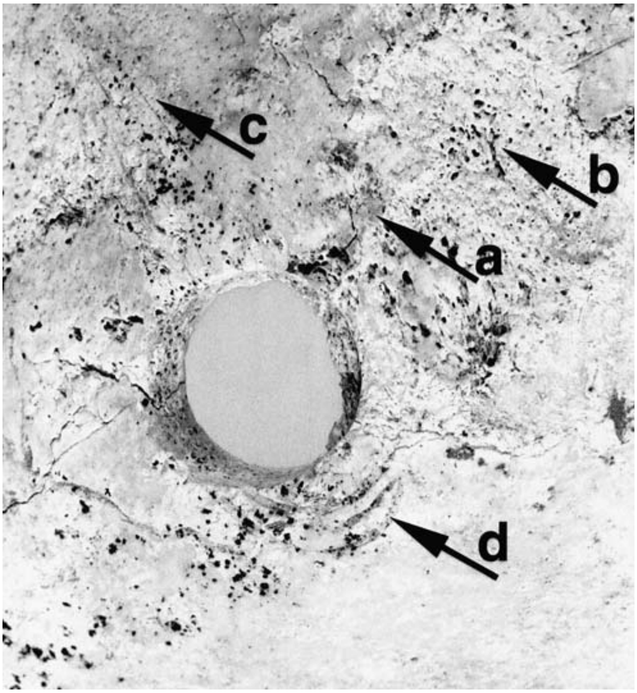


Plate 3. Close-up view of the St. Michael le Pole trepanation: a. linear depressed fracture; b. post-mortem deterioration of the bone; c. incisions probably resulting from the cutting of the scalp; d. grooves caused by the trepanation saw.

tween the coronal suture and the area subjected to the surgical procedure.

On the outer surface, the trepanation is ovoid in shape (Plate 3). The perforation has cut through the anterior end of a linear depressed fracture of the outer table alone that extends posteromedially from the trepanation (Plate 3a). The original extent of this injury cannot be assessed, since the posterior end of the wound has been obscured by a large area of post-mortem deterioration of the surface of the bone (Plate 3b). The depressed area was at least 5 mm wide and survives to a length of 15 mm. The fracture produced localised crushing of outer table bone only in a linear lesion, suggesting it was due to a blow from an object with a blunt edge. If, as seems likely, this wound was incurred prior to the trepanation procedure, symptoms that were perceived to be associated with the injury may have suggested the need for the operation.

The outer surface of the parietal also has two other sets of features. The first of these consists of at least four straight, shallow incisions that radiate antero-medially and posteriorly from the trepanation (Plate 3c). These were made with a sharp instrument and the longest extends 48.5 mm from the trepanned opening towards bregma (the junction of the frontal and parietal bones). Unfortunately, the incisions are also partially obscured by post mortem flaking of the bone's outer surface (Plate 3b). The second set of features on the outer surface of the bone consists of three shallow, semi-circular grooves that are immediately infero-lateral to and running into the perforation (Plate 3d). The uniform

Plate 4. Endocranial view of the St. Michael le Pole trepanation: a branch of the middle meningeal artery lay directly beneath the excised roundel of bone.

shape and size of these arcs and that of the perforation itself suggest that the grooves were made by a cutting instrument with a cylindrical blade that had a diameter of about 19 mm.

Although the perforation is ovoid on the outside of the cranium, it is D-shaped on the inner surface (Plate 4). The rounded anterior, medial, and lateral sides are smooth, but the straight-sided posterior margin is quite jagged. The form of the margins of the roundel that was removed indicates that the instrument cut cleanly through the inner table bone at the anterior, medial, and lateral sides. The cutting instrument must have been applied at an angle from the front to produce both the oblique anterior margin and the vertical medial and lateral margins. Once the inner table of bone had been penetrated anteriorly, the operator straightened the trepan, thereby prising out the disc of bone. While the roundel had been cut free anteriorly, it snapped at the posterior inner margin, producing the jagged edge described above. This suggests that the person carrying out the procedure was trying to minimise the risk of the cutting instrument penetrating the dura mater. Unfortunately perhaps, a groove for a branch of the left middle meningeal artery lay directly under the cut lateral margin (Plate 4). This artery runs in the most superficial layer of the dura mater.

The constellation of features noted on the bone offer clues to the motivation for the operation, the procedure that was followed, and its outcome. It seems likely that this

Plate 5. A nineteenth century trepanation saw.

individual incurred a skull fracture some time prior to undergoing the operation. This lesion was probably due to a blow to the left side of the head from an object with a blunt edge. The resulting wound was confined to the outer table bone and is unlikely to have been lethal. While it is possible that this injury was incurred accidentally, it could also be the result of some form of interpersonal violence. As most people are right-handed, head wounds that are the result of face-to-face combat tend to be more common on the left side of a victim. The fact that the area of the fracture was cut by the trepanation procedure suggests that two features are directly related. Pain, some degree of loss of consciousness, or other symptoms perceived to be associated with the fracture might have suggested the need for the operation. It is likely that the scalp was lacerated at the time the fracture was incurred. The straight incisions (Plate 3c) probably mark the initial stages of the surgical intervention where the scalp was cut again. If the patient were conscious during the surgery, alcohol or herbal preparations (Voights and Hudson, 1992) are likely to have been the only pain relief that was available. The initial incising of the scalp would have been the most painful part of the procedure and the cut soft tissues would have bled profusely. Turning back the scalp flaps would have staunched the bleeding as well as exposing the outer surface of the cranium. The semi-circular arcs and the shape of the perforation itself suggest that the skull was then cut with a cylindrical saw or trepan, like the nineteenth-century example illustrated in Plate 5.

The three semi-circular grooves probably represent some initial failure by the operator to get a good grip on the bone. This might have been due to the presence of blood and the periosteum or it could reflect the struggles of a squirming patient. The bones of the skull do not have the rich supply of sensory nerves that is found in the scalp, so this part of the procedure would not have been painful *per se*. But if the patient were conscious, it is likely that the individual would have been in considerable discomfort.

The cutting instrument must have been applied at an angle from the front to produce both the oblique anterior margin and the vertical medial and lateral margins of the perforation. Once the inner table of bone had been penetrated anteriorly, the operator straightened the trepan and snapped out the roundel of bone.

It is possible that the penetration of the inner table bone with the saw involved nicking the branch of the left middle meningeal artery that lay directly underneath (Plate 4). The laceration of this vessel would have resulted in haemorrhaging that would have been difficult to stop. Any attempt to do so would have been dangerous, as it would have run the risk of causing direct damage to the brain. Whether or not the blood vessel was cut, it is clear that this person did not survive for long after the procedure. Neither the scalp incisions nor the perforation itself show any signs of healing having occurred.

Lisowski (1967) described the healing and repair process in a trepanation. The diploë produces a small amount of endosteal callus, while the periosteal callus of the epicranium grows only a little. Although the perforation would never close, the healing process leaves characteristic new bone at the site of the procedure. This slight osseous regeneration results in the smoothening of the trepanned margin.

Macroscopic examination of the margins of the St. Michael le Pole trepanation shows that these are quite smooth anteriorly, medially and laterally. However, the use of a trepan would account for the form of these margins. Similar smooth diploic surfaces have been observed in skulls with sword cuts from which the victim could not possibly have survived (Ó Donnabháin, 1985). In the St. Michael le Pole trepanation, the diploë is still visible in the cut margin and the jagged posterior margin shows no sign of regrowth. Moreover, the straight incisions, which probably resulted from the operator incising the scalp and reflecting it back over the area to be trepanned, show no sign of healing. These would have been obliterated quickly if healing had taken place. The absence of any osteitis further supports the view that the patient did not survive for long after the trepanation.

While it is not possible to determine with certainty the cause of death, a fatal haemorrhage due to the laceration of a branch of the middle meningeal artery seems most likely. Direct injury to the brain could also have occurred. A catastrophic infection is also a possibility, since it is unlikely that the procedure was carried out under aseptic conditions.

Other Historic Period Trepanations

In the first reported Irish case of the procedure, Walmsley (1923) described a trepanation thought to be of Early Medieval date that was recovered from the monastic site at Nendrum, County Down. The skull was reported to be that of a younger adult and the trepanation was on the left parietal towards the antero-inferior angle of the bone, immediately inferior to the temporal line. Martin (1935) mentioned that the skull was in Queen's University Belfast, though it cannot now be located. A photograph published by Walmsley shows a circular defect, reported to be 8 mm in diameter. The bevelled margins of the defect indicated that it had been produced by scraping the bone. Walmsley did not mention if there were any signs of healing of the lesion, though he did note that there were no other marks of injury to the skull.

Lynn (1975) mentioned that he had found a skull with a trepanation on the left parietal during trial trenching at the Early Medieval church at Banagher, County Derry. Lynn did not discuss the context or dating of the remains and the trepanation was not mentioned in Waterman and Hamlin's (1976) subsequent report on the excavations. This skull has been examined by the writer and appears to be an example of a trepanation that had healed. The perforation is roughly circular and has a diameter of about 35 mm. It is on the left parietal in a location similar to that described above in the examples from Nendrum and the church of St. Michael le Pole. The margins of the trepanned defect in the Banagher example are bevelled and smooth. It was probably produced by scraping, and the individual survived for a considerable time after the operation.

Three trepanned skulls of early medieval date were recovered during recent excavations of an early medieval cemetery at Cabinteely, County Dublin (Conway, 1999, 2000). Six stratigraphic phases of burial were identified at the site. Radiocarbon dates are not yet available, but the earliest phases have been dated by artifactual associations to the fifth or sixth centuries AD. The trepanations were found in burials from each of the three later phases identified at the site and may date from as late as the tenth or eleventh centuries AD.

In each of the three cases, the techniques used involved scraping the bone. This produced similar bevelled lesions in each case. Each of the perforations is oval and two are on the right parietal, whereas one is on the left. Two of these lesions are quite extensive with maximum lengths of 52 mm and 65 mm. Although the *modus operandi* used in the trepanations is very similar in all three cases, the stratigraphic data suggest that the particular method used in the procedure had a long history in the community that used the site for burial. Of the three cases from the site, one has signs of some healing having taken place prior to the death of the individual, and the degree of remodelling in the other two suggests that the people involved had survived for a long time after the operation.

Martin (1935) mentioned a trepanned skull from Collierstown, County Meath that was recovered along with many other skeletons from a medieval cemetery. This was found in 1934 during excavations carried out by personnel attached to the National Museum of Ireland. The skull is that of an adolescent or young adult and the trepanation is located on the right frontal. The perforation is oval, measuring 29 mm by 22 mm and had been made by scraping the bone. It is surrounded by a large rectangular area of healed osteitis that measures 55 mm by 62 mm, and may have resulted from inflammation of the area of reflected scalp. Remodelling of the margins of the trepanation and of the area of osteitis indicate that the patient had survived for some time after the procedure.

A probable example of trepanation of Later Medieval date was recovered during recent excavations at the site of the church of the Holy Trinity, Carlingford, County Louth (personal communication, Laureen Buckley).

Two cases of trepanation are known from post-medieval contexts. Lynn (1975) found one at the Franciscan friary in Armagh among a group of skeletons thought to date from the late-seventeenth century. The roughly circular perforation is on the occipital bone and has a diameter of about 35 mm. The defect is surrounded by a bevelled band of bone that is 10 mm wide and the lesion, which had probably been produced by scraping the bone, had healed. Another post-medieval trepanation has recently been noted during excavations of an eighteenth-century cemetery at North King St in Dublin (personal communication, Jenny Coughlan).

Discussion

Cases of trepanation have been found in archaeologically-retrieved skeletal remains from all world areas and have also received some attention in the ethnographic literature (Oakley et al., 1959; Magretts, 1967), which includes eyewitness accounts (e.g. Crump, 1901). In his discussion of a dramatic example of Early Bronze Age date from southern Britain, Piggott (1940) suggested that the idea of trepanation had originated in prehistoric Europe. This type of eurocentric and diffusionist reasoning was typical of the traditional school of archaeology of the first half of the twentieth century and is no longer considered valid in archaeological interpretation. It seems more plausible to suggest that this is a procedure that has been developed independently by many peoples in different contexts over many millennia.

This diversity is presumably matched by an equally diverse set of motivating factors. Among the many potential motives that have been suggested in both the bioarchaeological and ethnographic literature, the majority fall under two general headings: magico-religious and curative. In the former, the focus is on both the perforation and the bone that was removed, which many suggest might have been retained as a powerful amulet (Ortner and Putschar, 1985).

There is strong circumstantial evidence for the curative motivating factors where the emphasis would have been on the effects of producing the perforation rather than on the excised piece of bone. Trepanations associated with trauma and other pathological conditions have been reported in archaeological material from a diverse range of cultural contexts (Lisowski, 1967; Brothwell et al., 1978; Wells, 1982; Mann, 1991; McKinley, 1992).

In the Irish examples reviewed above, the case from the church of St. Michael le Pole has direct evidence of an association with trauma, and the preference for the anterior portion of the left parietal may also be indicative of such an association. As most people are right handed, trauma to the head that is the result of face-to-face combat tends to be concentrated on the left side of the head. The association between the trepanation and other lesions suggests that the perforation was perceived in many different socio-cultural settings as a means of relieving at least some somatic conditions.

Although it is likely that medical knowledge systems in many early societies were conceptualised in a way that was radically different from modern western biomedicine, they probably had a strong empirical basis. Trepanation can indeed be an effective treatment in cases of trauma to the head that produce sub-dural bleeding. The procedure reduces the pressure placed on the brain by the resulting haematoma. The effects of such intra-cranial pressure will vary according to the location of the haematoma, but can include symptoms such as loss of consciousness, headache, cognitive impairment, and peripheral neurological signs. In the case of many head wounds, it would be clear to any observer of the victim that there was a direct relationship between the injury and the onset of such symptoms. The location of the initial injury would point to the site where the pressure-relieving operation would be most likely to be effective. If the efficacy of the treatment could be demonstrated, it may have encouraged early practitioners to use the procedure for other disorders, while also assuring the co-operation of other potential patients.

Perhaps it is misleading though to present the surgery as an experimental operation. It seems likely that the surgeon who operated on the individual from the church of St Michael le Pole was using an instrument specifically designed for an intervention that had a long history in the medical knowledge of the particular cultural milieu. This suggestion is reinforced by the data from the nearby site at Cabinteely where the differences in dating between the three cases suggest the particular method used at that site also had a long history of use.

Of the 18 trepanations, possible trepanations and pseudotrepanations from Ireland reviewed above, the majority date from the historic period. Information about the extent of healing was available in 12 cases. Remodelling of the bone suggested that eight of the individuals involved had survived the operations, though in at least one case this was only for a short period of time.

As the occurrence of trepanation varies widely both temporally and spatially, the technology associated with the procedure also shows considerable variation. Although subsequent healing can obscure the evidence of the techniques that were used, unsuccessful attempts, such as that from the church of St. Michael le Pole, can offer clues as to the form of the cutting instrument that was used and the manner in which it was applied.

The various techniques of trepanation that have been documented in archaeological contexts have been reviewed by a number of writers (Oakley et al., 1959; Lisowski, 1967; Ortner and Putschar, 1985) and involve a diverse range of cutting and scraping techniques and instruments. Brothwell (1974) described a set of trephining equipment that was found in a Roman period context at Bingen-am-Rhein in Germany. This type of equipment, including the cylindrical saw, was well known in the Classical World, as was the associated head surgery. The medical treatises attributed to Hippocrates (late fifth century BC) indicate that trepanation was used to relieve the effects of skull fracture and contain descriptions of cylindrical toothed saws. Similar objects were described by the Roman medical writer Celsus (c. 3 AD to 64 AD), who also left instructions on how the instrument should be used. These instructions imply that the instrument had a central pin that could be removed once the saw had begun to penetrate the bone. The cylindrical saw from Bingen described by Brothwell (1974) had a central anti-slip pin, such as that mentioned by Celsus. The presence of the three semi-circular grooves on the bone from the church of St. Michael le Pole suggests that a centre pin was not present in the cylindrical saw that was used during that procedure. However, the use of the cylindrical saw in the case from the St. Michael le Pole site seems to be unique in the Irish context.

The possibility that there were two trepanations at Castleknock, others of possibly similar date from Banagher, Nendrum, and St. Michael le Pole, as well as the three confirmed examples at Cabinteely, may suggest that this was a practice that was not uncommon in Early Medieval Ireland. We know very little about the medical knowledge systems and expertise that were obtained in that society. McDougall (1992) has noted the similarity between descriptions of surgical procedures in thirteenth- and fourteenth-century Icelandic manuscripts and those in contemporary and earlier texts from southern Europe. He has argued that this demonstrates the transmission of medical knowledge systems throughout medieval Europe. No doubt the people of Early Historic Ireland were also both generating and at the receiving end of the exchange of medical knowledge and expertise.

The examples of cranial surgery described in this paper offer us a tantalising glimpse of the level of medical intervention that was practised and is a graphic reminder of the interaction between biological and cultural systems that is fundamental to understanding the human career.

Acknowledgements

I would like to thank Jenny Coughlan and Laureen Buckley for information about the unpublished trepanations from Cabinteely and North King Street.

Note

1. In this paper, trepanation is understood as the removal of a portion of bone from the skull vault by various methods. A trepan is a cylindrical saw used in the operation. A trephine (hence trephination) is an improved form of trepan with a guiding centre-pin.

References

Brothwell DR (1967): Human remains from Gortnacargy, Co Cavan. *J Roy Soc Antiquar Ire 97*:75–84.
Brothwell DR (1974): Osteological evidence of the use of a surgical modiolus in a Romano-British population: an aspect of primitive technology. *J Archaeol Sci 1*:209–211.
Brothwell DR, Powers R, Denston B (1978): The human skeletal remains from Amesbury Barrow 51 with special reference to the case of trephination and its position in the history of trephining in Britain. *Wiltshire Archaeology Magazine*, pp 43–60.
Buckley L (1993): A bone to pick. *Tech Ire 25*:29–31.
Buckley L, Ó Donnabháin B (1992): Early cranial surgery in Ireland. *Arch Ire 6(4)*:10–12.
Buckley L, Murphy E, Ó Donnabháin B (1999): *The Treatment of Human Remains: Technical Paper for Archaeologists*. Dublin, Irish Association of Professional Archaeologists.
Conway M (1999): *Director's First Findings from Excavations in Cabinteely*. Dublin: Margaret Gowen and Company Transactions 1.
Conway M (2000): Mount Offaly, Cabinteely: early medieval enclosed cemetery. In: Bennett I, ed., *Excavations 1998: Summary Accounts of Archaeological Excavations in Ireland*, Bray, Wordwell, pp 36–37.
Crump JA (1901): Trephining in the south seas. *J Roy Anthropol Inst 31*:167–172.
Key CA, Aiello LC, Molleson T (1994): Cranial suture closure and its implications for age estimation. *Int J Osteoarch 4*:193–207.
Lisowski FP (1967): Prehistoric and early historic trepanation. In: Brothwell DR, Sandison

AT, eds., *Diseases in Antiquity: A Survey of the Diseases, Injuries and Surgery of Early Populations*. Springfield, Charles C Thomas, pp 651–672.

Lynn CJ (1975): Excavation in the Franciscan Friary church, Armagh. *Ulster J Archaeol 38*:61–80.

Magretts EL (1967): Trepanation of the skull by the medicine-men of primitive cultures, with particular reference to present-day native east African practice. In: Brothwell DR, Sandison AT, eds., *Diseases in Antiquity: A Survey of the Diseases, Injuries and Surgery of Early Populations*. Springfield, Charles C. Thomas, pp 673–701.

Mann G (1991): Chronic ear disease as a possible reason for trephination. *Int J Osteoarch 1*:165–168.

Martin CP (1935): *Prehistoric Man in Ireland*. London, Macmillan.

Masset C (1989): Age estimation on the basis of cranial sutures. In: Iscan MY, ed., *Age Markers in the Human Skeleton*. Springfield: Charles. C. Thomas, pp 71–103.

McDougall I (1992): The third instrument of medicine: some accounts of surgery in medieval Iceland. In: Campbell S, Hall B, Klausner D, eds., *Health, Disease and Healing in Medieval Culture*. London, Macmillan, pp 57–83.

McKinley JI (1992): A skull wound and possible trepanation from a Roman cemetery at Baldock, Hertfordshire. *Int J Osteoarch 2*:337–340.

McLoughlin EP (1950): *Report on the Anatomical Investigation of the Skeletal Remains unearthed at Castleknock in the Excavation of an Early Christian Cemetery in the Summer of 1938*. Dublin, Government Publications Office.

Mount C, Hartnett PJ (1993): Early Bronze Age cemetery at Edmondstown, Co Dublin. *Proc Roy Ir Acad 93C*:21–79.

Ó Donnabháin B (1985): *The human remains from Tintern Abbey, Co Wexford*. Unpublished thesis presented to Department of Archaeology, University College, Cork for an MA degree.

Ó Donnabháin B (1995a): Monuments of shame: some probable trophy heads from medieval Dublin. *Arch Ire 9*, pp 12–15.

Ó Donnabháin B (1995b): The human remains. In: Simpson L, ed., *Excavations at Essex Street West, Dublin*. Temple Bar Archaeological Reports 2, pp 117–120.

Ó Donnabháin B (In Press): A cut above: head surgery in medieval Dublin. In: Duffy S, ed., *Medieval Dublin II*. Dublin, Four Courts Press.

Ó Donnabháin B, O'Sullivan VR, Fraher JP (1985): A trepanned parietal bone. *J Dent Res 64*:727.

Oakley KP, Brooke MA, Akester AR, Brothwell DR (1959): Contributions on trepanning or trepanation in ancient and modern times. *Man 59*:92–96.

Ortner DJ, Putschar WGJ (1985): *Identification of Pathological Conditions in Human Skeletal Remains*. Reprint Edition. Washington: Smithsonian Institution Press.

Piggott S (1940): A trepanned skull of the Beaker period from Dorset and the practice of trepanning in prehistoric Europe. *Proc Prehist Soc 6*:112–133.

Prendergast E (1962): Archaeological acquisitions for the year 1960. *J Roy Soc Antiquar Ire 92*:152.

Rynne E (1974): Ancient burials at Ballinlough, Co Laois. *J Kildare Archaeol Soc 15*:430–433.

Simpson L (2000): Forty years a-digging: a preliminary synthesis of archaeological investigations in medieval Dublin. In: Duffy S, ed., *Medieval Dublin I*. Dublin, Four Courts Press, pp 11–68.

Voights LE, Hudson RP (1992): A drynke þat men callen dwale to make a man slepe whyle men kerven him: a surgical anesthetic from late medieval England. In: Campbell

S, Hall B, Klausner D, eds., *Health, Disease and Healing in Medieval Culture*, London, Macmillan, pp 34–56.
Walmsley T (1923): A trephined Irish skull. *Man 23*:108.
Waterman DM, Hamlin A (1976): Banagher Church, Co Derry. *Ulster J Archaeol 39*:25–42.
Wells C (1982): The Human Burials. In: McWhirr A, Viner L, Wells C, eds., *Romano-British Cemeteries at Cirencester*. Cirencester, Cirencester Excavation Committee, Corinium Museum, pp 135–202.

Chapter 6

Ancient Trepanations and Differential Diagnoses: A Re-evaluation of Skeletal Remains from Denmark

PIA BENNIKE
Laboratory of Biological Anthropology, University of Copenhagen, Copenhagen, Denmark

Abstract

A survey of 18 reported prehistoric Danish skulls that bore evidence of surgical treatment was discussed in a previous study (Bennike, 1985). The aim was to list the samples that had already been claimed to be cases of trepanation. However, these cases have recently been reassessed and in the light of accumulated experience in the field of palaeopathology it seems likely that at least some of the skulls should be diagnosed differently. Recently, they were compared with a number of skulls from a nineteenth-century pathological bone collection with known diagnoses and with 60 skulls from a fourteenth-century mass grave with more than 120 injuries produced by sharp weapons. As we cannot put a name to the battle, we do not know the nature of the fight, the combat methods or how the victims were killed (Bennike, 1998, 2000).

Keywords: Denmark, trepanation, medieval, combat, trauma

Introduction

A survey of 18 reported prehistoric Danish skulls that bore evidence of surgical treatment was discussed in a previous study (Bennike, 1985). The aim was to list the samples that had already been claimed to be cases of trepanation. However, these cases have recently been reassessed and in the light of accumulated experience in the field of palaeopathology, it seems likely that at least some of the skulls should be diagnosed differently. Recently, they were compared with a number of skulls from a nineteenth-century pathological bone collection with known diagnoses and with 60 skulls from a fourteenth-century mass grave with more than 120 injuries produced by sharp weapons. As we cannot put a name to the battle, we do not know the nature of the fight, the combat methods or how the victims were killed (Bennike, 1998, 2000).

The Previous Results

The previous survey (Bennike, 1985) of trepanned skulls from Denmark reported the distribution of age, sex, dating, geographical location, probable surgical procedures and the location on the skull (Table 1). None of the specimens were from the Mesolithic period, even though a very few have been reported from other geographical areas of Europe. Most of the Danish trepanned skulls were from the Neolithic. In general, trepanned skulls from the Neolithic have been reported relatively frequently from other European areas (Ullrich and Weickmann, 1965). The number of trepanned skulls from the Bronze and the Iron Ages in Denmark are rather few. None are from the Viking Period, but the paper by Charlotte Roberts and Jaqueline McKinley (in this volume) indicates that most such skulls from Great Britain are from this rather late prehistoric period. The number of relatively well preserved prehistoric Danish skulls represent around 500–1,000 individuals whereas those from the Middle Ages represent many more, around 6,000–10,000 individuals. It is therefore interesting to note that there are exceptionally few, if any, medieval skulls from Denmark with reliable evidence of trepanation. Less than five possible cases have been reported (Isager, 1936; Møller-Christensen, 1958; Jørgensen, 1997). However, both this author and a number of colleagues experienced in palaeopathology have found that none of them

Table 1. List of Reported Trepanations in Denmark (Bennike, 1985).

Site	*Geogr.*	*Dating*	*Location*	*Healing*	*Diff. diagn.*
Dræby I	Fynen	Neol.	mid. parietal	+	blade injury
Dræby II	Fynen	Neol.	l. parietal	+	blade injury
Døjringe I	W. Zealand	E. Neol.	l. pararietal (2)	+	blade injury + glancing blade injury
Døjringe II	W. Zealand	E. Neol.	l. frontal	+	blunt injury
Frederiksgave	Fynen	Neol.	l. parietal	+	?
Gadevang	N. Zealand	Iron Age	l. pariet./front.	+	
Ganløse	N. Zealand	Neol.	l. pariet./front.	+	blunt injury
Gjerrild	Jutland	Neol.	l. parietal	+	
Grydehøj	S. Fynen	Neol.	l. frontal	+	depression fracture
Havbyrd	W. Zealand	Iron Age?	r. frontal	no	post-mortem damage?
Hulbjerg	S. Fynen	Neol.	l. frontal	+	blade injury
Kelderød	W. Zealand	E. Neol.	l. parietal	no	post-mortem damage?
Lundtofte	N.Zealand	Bronze Age	m. pariet./front.	no	post-mortem?
Næs	S. Zealand	Neol.	m. pariet./front.	+	tumour?
Nr. Åmose	N. Jutland	Br./Iron Age	m. occipitale	+	glancing blade injury
Vandet	N. Jutland	Iron Age	l. pariet./front.	+	
Varpelev	S. Zealand	Iron Age	l. pariet./front.	no	blade injury
Vibygårds mose	Zealand	E. Neol.	l. pariet./l.occip.	+	blade injury

E. Neol.=Early Neolithic	4,200 – 3,200 BC
Neol. = Mid./late Neolithic	3,200 – 1,800 BC
Bronze Age	1,800 – 500 BC
Iron Age	500 BC – 800 AD
Viking Period	800 – 1050 AD
Middle Ages	1050 – 1536 AD

seem to present convincing evidence of skull surgery. Like some of the prehistoric skulls with reported trepanations, they may instead be cases of spontaneously healed skull lesions.

During the Middle Ages in Denmark the monasteries were forbidden by the church to perform extensive invasive surgery on human beings (Madsen and Robinson, 1999). The body was created by God and no one was allowed to interfere with it. The church's main concern was to save souls, not bodies. Diagnoses were generally made from the colour, taste and smell of the urine, and the treatment of diseases and disabilities was often based on the Salerno School's theories, namely maintaining a balance between the four fluids. The usual treatment was to reduce the amount of one or more fluids in one way or another or to stimulate an increase by prescribing herbs. This may explain why there are so few, if any, trepanned skulls from the Middle Ages in Denmark compared to the suggested number of skulls with possible trepanations from the much smaller prehistoric skeletal collections. Furthermore, some of the previously reported traces of other types of treatment i.e. cauterization, amputation, bandaging from the Middle Ages have been disproved. It seems much more likely that holes found in the sternum are traces of malformations, that *cloacae* are evidence of ostemyelitis, that reported amputations are in reality severe injuries and that the imprints from supposed bandages of the long bones rather stem from blood vessels (due to periostotis) (Bennike and Brade, 1999).

Four of the reported prehistoric skulls with possible evidence of surgery are from the Early Neolithic period (4,000–3,200 BC). The majority of skeletons from this period, the early days of agriculture in Denmark, mainly belong to an interesting group which were recovered from the wetlands in which skeletal remains are extremely well preserved under certain circumstances (Bennike, 1999). The skeletons represent the first farmers in Denmark, and in addition to the so-called trepanations they display much pathology and evidence of violence (Bennike, 1985, 1999; Bennike et al., 1986a,1986b). In general, these skeletons are much more gracile than those of their mesolithic predecessors who depended on hunting, gathering and fishing for survival. The genetic and/or environmental differences between populations play an important role in the replacement theory in which the Mesolithic inhabitants were replaced by the Neolithic (which may have caused violent episodes and injuries) or the theory that the Mesolithic population changed morphologically due to a shift in subsistence and life-style.

The geographical distribution of the reported trepanned skulls showed no specific local concentration in relation to the distribution of all skulls excavated in Denmark. The clear scarcity of skulls in some areas is due to differences in preservation conditions (sand), fewer inhabitants in the less fertile areas and probably fewer excavations. The geographical pattern fits with the total number of skeletal finds and with the distribution of megalith graves registered in Denmark.

In the previous study almost 75% of the Danish so-called trepanations were described as having been produced by the scraping the skull and the rest with instruments like saws or knives (Bennike, 1985). Neither the rectangular holes commonly seen in Peruvian skulls, nor holes made with a drill were reported. The number of possibly trepanned skulls which exhibited evidence of survival was 14, which is 78% compared to the four skulls without any bone reaction around the edge of the injury.

In some German studies (for example by Ullrich and Weickmann, 1965), trepanation

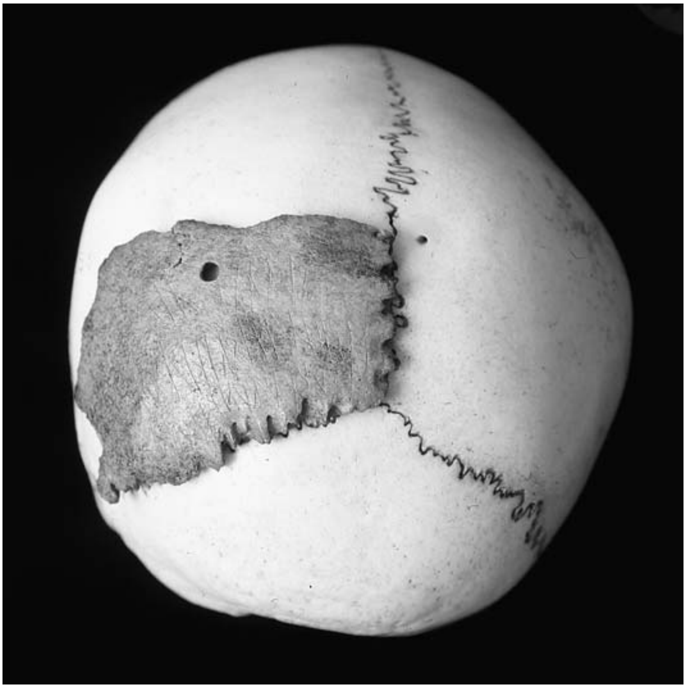


Figure 1. Human skull fragments with a hole for suspension are known from the Neolithic Age in France. These were probably used as amulets and may have been taken from the skull post-mortem. Only from Ribe in Denmark is a skull fragment with a suspension hole known. It is inscribed with runes on the outer side. The skull has not been found and the person who wrote the runes may not even have known whether it was a piece of bone from a human being or an animal.

is defined as surgically produced holes in an otherwise healthy bone. However, it is the opinion of this author that, as the removed piece of bone is missing in most cases, it is usually impossible to determine whether it was marked by pathological or traumatic lesions. As all surgical treatment of skulls is of interest, it may seem to be a strange restriction.

Considerations and theories on why the trepanations were performed are probably well known to most readers of this volume. Generally, they may have been performed for ritual reasons or for treating skull lesions. The former is supported by a few Neolithic finds in France of human skull fragments with a hole for suspension. These were probably used as amulets and may have been taken from the skull of a deceased. Only one skull fragment with a suspension hole has been found in Denmark. Its other side is inscribed with runes (Fig. 1). The runes were cut into the bone and were common during the Viking Period. The skull fragment was found during the excavation of a midden in the town of Ribe that was founded during the Viking Age. As it was an isolated find without any trace of the rest of the skull, it is impossible to tell whether it was a skull fragment from the Viking Period or just a chance find from any period. The person who wrote the runes may not even have known whether it was a piece of bone from a human being or an animal.

Figure 2. A skull with a large opening at the back from Vibygårds mose. The posterior edge may have been caused by a blow with an axe. It is at least hard to believe that any surgery would have been performed without the prior infliction of an injury.

The location of the so-called trepanations on the prehistoric skulls revealed an interesting pattern, which for a while was a factor worth considering in the search for an explanation for the practice of trepanation. All 18 cases of trepanations have been outlined on an undated skull and are mainly concentrated on the left side with only a few in the middle and the back. Only one was located on the right side on the frontal bone. Other studies have reported similar side patterns. Looking at the location of skull injuries without evidence of treatment in a Danish Medieval collection of 700 skeletons from a Medieval monastery (Æbelholt), Møller-Christensen (1958) found that the majority of injuries were also on the left side of the skulls. This was also the case for the many lesions on skulls from the battle of Visby in Sweden (1361), where skeletal remains of 1,200 men were found in mass graves. These lesions formed a similar pattern with 69% on the left and only 31% on the right side (Knowles, 1983). In both studies the pattern was explained as lesions produced by right-handed blows during frontal attacks. The shape and the direction of the lesions seem to support this interpretation. A recent study of injured skulls from Germany showed that two thirds had injuries on the left side. They were compared to machete wounds in South Africa that showed the same pattern (Weber and Czarnetzki, 2001). The previous study of Danish so-called trepanned skulls also suggested that the explanation for the majority of trepanations on the left side of the skull was to be found in the many left-sided injuries. If this were so, many of the trepanations were being performed in order to "repair" or treat an injury (Bennike, 1985).

Those studies that reveal similar patterns of trepanations and injuries, also reveal similar sex distribution patterns with a majority of men. Of the 36 skulls with injuries

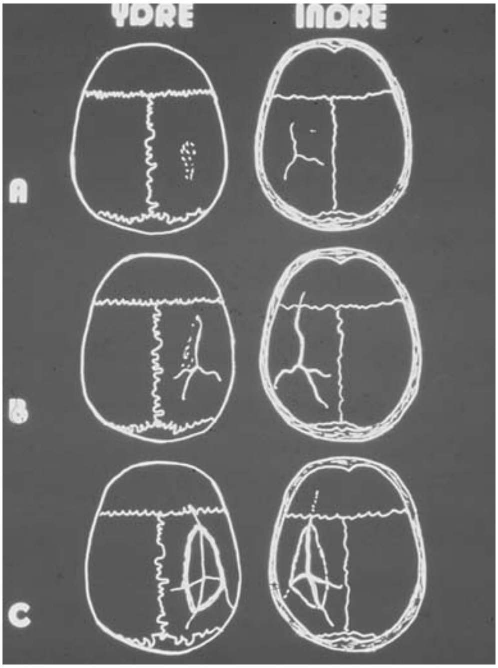


Figure 3. The injury of the skull from Vibygårds mose (Fig. 2) may be similar to the injury (c) caused by a very serious blow reproduced from a book on forensic medicine.

from the Medieval cemetery at Æbelholt, 34 were male and, as expected, all the skeletons from the battle of Visby were male. The sex evaluation of the reported trepanned skulls from Denmark showed that 14 of the 18 skulls were male, only one was female and three were impossible to identify. It may be postulated that more men were trepanned because they were considered the most important members of a community, but from an archaeological point of view nothing seems to support this theory. Danish prehistoric skeletons with other man-inflicted injuries, such as an arrow-head lodged in a bone, decapitation and the like are predominantly male as well. The Grauballe man who had his throat cut from ear to ear and the Tollund who was found with a rope around his neck were two of the most famous finds from the bogs. In the previous survey it was therefore concluded that the results so far seemed to indicate that skull surgery in Denmark from the Stone Age up to the Viking Period was probably mainly practised in order to repair primary lesions and probably for the same reasons as it is practiced today; to prevent fragments of bone from inducing fatal, chronic haemorrhage and infection, and damage to the brain.

Present Interpretation

After the recent reevaluation of the cases previously described as trepanations, and after an extensive accumulation of experience from studies of injured skulls, it may be argued

Figure 4. An untreated Medieval skull with a rather similar but unhealed injury caused by a violent blow. If the man had survived long enough, the lesion may have looked very much like the suggested trepanations (Figs 3 and 5).

that the coincidence of the side patterns of lesions and trepanations may as well be due to a misinterpretation of what has been called trepanations. That this indeed may be the case will be demonstrated in the following where a number of the skulls which previously were reported as trepanned may be cases of skull injuries that lack any traces of treatment.

The back of a skull that was found in Vibygårds bog has a large triangular opening with the apex pointing upwards (Fig. 2). The posterior edge may have been caused by a blow with an axe. It is difficult to believe that this opening would have been made without the occurence of any prior injury, which may have been caused by a very serious blow similar to the injury (c) in Figure 3. Fused fracture lines which commonly appear after a serious blow are also seen at the back of the skull. It is, however, still obscure whether the edges were smoothed and the fragments removed, or whether the lesion healed spontaneously. Such obscurities are actually of primary interest when discussing evidence of treatment or spontaneous events. For comparison, Figure 4 shows an untreated Medieval skull with a rather similar, but unhealed injury, also a result of a vio-

Figure 5. A skull from the Iron Age, Varpelev, has been reported to have traces of surgical intervention after a heavy blow with a sharp weapon which left a sharp edge at the upper side of a triangular opening. The posterior edge was described as possibly having been broken off by humans. It seems very doubtful that this case should be classified as a “treated” skull.

lent blow. If the man had survived long enough, the lesion may have looked very much like the suggested trepanation from the Early Neolithic period (Fig. 2).

An Iron Age skull excavated at Varpelev was reported to have traces of surgical intervention following a heavy blow with a sharp weapon, which left a sharp edge at the upper side of a triangular opening (Fig. 5). The posterior edge was described as having possibly been broken off by humans and the case was therefore interpreted as presenting evidence of treatment. It seems very doubtful whether this case should be classified as a “treated” skull. Having studied and compared many other skulls with severe lesions after serious blows, the same may be said of another early Neolithic skull from Døjringe with two lesions (Fig. 6). Almost parallel to the sagittal suture, an elongated depression with smooth sides can be discerned at the left parietal bone. The healed sloping edges have been interpreted as evidence of a trepanation, but they may just as well be the result of a healed injury from an axe or a similar weapon. The second and lower lesion, also at the left parietal bone has as well been interpreted as a trepanation, but this author feels that the injury may possibly have been inflicted by a glancing cut with a blade. The skeleton to which this skull belonged was found close to another skeleton of a 18–20 year old man. The skull of this skeleton had a partially healed lesion which was also previously described as a trepanation. It may, however, rather be the result of a blow with a sharp or blunt weapon. The injury is seen as an almost sagittal groove and a circular depression on the frontal bone. No perforation and reaction are visible at the inner table (Fig. 7).

The so-called trepanned skulls were compared with skulls of 60 male skeletons with at least 120 blade injuries from a Danish fourteenth-century mass grave in Næstved. Several had traces of glancing blade injuries, and it became evident how a superficially

Figure 6. An Early Neolithic skull from Døjringe I with two lesions. Almost parallel to the sagittal suture, an elongated depression with smooth sides can be discerned at the left parietal bone. The healed sloping edges have been interpreted as evidence of a trepanation, but it may just as well be a healed blow-injury with an axe or a similar weapon. The second lesion at the left parietal bone has been interpreted as a trepanation, but this author believes that it may have been caused by a glancing cut with a blade weapon.

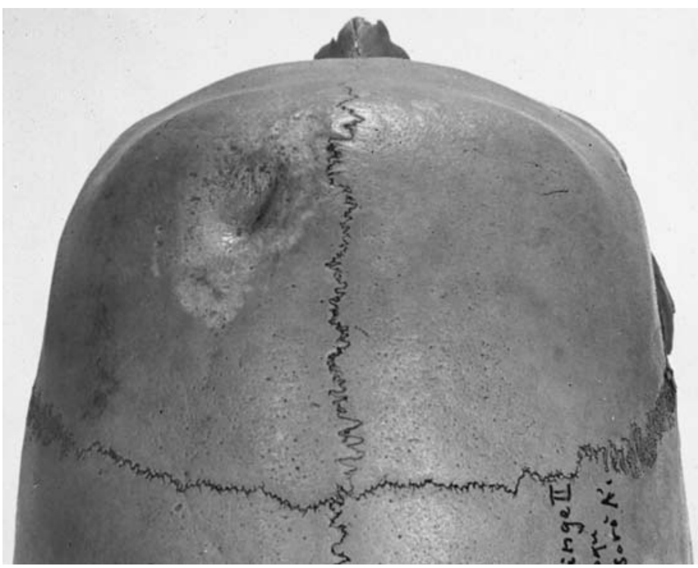


Figure 7. One of two skulls from Døjringe, Døjringe II. This injury may be a result of a blow with a sharp or blunt weapon. No reaction is visible at the inner table of the frontal bone.

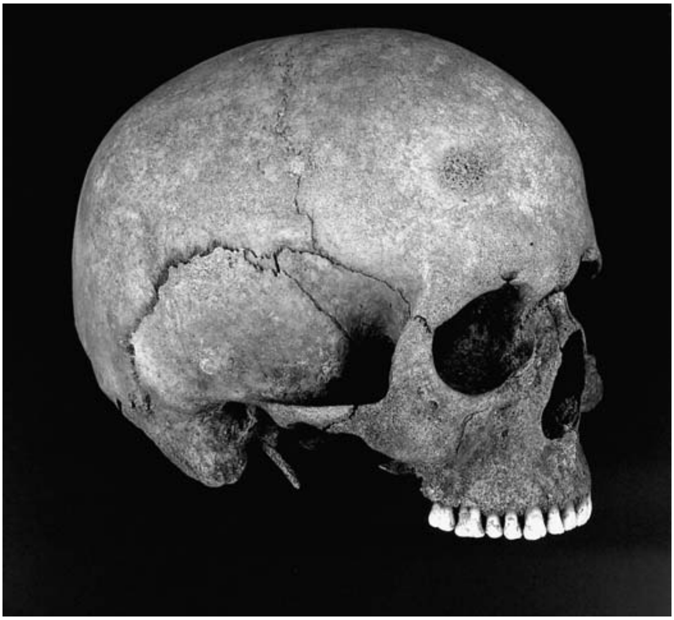


Figure 8. Several skulls from a Mediaeval mass grave had traces of glancing blade injuries. This one is an example of how a superficially healed glancing cut may easily be misinterpreted as trepanation performed by the scraping technique.

healed glancing cut may easily be misinterpreted as a trepanation produced by the scraping technique (Fig. 8). This may have been the case for a few of the previously reported trepanations. One example may be the already mentioned skull from Døjringe I (Fig. 6), and another, the skull from the Nørre Åmose site dated to the Iron Age. The occipital bone on the latter has a partly healed circular opening described as a scraped hole. The edges slope gently towards the opening (Fig. 9). Both skulls exhibit a perforation in the center of the lesion, but whereas the perforation is rather small compared to the involved bone area in the Stone Age skull, the perforation in the Iron Age skull is much larger in relation to the involved area of the skull. An interesting study (Janssens, 1987) has shown the difficulties differentiating glancing or tangential injuries from trepanations.

A skull from the Hulbjerg passage grave has a partially healed lesion on the left temporal side (Fig. 10). The lesion was previously interpreted as a trepanation. The left temple region exhibits an oval to triangular opening with rounded edges, almost vertical at the back. Changes in the bone structure seem to cover a much larger area. The outer edge of the left brow ridge is missing and the temporal lines almost extinguished (Fig. 11). This is probably an example of a slash injury, where the weapon grazed the skull and injured the brow ridges and the layer of the outer table. It is, however, open to a discussion whether the injury shows any signs of having been treated. This author is not convinced, even though another skull in the same passage grave bore evidence of the first dental treatment described in a neolithic skull. A tooth had been drilled with a bow

Figure 9. A skull from Nørre Åmose dated to the Iron Age. The occipital bone has a partly healed circular opening described as having been scraped. The edges slope gently towards the opening. One cannot rule out the fact that the lesion may have been caused by a glancing blade injury.

drill 4,000–5,000 years ago and bears clear striations (Bennike, 1985; Bennike and Fredebo, 1986).

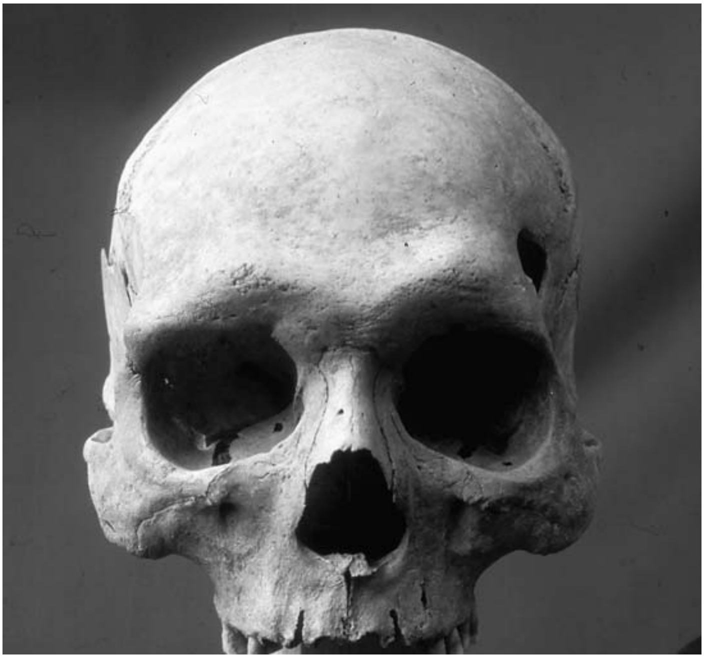
In several cases one may ask what happened to the bone fragments which may have been loosened during a blow. Whether they were removed manually or atrophied by osteoclast activity is vital to our interpretation. There are only sporadic specimens in which the loosened bone fragments are fused to the cranial bone.

Depression Fractures

A neolithic skull from Grydehøj has a circular depression with smoothly rounded edges sloping towards the base of the depression (Fig. 12). Two healed radiated fracture lines run towards the orbit. At the most medial line, the inner table exhibits pieces of fragmented bone that are fused and extend 1–2 mm into the skull cavity. This is undoubtly a classical case of an injury caused by a blow with a blunt weapon. Several other skulls previously described as trepanned may likewise be cases of depressed fractures rather than surgical treatment.

The left fronto-temporal region on a Neolithic skull from Ganløse has a large healed oval depression which may have been caused by a blunt weapon (Fig. 13). A posterior hole has fresh cracks and is probably a post-mortem artifact. The large depressed area has been described as a trepanation, which seems to be a dubious diagnosis. The lesion

10



11

Figures 10 and 11. A skull from Hulbjerg passage grave with a partly healed lesion on the left temporal side, previously interpreted as a trepanation. The region of the left temple exhibits an oval to triangular opening with rounded edges, almost vertical at the back. However, changes in the bone structure seem to cover a much larger area, as the outer edge of the left brow ridge is missing and the temporal lines are almost extinguished.

Figure 12. A Neolithic skull from Grydehøj with a circular depression with smoothly rounded edges sloping towards the base of the depression. Two healed radiated fracture lines run towards the orbit. At the medial fracture line, the inner table exhibits pieces of fragmented bone which have fused and extend 1–2 mm into the skull cavity. This case is undoubtly a classical case of a depression fracture caused by a blow with a blunt weapon.

Figure 13. The left fronto-temporal region of a Neolithic skull from Ganløse with a large healed oval depression that may have been caused by a blunt injury. A posterior hole exhibits fresh edges and is probably a post-mortem artifact. The large depressed area has been described as a trepanation, which seems dubious, as it may just as well have been caused by a blow with a blunt weapon.

seems to have been caused by a blow with a blunt weapon.

A third Neolithic skull from a dolmen at Kelderød has, beside a lesion at the right orbit (Fig. 14), a lozenge-shaped opening in the left temporal area with edges which actually look fairly recent. During the previous study, however, it seemed likely that the the scratches around the anterior and superior edges were traces of surgery (Fig. 15). It has been suggested that the primary lesion may have been produced by a sling-stone and that the scratches around the hole may stem from scraping during "treatment". Shot wounds are usually rather easy to detect as both an entrance and an exit hole have very characteristic appearances. In this case, however, it is difficult. If the hole is a shot wound as first suggested, the "bullet" must have been a stone. On re-examination during the recent study, it seems possible that the hole is a post-mortem artifact, as the edges appear to be rather "recent". They are rather light in colour and the surface suggests a recent break. The mentioned scratches in the surrounding area of the hole also look rather recent and one may ask whether they are man-made or made by rodents. It is well known that rats and mice gnaw on bones and produce similar scratches. During the re-examination of the case such scratches were found on several bones, most clearly on the bones of the lower arm of this skeleton.

Tumours and Tumour-like Lesions

Meningioma is one of the most frequent tumours that affect the central nervous system and it originates in the meninges, the outer membranous covering of the brain and spinal cord. It is often seen along the intracranial sinus and the size of the tumour may vary from a few millimeters to 10 centimeters. The tumour may erode into the cranial bone. Between 10–25% of all cases of meningioma lead to the production of osteocytes (Campillo, 1977, 1991).

Domingo Campillo (1998) has divided the various types of tumours which may leave traces on the skull into the following categories: 1. Multilobular depression due to a fibroma, 2. Intraosseus cranial angioma, 3. Epidermoid tumour, 4. Eosinophyl granuloma, 5. Angioma cavernosum, 6. Anteriovenous aneurysms (pulsation), 7. Meningocele.

The meningocele or the meningoencephalocele communicates with the exocranium through an orifice and is more or less circular. As mentioned, it is often situated in the midline of the skull and/or in an area previously occupied by a fontanelle. A Neolithic skull from a passage grave at Næs has a partially healed opening that has been described as a trepanation at Bregma (Fig. 16). Its location, however, may suggest that the opening was caused by a tumour that may possibly have formed when the frontanella opening failed to fuse (Barnes, 1994). Also the edges of this hole seem to be rather similar to other holes that may be due to congenital defects such as like parietal foramina (Geldhauser et al., 1996). A nineteenth-century pathological collection of bone specimens contain a syphilitic skull (diagnosed by clinical pathologists) with bone changes at the exact same location. The holes are almost the same size and are ca 5 cm in diameter. The edges of this syphilitic hole provide evidence of both destruction and healing (Fig. 17). A meningocele in another skull from the same pathological bone collection has grown through an already extant trepanation. This case alert us to the possibility of more than one


14


15

Figures 14 and 15. A Neolithic skull from Kelderød with a healed injury above the right eyebrow. The injury has not perforated the frontal sinus. It is generally believed that this injury stems from a blow with a blunt instrument. The skull also has a lozenge-shaped opening in the left temporal area. It has cracks that actually look fairly recent, but scratches around the anterior and superior edges have been interpreted to be traces of surgery. They look, however, rather recent and during the re-examination of the case similar scratches were found on several bones of the skeleton from Kelderød, most clearly in the bones of the lower forearm.

Figure 16. A Neolithic skull from a passage grave at Næs with a partially healed opening at the bregma, described as a trepanation. Its location, however, may suggest that it could stem from a tumour, such as one for example due to a non-fusion of the frontanella opening.

Figure 17. A specimen from a Danish pathological bone collection (nineteenth century). Syphilitic changes on a skull, diagnosed by the clinical pathologists, have the same location as the so-called trepanation from Næs (Fig. 16). However, the edges of this hole show evidence of both destruction and healing,

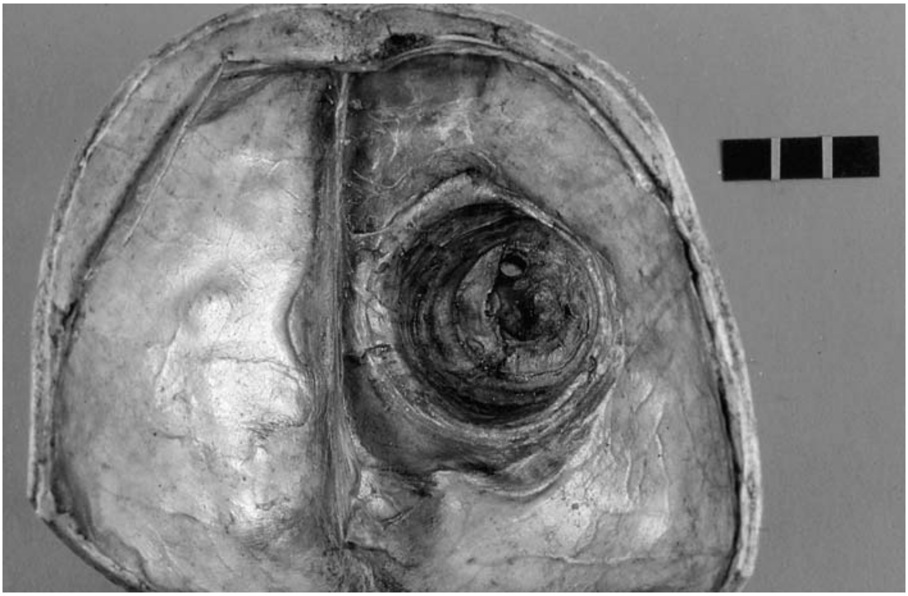


Figure 18. A skull from the nineteenth-century pathological bone collection with the growth of a meningoele through an extant trepanned opening.

diagnosis when studying the various marks, lesions and injuries on the skeletons in the many collections (Fig. 18).

Only very few of the Danish skulls may without much doubt have been trepanned. One of them may be an Iron Age skull from the bog at Gadevang (Fig. 19). The frontal and left parietal bone exhibit part of an almost circular opening. The healed edge in the back is almost vertical and in the front it has a slight inclination. If the skull was trepanned with the ordinary scraping technique, a sharper instrument must have been applied afterwards. The upper edge is characterized by an irregular area of about 4 cm^2 that may either derive from a minor infection or from the surgical treatment. It is hard to picture this lesion as having been caused by an injury or a tumour, but after the revision of the cases discussed in this paper one can never be sure.

Discussion

The fact that it is extremely difficult to conclusively identify trepanation in archaeological specimens is definitely one of the major elements in the "trepanation" controversy. Given a partial or complete hole in a skull, its origin must be sought in many areas. Finding a differential diagnosis for trepanations may prove difficult, as a number of lesions may closely resemble a trepanned hole made by various scraping or a cutting methods. Many, if not most, trepanations occur in association with skull fractures. A blade injury or glancing cuts with swords or axes that remove a small section of the skull may simulate an unhealed trepanation (Janssons, 1987; Weber and Czarnetzki, 2001).

Figure 19. The Iron Age skull from Gadevang may be one of the few that, without much doubt, has been trepanned.

Similarly, accidental holes made with sharp instruments or picks during excavation or postmortem erosions are rather easily mistaken for trepanations. What would the skull of a man look like if he had been dragged behind a horse? What would it look like if the body had been submerged in water for some time with the forehead scraping against the sea-bottom? How would a fragile skull appear under poor preservation conditions with a stone lying on top of it and eroding the bone? There are plenty of forensic and archaeological examples of this type (Berg et al., 1981). Even though the circumstances under which they were found are documented, some of the cases have nonetheless been diagnosed as trepanned skulls.

Congenital defects or endocrine disorders, such as thinned parietal bones (Fig. 20), enlarged parietal foramina (Fig. 21), and dysraphism (herniation of the brain as seen when cranial sutures fuse prematurely) have also been confused with trepanations (Ortner, 1985; Barnes, 1994). Both infection and neoplasm can produce holes in the skull that might be confused with trepanation. Benign bone tumours may cause cysts. Malignant tumours, such as metastatic carcinoma or multiple myeloma, can cause lytic bone defects similar to unhealed trepanned openings. Finally, infections of the bone, such as syphilis, tuberculosis, and localized osteomyelitis may produce various types of openings in the skull.

According to Steinbock (1976)

> "It is important to note that if only one or two skulls in a large amount of skeletal material have possible trephine holes, the diagnosis must remain tentative. Where practiced, trephination was usually performed on significant numbers of people – and the very nature of this operation must have required constant practice!"

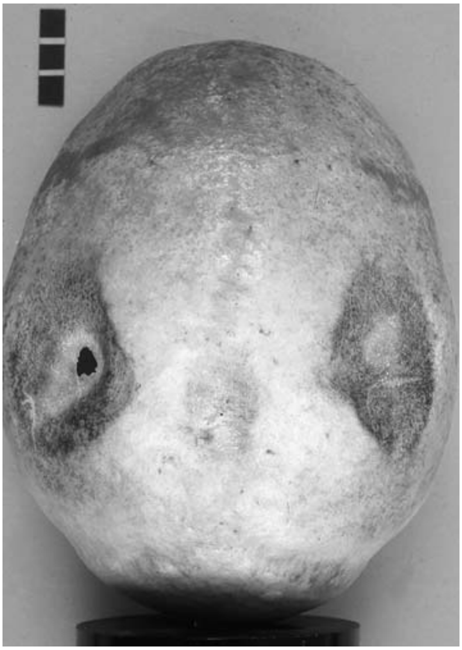


Figure 20. Congenital defects or endocrine disorders may cause thinned parietal bones. The defects have often been confused with trepanations. They are usually bilateral and situated in the parietal region. This case is from the Danish pathological bone collection.

Figure 21. Enlarged parietal foramina, a congenital defect, have also been confused with trepanations. This is an undated skull from Greenland.

We must remain very aware of this point in osteological studies. However, we should also discuss whether the reason for finding just a few cases of a sample may be based on poor preservation conditions. As with most other problems in palaeopathology, careful observation combined with a comprehensive knowledge of the options and differential diagnoses is the most important prerequisite in determining the presence of trepanation (Ortner, 1985).

Conclusion

Several of the previously described Danish skulls have recently been reexamined. The results show that several, if not most, of the so-called trepanations may ultimately be traces of injuries, post-mortem damage, congenital malformations or tumours. The study also showed that possible "differential causes" should not be ignored but considered seriously and compared with both pathological bone collections that include specimens with an identified diagnosis and archaeological cases with evidence of violent injuries. They clearly help to illustrate the problems surrounding a reliable diagnosis for a hole in the skull.

References

Barnes E (1994): *Developmental Defects of the Axial Skeleton in Paleopathology*. Colorado, Univ Press Colorado.

Bennike P (1985): *Palaeopathology of Danish Skeletons. A Comparative Study of Demography, Disease and Injury.* Copenhagen, Akademisk Forlag.

Bennike P (1998): De faldne fra krigergraven-analyse af skeletterne fra Sandbjerget. *Liv & Levn, Næstved Museum 12*: 14–21.

Bennike P (1999): The Early Neolithic Danish bog finds: a strange group of people! In: Coles B, Coles J, Schou Jørgensen M, eds., *Bog Bodies, Sacred Sites and Wetland Archaeology*. WARP 12: 27–32.

Bennike P (2000): A Medieval Mass Grave from Denmark (1300–1350 AD). *Am. J. Phys. Anthrop. Supp. 30*:106.

Bennike P, Brade AE (1999): *Middelalderens sygdomme og behandlingsformer*. København, Medicinsk Historisk Museum.

Bennike P, Fredebo L (1986): Dental Treatment in the Stone Age. *Bull Hist Dent 34*: 81–87.

Bennike P, Ebbesen K (1986a): The Bog Find From Sigersdal. Human sacrifice in the Early Neolithic. *J Dan Archaeol 5* :85–115.

Bennike P, Ebbesen K, Jørgensen L, Bender (1986b): Two Early Neolithic Bog Skeletons from Boelkilde. *Antiquity LX* :199–209.

Berg S, Rolle R, Seemann H (1981): *Der Archäologe und der Tod*. München, Bucher Report.

Campillo D (1977): *Paleopatologia del Craneo.* Barcelona, Editorial Montblanc-Martin.

Campillo D (1991): The Possibility of diagnosing Meningeomas in Paleopathology. *Int J Osteoarchaeol 1*: 225–230.

Campillo D (1998): Primary Benign Skull Tumors in Paleopathology. *J Paleopath 10*: 73–89.

Geldhauser B, Guckenhan S, Heudorfer R (1996): Hiebverletzungen und Trepanationen. In: Czarnetzki A, ed., *Stumme Zeugen ihrer Leider*. Tübingen, Attempto Verlag, pp. 183–205.

Isager K (1936): *Skeletfundene ved Øm Kloster*. Copenhagen, Levin & Munksgaard.

Janssens P (1987): Tangential Traumata of the Cranial Vault, Imitating Trepanations. In: Capecci V, Rabino E, eds., *Massa Vth European Meeting, Siena 1984. Paleopathology Assoc*: 173–183.

Jørgensen J Balslev (1997): Skeletfundene fra den middelalderlige St. Nicolai kirkegård i Holbæk. *Aarbøger for Nordisk Oldkyndighed og Historie 1994–95*: 225–263.

Knowles AK (1983): Acute Traumatic Lesions. In: Hart GD, ed., *Disease in Ancient Man*. Toronto, Clarke Irwin, pp. 61–83.

Madsen PK, Robinson E (1999): Sygdom og sundhed. In: Ingesman P et al., eds., *Middelalderens Danmark*. Copenhagen, Gads Forlag, pp. 208–219.

Møller-Christensen V (1958): *Bogen om Æbelholt Kloster*. Dansk Videnskabs Forlag, Copenhagen.

Ortner DJ, Putschar WG (1985): *Identification of Pathological Conditions in Human Skeletal Remains.* Washington DC, Smithsonian Press.

Steinbock RT (1976): *Paleopathological Diagnosis and Interpretation*. Springfield, Charles C Thomas.

Ullrich H, Weickmann F (1965): Prähistorische Trepanationen und ihre Abgrenzung gegen andere Schädeldachdefekte. Neue Untersuchungen am mitteldeutschen Fundmaterial. *Anthrop Anz 29*:261–272.

Weber J, Czarnetzki A (2001): Neurotraumatological Aspects of Head Injuries Resulting From Sharp and Blunt Force in the Early Medieval Period of Southwestern Germany. *Am J Phys Anthrop 114*: 352–56.

Chapter 7

Trepanation in the Portuguese Late Neolithic, Chalcolithic and Early Bronze Age Periods

ANA MARIA SILVA
Departamento de Antropologia, Universidade de Coimbra, Coimbra, Portugal

Abstract

In Portugal, the study of prehistoric trepanation started 120 years ago, when Néry Delgado announced the discovery of the first Portuguese trepanned skull, dated to the Neolithic. Since then, a considerable number of trepanations from the Late Neolithic to the Early Bronze Age periods have been discovered and described in Europe. In Portugal, however, they seem to be very rare. This contribution reviews the Portuguese trepanations and reports some new discoveries. Twenty-five trepanations (including some doubtful instances) are reported. The trepanations are discussed in terms of sex of the individual, location and size of the surgical intervention, technique used, indications of survival or non-survival, and the possible motivating circumstances of the surgery. Finally, some general factors are advanced to explain the relative small number of trepanations known from Portugal.

Keywords: Portugal, Late Neolithic, Chalcolithic and Early Bronze Age trepanations

Introduction

Trepanation in prehistoric times was recognised at the end of the nineteenth century. In 1867, during a meeting of the Anthropological Society of Paris, Paul Broca concluded that the hole found in an ancient skull from Peru was the product of a prehistoric surgical procedure on a living patient who survived (Broca, 1867). Only few years later, in 1880, Néry Delgado reported the first prehistoric Portuguese trepanation it was discovered in the cave of Furninha. Since then many skulls with signs of this practice were found in populations thoughout the world (Aufderheide, 1985; Aufderheide and Rodríguez-Martín, 1998; Brothwell, 1994; Crubézy et al., 2000).

In Europe and North Africa, trepanation can be traced to the Mesolithic but most cases date from the Late Neolithic and early Bronze Age. However, in Portugal this cranial surgery seems to be rare. Recently, the most ancient trepanation from Portugal, dating around 6,000 BC, was found among the large Mesolithic sample of the Concheiro da Moita de Sebastião in Muge (skull XLI, housed in the Museu do Instituto Geológicoe Mineiro, Lisbon). The partial trepanation seems to have been made by the drilling method at the lateral part of the right frontal bone of an adult male skull. The irregular area found has a conic healed depression from 13 mm anteroposterior to 17 mm mediolateral of major diameter. The depth is around 10 mm, apparently not penetrating the inner part of the skull. This intervention shows signs of healing, in that the periosteal reaction was not active at the moment of death. An ancient trauma is believed to have led to the trepanation (Crubézy et al., 2000).

An initial literature search on the prehistoric trepanations reported in Portugal to date, revealed that the findings were mostly published in archaeological journals. Especially after the publications of the forties, the new findings are frequently only briefly described and sometimes only the site where the trepanation was discovered is mentioned. There is therefore a need for a survey and review of the Portuguese prehistoric trepanations.

The already known trepanations were assessed through literature research and, whenever possible, personal observation. All the new cases and the one recently described by Gama (2000) were observed by the author.

Review of the Portuguese Prehistoric Trepanations (Neolithic, Chalcolithic and Early Bronze Age)

In 1880, during the ninth session of the Congrés International d'Anthropologie et d'Archéologie Prehistoriques, held in Lisbon, Néry Delgado reported the first Portuguese case of prehistoric trepanation. A small fragment of parietal bone was recovered among the ossuary of the cave of Furninha (council: Peniche; district: Leiria) (Fig. 1), a natural cave used as a burial place in the end of the Neolithic. This bone fragment showed a circular hole with 20 mm of diameter and 5 mm of depth. Signs of healing are evident in this incomplete trepanation (Néry Delgado, 1880: 219).

In his communication, Néry Delgado (1880: 219) also described another example, a cranium found in the natural cave of Casa da Moura (Cesareda, council: Peniche; district: Leiria) (Fig. 1). This skull can also be dated to the end of the Neolithic. This second trepanation, also an incomplete one, was performed on the left parietal bone of an adult male skull. The hole measuring 6 mm length and 2 mm width lacked healing changes. Thus, a post-mortem trepanation cannot be excluded. Both findings are housed in the Museu Instituto Geológico e Mineiro (ancient Serviços Geológicos de Portugal, Lisbon).

In 1933, Barbosa Sueiro added three more examples found in the natural cave of Fontainhas (council: Cadaval; district: Lisbon, Fig. 1). The bones recovered from this Neolithic burial place are housed in the Museu Instituto Geológico e Mineiro (Lisbon). In all findings, there was nothing to indicate the motive behind the operation.

An adult male skull from Fontainhas had been trepanned on the left part of the frontal bone, near the orbit. The small oval depression measures 25 mm length and 14 mm width. The intervention was incomplete, since the lesion did not penetrate the inner table. It varies in thickness from 1 cm on the edge to 0.5 cm in the middle of the depression. According to Barbosa Sueiro (1933) the appearance of the lesion would suggest a scraping method. The signs of healing found around the trepanned area confirm a post-

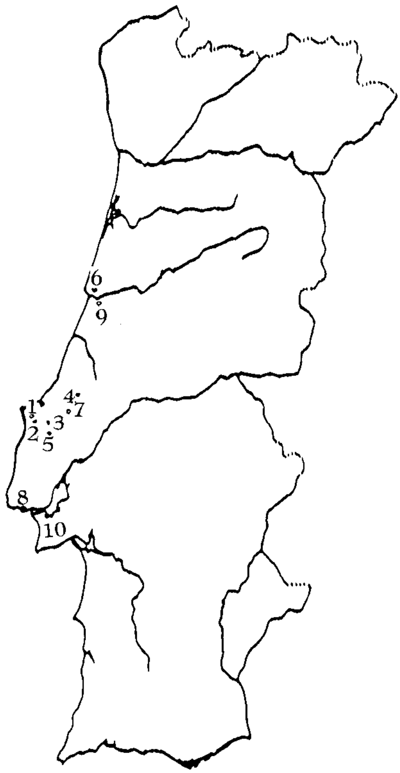


Figure 1. Distribution of prehistoric trepanations in Portugal. 1 – Furinha; 2 – Casa da Moura; 3 – Fontainhas; 4 – Lapa da Galinha; 5 – Pragança (Vale Côvo and Castelo de Pragança); 6 – Dolmen de Capela (Figueira da Foz); 7 – Lugar do Canto; 8 – São Pedro do Estoril III; 9 – Eira Pedrinha; 10 – São Paulo.

operative survival period. However, some authors suggest a different diagnosis, namely a traumatic lesion (Barbosa Sueiro, 1933; Campillo, 1977).

Another cranium from Fontainhas presents two incomplete trepanations. The individual was identified as an older adult male (all sutures with the exception of the lateral parts of the lambdoidal suture, were closed) with a dolichocranic skull form. One lesion is located on the left parietal bone over the parietal boss. The depression has an oval form, measuring 46 mm x 35 mm, with the long axis elongated obliquely to the anterior part of the bone. The bone is only 2 mm thick in the centre of the lesion. The appearance of the lesion would suggest that the scraping method was used (Barbosa Sueiro, 1933; Campillo, 1977).

The second trepanation, on the right parietal bone, 1 cm to the right of the anterior sagittal suture is also oval in shape, but smaller: 16 mm x 14 mm. The long axis is orientated mediolaterally. The thickness of the bone in the depression is about 4 mm, against 6 mm in the area surrounding the lesion. Concerning the method used, both grooving (Barbosa Sueiro, 1933) and scraping methods (Campillo, 1977) were suggested. Radiographic analysis of this cranium showed signs of healing on the two trepanations of this individual (Barbosa Sueiro, 1933).

Leite de Vasconcellos (1925, 1938) described another skull, found in Gruta da Galinha (or Lapa da Galinha). This natural cave situated near Alcanena (Torres Novas; district: Santarém; Fig. 1) was excavated during 1908. Many human bones were recovered (minimal number of individuals, 70; according to Sá, 1959: 120) but, with the exception of a cranium and a mandible (housed in the Museu Nacional de Arqueologia, Lisbon) all were lost (Sá, 1959). The cranium, dated to the end of Neolithic or Chalcolithic, was identified as an adult male with dolichocranic skull form. A well-healed hole is situated along the sagittal suture very near the bregma. The opening is roughly ellipsoid with a long axis of maximum of 6 mm, and a minor axis of 5 mm. There is considerable healing and bone remodelling around the perforation, which extends in a rounded area of 12 to 15 cm of diameter. Unfortunately, it was impossible for the writer to see this cranium but the description would suggest that the scraping method was used.

In 1946, Mac White published some notes about trepanation in the Iberian Peninsula. Besides the five Portuguese skulls with the trepanations already described (with 6 possible trepanations), he cited two more cases coming from the region of Pragança in the Serra de Montejunto (council: Cadaval; district: Lisbon). The findings, Castelo de Pragança and Vale Tomate (Pragança) are housed in the Museu Nacional de Arqueologia in Lisbon (at that time, Museu Etnológico de Belém). Due to the incompleteness of the descriptions made by Mac White and since these findings were personally studied by the writer (which led to the discovering of one more possible case) they are described within the new cases.

Since the end of the last century the region of Figueira da Foz (district: Coimbra) has been explored by Santos Rocha. In 1895, during fieldwork, he discovered a megalithic tomb next to the north frontage of the Chapel of Santo Amaro – Dolmen da Capela (Fig. 1). This funerary monument was completely destroyed and practically all the contents were mixed (Leisner, 1998). Between the fragmentary human bones, housed in the Museu Municipal Dr. Santos Rocha in Figueira da Foz, an incision was observed on a right parietal bone (Fig. 2) (Santos Rocha, 1949). The curved incision ends in a recent fracture of the bone, but it can be seen that the minimum length is 28 mm, the maximum width of 4 mm and 2 mm of depth (Santos Rocha, 1949). Signs of healing are seen (few) but no reason for the surgical intervention was found.[1]

In 1972, Vitor Guerra and Veiga Ferreira (1973/4) during the "II Jornadas Arqueológicas" presented a paper about trepanations. A new case is included in their list: Vale de Tomar (Nabão) (Vitor Guerra and Veiga Ferreira, 1973/4). After some research I presume that this finding is from Gruta dos Ossos (council: Tomar, district: Santarém).[2] It seems that, many years ago, Dr. Veiga Ferreira confirmed to Dr. Ana Rosa Cruz (from the Centro Pré-História, Instituto Politécnico de Tomar).[3] In 1980, Veiga Ferreira and Manuel Leitão included this case among their list of Portuguese prehistoric trepanations but, once more, without any kind of description. Unfortunately, this cranium has been lost.[4]

Five trepanations observed in four skulls recovered among the ossuary of the natural cave of Lugar do Canto (Alcanede, Rio Maior; district: Santarém; Fig. 1) were briefly described in 1987 by Leitão and co-workers. The writer has tried to localise these skulls

Figure 2. Lateral view of the right parietal bone from Dolmen da Capela (Figueira da Foz), exhibiting an incision.

to complete the descriptions, but without success.[5] In this cave, used as a burial place in the end of the Neolithic period, many human remains were recovered. Among the cranium remains, four individuals showed signs of trepanation (9% of the individuals according to Leitão et al., 1987).

An adult male cranium, 30 to 40 years of age at death, showed a trepanation performed by scraping method. No information about the skull region that was submitted to the surgical intervention was given. Another adult male skull belonging to an individual who died between 35 and 45 years of age had been trepanned twice on the right parietal bone: in one case signs of healing are evident and in the other, the grooving and scraping method was employed. No more information was given. A third cranium, identified as a male who died between 45 and 55 years of age, showed a great rounded hole on the left temporal bone measuring 26 mm in diameter. No signs of healing are evident. The method used was incision (Leitão et al., 1987). The last case concerns a skull of unknown sex with signs of incision on the parietal bone. No signs of healing can be seen in this complete trepanation.

In 1944, Leonel Trindade identified a necropolis near the Lisbon – Cascais marginal road on a small peninsula, which extends into the ocean, near to the beach of São Pedro do Estoril (Leisner et al., 1964). This necropolis is composed of two caves situated very close to one another (15 m) on the cliff above the ocean. The bones recovered from the second hipogeum, São Pedro Estoril II (Fig. 1) were studied in 1991–92 by Silva. Among the very fragmentary human bones, Silva (1999), recovered one complete young adult male skull with a trepanation on the right parietal bone near the sagittal and coronal sutures. The trepanation hole is rectangular, measuring 4.5 cm anteroposterially and a maximum of 5 mm mediolaterally. Signs of healing are evident confirming that the individual survived the surgical operation made by the incision method. No kind of traumatic lesion was detected in this cranium that would have justified the intervention.

The natural cave of Covão de Almeida (Eira Pedrinha – district: Coimbra, Fig. 1) was excavated in 1945 by the Serviços Geológicos de Portugal (nowadays, Instituto Geológico e Mineiro) (Mendes Correa and Teixeira, 1949). During a restudy of the recovered bones Gama (2000) found a male skull (> 50 years of age at death) with signs of surgery. The trepanation, probably by the grooving method, was localised in the middle of the left frontal bone. The injury has an ovoid/elliptical shape. In the central part of the lesion, a depression measuring 18 mm of transversal diameter and 8 mm of the longitudinal one, is surrounded by a zone of reactive bone measuring 28 mm of transversal diameter and 18 mm of longitudinal diameter. In the endocranial view a callus osseous can be seen. Gama (2000) considered that an ancient cranial trauma was probably the reason for this surgical intervention.[6]

So far, fourteen prehistoric trepanations have been reported in Portugal (excluding the case of Vale de Tomar – Nabão, since the skull was not localised nor was any kind of description found).

New Cases (or Descriptions)

As already mentioned, the findings from Pragança are described in this chapter. The opportunity for personal observation allowed the writer to complete their description and to discover one more possible case.

Castelo de Pragança is a fortified settlement, probably constructed in the Early Bronze Age. Surrounding this settlement and in all Serra de Montejunto, there are many caves that began to be explored and excavated in the end of the 1800s by a local teacher of Pragança, António Maria Garcia. During the years of 1887 and 1888, Leite de Vasconcellos also discovered and excavated some of these caves. However, little attention was given to their exact locations. Consequently many of them cannot be found today. Furthermore, different names could have been given to the same cave (Perreira, 1976/7; Gonçalves, 1990/2).

After this first period of explorations, Leonel Trindade found and excavated additional caves between the years of 1930 and 1940 (Perreira, 1976/7; Gonçalves, 1990/2). On 15th December, 1940, the Museu Nacional de Arqueologia (Lisbon) bought the findings that Leonel Trindade excavated between 1930–1940 in Pragança (Serra de Montejunto). In the notes that Manuel Heleno (at that time Director of the Museu Etnológico de Belém, nowadays Museu Nacional de Arqueologia, Lisbon) wrote in a copybook about this collection, he mentioned one trepanned skull, discovered in the cave of Vale Côvo in Vale Tomate (Pragança).[7] The exact location of this finding is hence unknown, but there is no doubt that it comes from the Vale Tomate. Consequently, it was housed in the museum with the designation of Vale Côvo em Vale Tomate. This skull has no exact

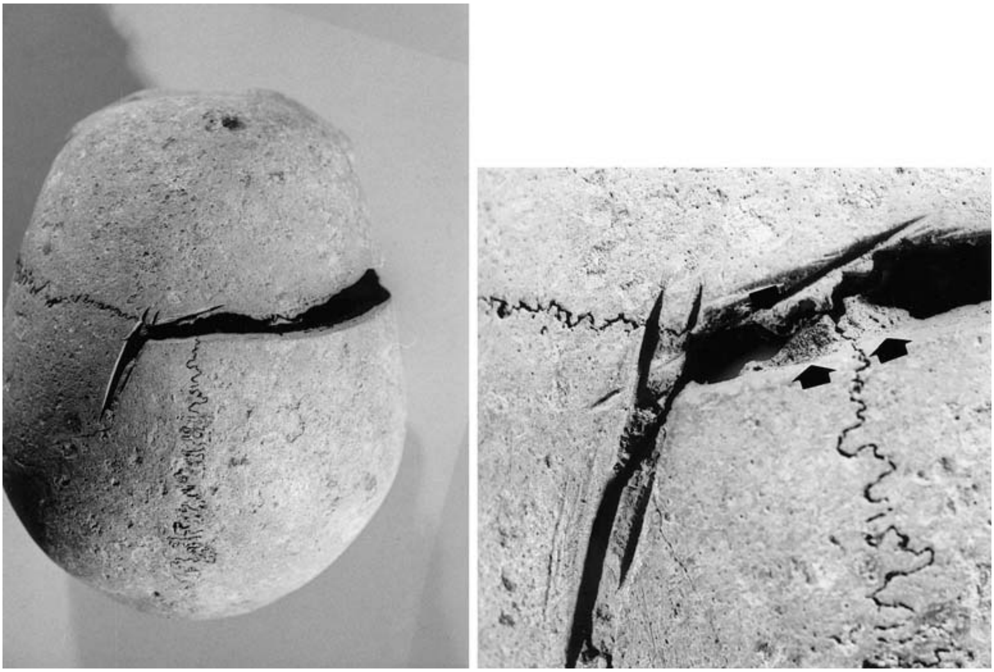
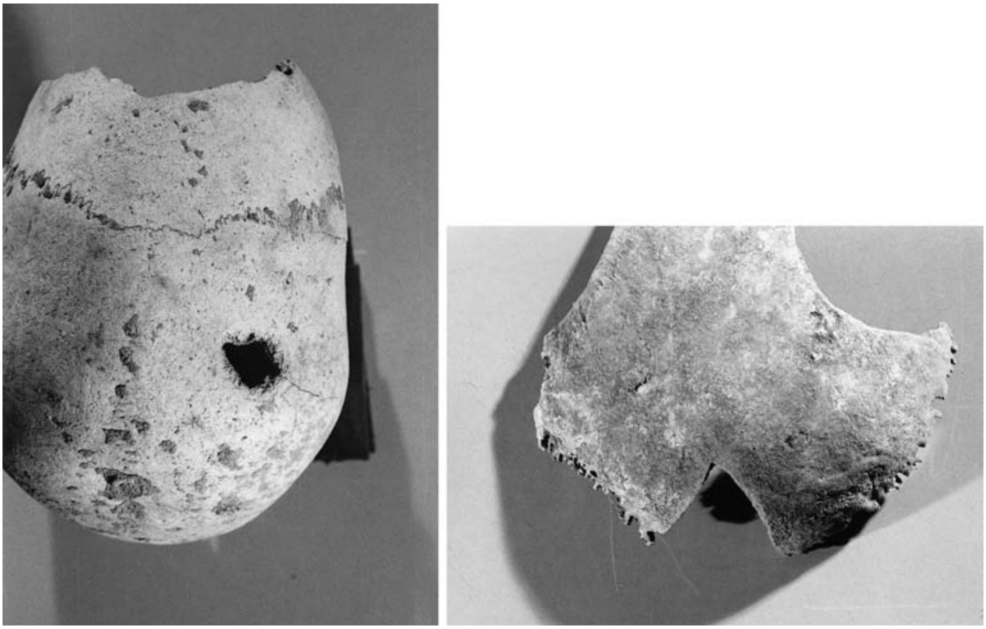

a b

Figure 3. Superior anterior view of the skull from Vale Côvo em Vale Tomate (Pragança), showing several incisions over the parietal bones. Note that in some parts the incisions extend over the coronal suture. The arrows (b) indicate the parts where some healing seems to have started.

date, but it is probably from the Chalcolithic period (according to the archaeological artefacts).

The adult cranium from Vale Côvo em Vale Tomate (Pragança; council: Cadaval; district: Lisbon, Fig. 1), from a middle aged individual, probably male, showed several incisions (Fig. 3a). The procedure has been executed mostly in the right parietal bone along the right coronal suture. It extends 11.5 cm to the right from bregma. The hole is irregularly rectangular in shape, measuring 11.5 cm mediolaterally and 1 cm anteroposteriorly along the coronal suture mostly into the right parietal bone. There are two small areas in this hole that seem to show tenuous signs of healing, since it appears that the compact bone began to cover the diploid tissue (see arrows in Fig. 3b). Thus, if the individual survived the operation, it would have been for a short period of time. Two more parallel incisions on the anterior part of the left parietal bone, 3.5 cm long and running approximately parallel to the anterior sagittal suture, can also be seen (Fig. 3b). These incisions are scratches upon the outer table with 2 mm depth. No signs of infection or any signs of injury for which the operation might have been undertaken were detected.

Among the human remains named as Castelo de Pragança (council: Cadaval; district: Lisbon; Fig. 1), a fortified settlement dated to the Early Bronze Age, a male cranium, probably middle age (CP 1) with trepanation was found (Fig. 4a). This cranium also



a b

Figure 4. Findings from Castelo de Pragança. a. Superior view of the cranium of Castelo de Pragança 1, showing the position of the unhealed lesion on the right parietal bone. b. Exocranial view of the left parietal bone from Castelo de Pragança 2 exhibiting a complete removal of the bone by the incision method (post-mortem case).

does not have an exact date, but it is probably from the Chalcolithic or Early Bronze Age.[8] The surgery was performed on the right parietal bone, 4 cm from the coronal suture and 3 cm from the sagittal suture. The elliptical orifice has a long axis (orientated more or less mediolaterally) of 2.5 cm (maximum) and 1.8 cm, the short one. The endocranial opening has a narrower margin. The edges of the hole show signs of bevelling, suggesting the scraping method. No signs of healing are seen. Once again, no indication of the purpose of the cranial surgery was detected.

The observation of the other human bones as coming from the same place led to the discovery of one left parietal bone with a trepanation (CP 2),[9] probably a post-mortem one. No signs of healing are seen in this left parietal bone belonging to an individual of unknown sex. The incision, that lead to the complete removal of the bone was done from the left part of the lambdoidal suture, 3.5 cm in a straight line into the left parietal bone and then curved to the right, 5 cm long, ending in the sagittal suture (Fig. 4b). Since this was the only bone preserved of this cranium, the real dimension of this hole is unknown. This case is probably a post-mortem trepanation.

In 1988, the artificial cave of São Paulo was found in the courtyard of the S. Paulo church (Almada, district: Sétubal; Fig. 1). This hipogeum was built in the Late Neolithic period and was used as a burial place until the Bronze Age (III millennium and beginning of the II millennium BC) (Barros and Espírito Santo, 1997). The osteological re-

Figure 5. Lateral view of the cranium São Paulo 1 exhiting two holes on the left parietal bone without signs of remodelling (probably a post-mortem case).

mains of this collective burial place, still under study by the writer, contained a minimal number of 170 individuals. In three skulls, signs of trepanation were found.

Skull 1 (SP 1) belongs to an old adult (> 50 years) of unknown sex. On the left parietal bone, near the temporal bone, two small holes can be seen (Fig. 5). The bone is incomplete but the diameter of both holes would be around 1.2 cm. The taphonomic alterations on this bone makes the observation of the lesions difficult, but in both holes there seems to be no signs of healing. Probably they are post-mortem trepanations.

A probable (due to the incompleteness of the bone) elliptical trepanation (long axis with a minimum of 2.4 cm) situated on the right parietal bone, 8 cm from the bregma, was observed in Skull 65 (SP 65), an old individual of unknown sex. Once again, the hole has not been completely preserved. The surgical procedure was probably done by the scraping method since the preserved margin shows some bevelling on the exocranials. Since the diploe is covered in some areas by the compact bone, a short period of survival occurred.

In skull 111 (SP 111), identified as a young adult male, an elliptical trepanation (3 cm x 1.5 cm) is situated on the right parietal bone with the posterior edge lying along the lambdoidal suture (Fig. 6). The orifice commences 4 cm from the lambda. The edges of the lesion are bevelled, especially the lateral one, where the diploe is not exposed, at least in some parts. The appearance of the lesion would suggest a scraping method and that the individual survived. There were no other lesions in this area and it appears that no subsequent infection occurred.

This cranium also has a possible trepanation on the right parietal bone, near the tem-

Figure 6. Posterior view of skull São Paulo 111 showing the elliptical lesion on the right parietal bone. Note the bevelling at the lateral edge of the lesion.

poral bone. The orifice, partially preserved, is elliptical with the minimum axis measuring at least 2 cm. The minimum length for the major axis of this hole is 2.5 cm. On the edge that faces the lambdoidal suture some bevelling on the exocranium suggest that its removal had been achieved by scraping method. Signs of healing (few) are also evident in this edge. No skull lesion that would justify this procedure was identified.

Conclusions and Discussion

Twenty-two trepanations from Portugal, dated from the Late Neolithic to the Early Bronze Age are reported in this survey, including some probable or possible cases. For the reasons already mentioned, the finding of Vale de Tomar (Nabão) is not included. Difficulties in diagnosis arise from several factors starting with the incompleteness of many findings, occasionally made worse by taphonomic alterations (example: cases from the Hipogeum of São Paulo).

In view of all the trepanation examples now available from the periods under study, the more important points for the Portuguese prehistoric trepanations can be summarised as follows:

• Twenty-two trepanations reported were performed in eighteen individuals.

• All cases reported to date come from burial places in the littoral part of Portugal, between the region of Cabo Mondego (district: Coimbra) and Almada (south to Lisbon; district: Sétubal) (Fig. 1). To explain the absence of cases from the inland at the time of writing, some factors can be advanced. The human remains, especially in megalithic tombs, are frequently very badly preserved. Many times they were also submitted to fire, making it even more difficult to detect lesions. However, according to personal communication of Prof. Victor Gonçalves (University of Lisbon), there are possible cases coming from two dolmens from the Alentejo (inland), Antas (dolmen) 1 and 2 do Olival da Pêga (Reguengos de Monsaraz).

• The trepanations were performed above all (if not exclusively) in male individuals; no female skulls with signs of surgery were found, but there are some findings belonging to individuals of unknown sex.

• The parietal bone (85%) was the most frequently trepanned skull element, followed by the frontal (10%) and temporal bones (5%). More than half of the interventions performed on the parietal bone were on the right side (1 covering both sides; 9 right; 5 left; 2 unknown).[10]

• The majority of the trepanations performed were complete ones.

• The fear of opening the skull over the cranial suture is lost in antiquity, due to the danger of this procedure. Still, in the Portuguese prehistoric sample, some interventions were made over (Lapa da Galinha, Vale Côvo em Vale Tomate and Castelo de Pragança) or very near the sutures (São Pedro do Estoril II). In Lapa da Galinha and in São Pedro do Estoril II the operations were a success and the individuals survived many years. On the contrary, in the Vale Côvo em Vale Tomate case, apparently the individual did not survive or, if he did, only for a short period of time. The case of Castelo de Pragança (2) is probably a post-mortem trepanation.

• Concerning the methods, the two most used by the Portuguese prehistoric "surgeons" were scraping method and incisions. The other two methods, drilling and grooving were also found, apparently in the older findings (from the end of the Neolithic).

• Only four individuals showed signs of two trepanations.

• Excepting the case from Eira Pedrinha, which was probably performed as consequence of a traumatic lesion, a reason to justify the cranial surgery was not detected. The case of Furninha could be a traumatic injury.

• The high rate of survival after the operations, many times for several years, demonstrates the good knowledge of the Portuguese "surgeons" at the time.

• Some cases, without signs of cicatrization, appear to be post-mortem trepanations (examples: Castelo de Pragança 2 and São Paulo 1).

Comparing the Portuguese prehistoric trepanations with those from Spain, the most noteworthy difference seems to be the frequency of the employed methods. According to Campillo (1986, 1988) the one most frequently used in Spain is the drilling method, which is, at least until now, very rare in Portugal. Incisions, on the contrary, seem to be rare in Spain and are restricted to post-mortem cases (following Campillo, 1986, 1988). In Portugal, the methods most frequently employed are scraping method followed by incisions. Some Portuguese cases of cranial interventions performed by incision are probably post-mortem ones, but in São Pedro do Estoril II there are no doubts that the surgery was followed by a prolonged period of survival.

Few trepanations are known from Portugal from the Late Neolithic to the early Bronze Age period. The collective burial practices, especially ossuary and sometimes secondary burials, may explain the poor preservation and incompleteness of the skulls recovered from these periods and the small sample of trepanations. However, as detailed osteological analyses of all skeletal material from archaeological sites becomes increasingly routine in Portugal, as well as the reevaluation (in many cases, the first study) of collections already housed in local museums, it seems likely that more examples will be found.

Acknowledgements

Dr[a]. Ana Margarida Ferreira and Dr[a] Maria Isabel Pereira – Museu Municipal Dr. Santos Rocha – Figueira da Foz (Portugal); Sr. Carlos Barata – Museu Antropológico, Dep. Antropologia – Universidade de Coimbra (Portugal); Prof[a]. Eugénia Cunha – Departamento de Antropologia – Universidade de Coimbra (Portugal); Dr[a]. Isabel Luna – Museu Municipal de Torres Vedras (Portugal; Dr. João Ludgero Gonçalves – Museu Municipal do Cadaval (Portugal); Dr. Luís Raposo, D[a] Luísa Guerreiro and Sandra Correia – Museu Nacional de Arqueologia (Lisboa, Portugal); Prof. Luíz Oosterbeek – Instituto Politécnico de Tomar (Portugal); Dr. Robert Arnott – Director of the Centre for the History of Medicine, The Medical School. University of Birmingham (UK); Dr. Vitor Gonçalves – Centro de Arqueologia e História, Universidade de Lisboa (Portugal).

Notes

1. Personally observed by the writer.
2. Toponymy: Casais Novos and Lapa dos Ossos.
3. Personal communication of Prof. Luíz Oosterbeek from the Instituto Politécnico de Tomar.
4. It is not housed in the Centro de Pré-História in the Instituto Politécnico de Tomar, neither in the Museu Nacional de Arqueologia (Lisbon) or Museu dos Serviços Geológico e Mineiro (Lisbon). It could be lost or now belong to a private collection.
5. They are not housed in the Museu Nacional de Arqueologia (Lisbon) neither in Museu dos Serviços Geológico e Mineiro. Again, it could be lost or now belong to a private collection.
6. See paper of Rui Pedro Gama and Eugénia Cunha in this volume.
7. Information took from a Copybook from Manuel Heleno with notes about the collection Leonel Trindade. Museo Nacional de Arqueologia, Lisboa. Not published.
8. The exact provenance is also probably not the settlement but one of the small caves that are linked to it, since two of the human bones housed as Castelo de Pragança have etiquette's with the name of a Cave (see footnote 9).
9. Inside the cranium an etiquette gives the following information: "António Maria Garcia Junior. Pragança. Lapas. Cadaval. Covão de José Bruno. 14-4-1893". Therefore the bone probably came not directly from the settlement but from one of the small caves that surround it.
10. In two cases, no kind of information about the location of the trepanation is available.

References

Aufderheide A (1985): The enigma of ancient cranial trepanation. *Minn Med 68*: 119–122.

Aufderheide A, Rodríguez-Martín C (1998): *The Cambridge Encyclopedia of Human Paleopathology*. Cambridge, Cambridge University Press.

Barbosa Sueiro MB (1933): La trépanation cranienne chez l'homme néolithique des stations portugaises. *Com Serv Geol Port 19*: 41–51.

Barros L, Espírito Santo P (1997): Gruta artificial de S. Paulo. *Setúbal Arqueol* 11/*12*: 217–220.

Broca, P (1867): Cas singulier de trépanation chez les Incas. *Bull Soc Anthrop Paris,* 2 série *2*: 403–408.

Brothwell D (1994): Ancient trephinning: Multi-focal evolution or trans-world diffusion? *J Paleopath 6(3)*: 129–138.

Campillo D (1977): *Paleopatologia del Craneo. En Cataluna, Valencia e Balneares*. Barcelona, Editorial Montblanc-Martin.

Campillo D (1986): Study of a thepaned skull belonging to the Neolithic Period, coming from the site of "Can Tintorer" in Gava (Barcelona, Spain). Acts from the "VI European Meeting of the Paleopathology Association". Madrid: pp. 95–101.

Campillo D; Mercadal O (1988): *New trephined skulls in Minorca*. Abstacts of the 7th European Meeting of the Paleopathology Association. Lyon, France, 1–4/9/1988.

Crubézy E, Bruzek J, Guilaine E, Cunha E, Rougé D, Jelinek J (2000): The Antiquity of cranial surgery in Europe and in the Mediterranean Bassin. Paris, *Compte Acad Sci. In press*.

Gama RP (2000): *A Neolithic case of cranial trepanation from Eira Pedrinha*. Poster presented in the "International Colloquim Trepanation in Human History". Birmingham, 7–9 April 2000.

Gonçalves, JL (1990/2): As grutas da Serra de Montejunto (Cadaval). *O Arqueól Port* IV (8/10): 41–201.

Leisner V (1998): Die Megalithgraeber der Iberische Halbinsel. Der Western. *Madrid Forsch* 1 / 4. Berlin, Walter de Gruyter & Co.

Leisner V, Paço A, Ribeiro L (1964): *As Grutas Artificiais de São Pedro do Estoril*. Lisboa, Fundação Calouste Gulbenkian.

Leitão M, North C, Norton J, Veiga Ferreira O, Zbyszewski G (1987): A gruta pré-histórica do Lugar do Canto, Valverde (Alcanede). *O Arqueól Port* IV *(5)*: 37–65.

Leite de Vasconcellos J (1925): *Medicina dos Lusitanos*. Lisboa.

Leite de Vasconcellos J (1938): *Opúsculos V. Etnologia (Parte 1)*. Lisboa, Impresa Nacional de Lisboa.

Mac White E (1946): Notas sobre la trepanation Prehistorica en la Peninsula Hispanica. *Cad Hist Prim 2*: 61–69.

Mendes Correa A, Teixeira C (1949): *A Jazida Pré-histórica de Eira Pedrinha*. Lisboa, Publicações do Serviço Geológico de Portugal.

Néry Delgado J (1880): La grotte de Furninha a Peniche. *Congrès International d'Anthropologie et d'Archaeologie Préhistoriques* (compe rendu de la 9éme session à Lisbonne): 207–278.

Pereira, JP (1976/7): A gruta natural de Salvé Rainha (Serra de Montejunto). *Setúbal Arqueol 2/3*: 49–95.

Sá MCM (1959): A Lapa da Galinha. *Actas e Memórias do I Congresso Nacional d*e *Arqueologia*. Vol I: 117–128.

Santos Rocha A (1949): Mémorias e Explorações Arqueológicas. Antiguidades Pré-históricas do concelho da Figueira da Foz. Vol. 1. *Acta Univ Conimbrig*: 287–293.

Silva AM (1999): Human remains from the artificial cave of São Pedro do Estoril II (Cascais, Portugal). *Human Evol 14(3)*: 199–206.

Veiga Ferreira O, Leitão M (1980): *Portugal Pré-histórico. Seu Enquadramento no Mediterrâneo*. Lisboa, Publicações Europa América.

Vitor Guerra A, Veiga Ferreira O (1973/4): A propósito de um fragmento de crânio com vestígios de trepanação do Museu Dr. Santos Rocha na Figueira da Foz. *Actas das II Jornadas Arqueológicas"*. Lisboa 1972, Associação dos Arqueólogos Portugueses: 133–138.

Chapter 8

A Neolithic Case of Cranial Trepanation (Eira Pedrinha, Portugal)

RUI PEDRO GAMA AND EUGÉNIA CUNHA
Departamento de Antropologia, Faculdade de Ciências e Tecnologia, Universidade de Coimbra, Coimbra, Portugal

Abstract

The Neolithic necropolis of Covão d'Almeida, at Eira Pedrinha (Condeixa, Coimbra, Portugal) was discovered in 1945. From there a great amount of human remains were retrieved. Their quantification gives a minimum number of 144 individuals. More than 50 years after their excavation, a paleobiological analysis is now being performed. From it we encountered a case of cranial trepanation, which we discuss here. This short report focuses on its identification and pathological interpretation, also discussing the success of the surgery. The case reported here is one of the few Neolithic Portuguese cases.

Keywords: Neolithic, Necropolis, Covão d'Almeida, Cranial trepanation

Introduction

Eira Pedrinha is an important Late Neolithic skeletal sample made of at least 144 individuals. The excavation of Covão de Almeida cave was performed in 1945 by a team from the *Serviços Geológicos de Portugal* (Correia and Teixeira, 1949). By then, a first anthropological analysis was also done. More than 50 years later, we decided to revisit Eira Pedrinha community striving to retrieve more information which could help us make this journey to a Late Neolithic community from the center of Portugal more real.

Among the new data obtained, we here present a cranial trepanation. Despite the fact that cases of cranial trepanation are well known in paleopathology (Campillo, 1977; Ortner and Putschar, 1981; Brothwell, 1981; Lisowski, 1967; among others) for Portugal, specifically for the Neolithic-Chalcolithic periods, the known cases are not abundant (see Silva, in this volume). This is particularly true when we compare the number of cases retrieved until now with the frequencies found in Spain and mainly in France in the same period. Furthermore, if we take into account the great number of Neolithic and Chalcolithic skulls available to study (more than 1,000), it becomes more evident that the percentage of trepanned skulls found in Portugal is low. Thus the description and contextualization of the present case, being one of a few, acquires more relevance.

Type of Funerary Monument and Geographical and Chronological Aspects

Covão d'Almeida is a natural limestone cave, located in Eira Pedrinha, Condeixa (Coimbra, Portugal). This funerary monument with moderate size of 5 m high, 10 m depth and 6 m width (Correia and Teixeira, 1949) was used as a funerary space in Late Neolithic.

The absolute chronology achieved by means of radiocarbon dating of human bone collagen, performed by *Beta Analytic Radiocarbon Dating Laboratory (laboratory number – Beta–134363),* confirms that this is undoubtedly a Late Neolithic skeletal sample (Table 1).

Table 1. Radiocarbon dates for Covão de Almeida sample of human collagen.

	Result
Conventional radiocarbon age (Data BP)	4480+/–60
2 Sigma Calibrated	3360 a 2925 Cal BC (5310 a 4875 Cal BP)

Anthropological Sample

The skeletal sample exhumed from Covão de Almeida natural cave corresponds to an ossuary made of fairly well-preserved human bones which, besides some fragmentation, are apparently free from other taphonomic alterations. The minimum number of individuals was achieved by counting the mandibles, indicating 144 individuals. The individuals are mainly adults, including only 21.5% (31/144) sub-adults. Regarding the sex-ratio, when only the adult skulls are taken into account, around 48% are males, 42% females and the remaining ones are undetermined.

This ossuary had already been analysed in 1949, focusing mainly on morphological aspects, as was the case with other anthropological studies of that time. In addition, a brief paleopathological approach was performed by Professor Salvador Junior who had already described a cranial lesion (skull 87) among the three pathological cases reported (Correia and Teixeira, 1949). Half a century later, the case remains significant both because of its rarity and the lesions aspect.

The Trepanation Case

The Individual

The trepanation was performed on an adult male individual who died in his late fifties (Ferembach et al., 1980; Masset, 1982). As we are dealing with an ossuary, we can not associate any postcranial remains to the skull. Specifically, it is a *calvaria*, with no face.

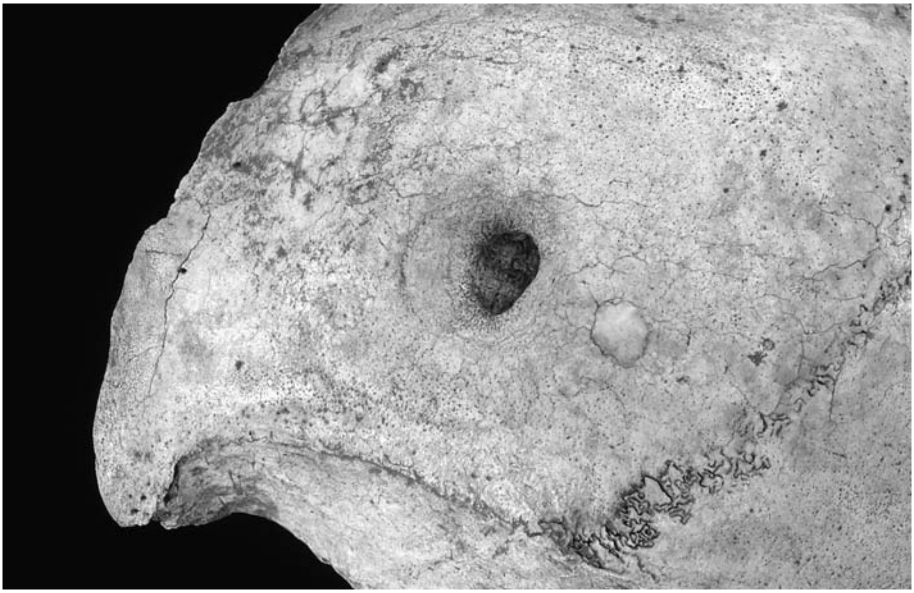


Figure 1. A general view of the trepanation.

Moreover, this skull does not have any mandible associated. Besides the trepanation, no other relevant alterations were observed.

Lesion Characterisation

The lesion is located in the middle portion of the left frontal bone. It has an ovoid/elliptical shape, having in its central portion a depression measuring 18 mm in transversal diameter and 8 mm in the longitudinal one (Fig. 1).

An area of reactive and smooth bone, clearly reflecting a process of reparative remodelling, surrounds the central depression of the injury on the exocranial aspect. This large area has 28 mm of transversal diameter and 18 mm of longitudinal one (Fig. 2). In the endocranium aspects, it is possible to observe a *callus osseous* with a transversal diameter of 27 mm and a longitudinal diameter of 16 mm (Fig. 3).

Lesion Interpretation

In the first presentation of this series, Professor Salvador Junior (Correia e Teixeira, 1949) described this lesion as probably the result of an accidental trauma (fracture) with an imperfect consolidation. However, our new analysis has led to a different interpretation. Thus, we can hypothesise that as a result of a cranial trauma, a callus osseous was formed in the endocranium which would have provoked strong pressure on the brain. Therefore the trepanation was probably performed as a therapeutic treatment to relieve the pressure.

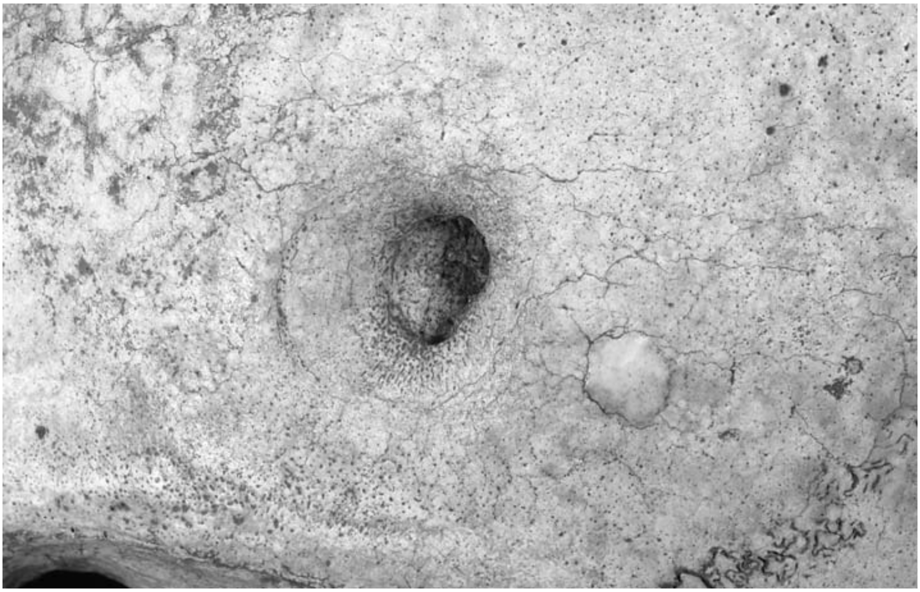


Figure 2. A close-up of the exocranial aspect of the trepanation.

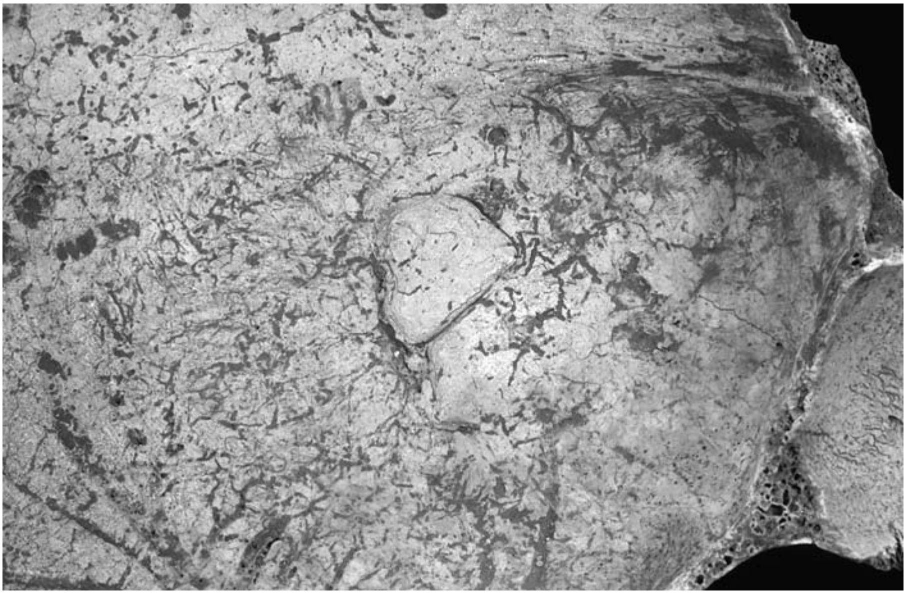


Figure 3. The endocranial aspect of the trepanation.

The location of the lesion accords with one the most frequent locations of trepanation: the left side of the frontal bone away from cranial sutures (Roberts and Manchester, 1995). Furthermore, we believe that the technique used was the grooving method, involving the creation of a small hole. It is undoubtedly a healed lesion. The formation of reactive bone, surrounding the surgical area, which partly refilled the hole, indicates that the operation was performed with success and that the individual survived several years after the operation.

In Portugal, cases of trepanned skulls in prehistory are not abundant. For the Mesolithic period, not withstanding the large amount of available skulls – more than 250 individuals –, only one case is known. It shows a partial trephination made by drilling method in a frontal bone of an adult male from Moita do Sebastião, one of the most famous mesolithic shell middens in the world (Crubézy et al., 2000). This is the only case of Mesolithic trepanation known so far for the Portuguese Mesolithic period. Later on, from the Neolithic period, whereas the trepanations are extensive for Europe in general, for Portugal only twenty-two cases are reported (see Silva in this volume), mainly from the Late Neolithic. The case here described is included in this late assemblage.

There is no doubt that trepanation was an active practice throughout the Portuguese Neolithic period. However, the low proportion of cases, very far from the 6 to 10% value found by Prioreschi (1991 in Aufderheide and Martin, 1998) in excavated Neolithic skulls, can be interpreted as an argument for the hypothesis which claims that the original home of trepanation is central and northern Europe (Roberts and Manchester, 1995). Yet, in line with the difficulties in supporting a theory of the spread of trepanation by cultural diffusion, it is more likely that, in Portugal, as in other countries, trepanation is a product of independent invention (Aufderheide and Martín, 1998, p. 31). Further, it concerns a case of survivorship which is in accord with the high proportion of survivors of this operation in the past (Roberts and Manchester, 1995). Finally, the motive behind the operation seems to be known. Thus, it seems to be the only Neolithic Portuguese case where we can argue in favour of an intervention performed subsequently to a traumatic injury.

Acknowledgements

Special thanks to Sr.Carlos Barata who took the pictures and Ana Maria Silva and Cláudia Umbelino for their comments.

References

Aufderheide A Rodriguez-Martín C (1998*): The Cambridge Encyclopedia of Human Paleopathology.* Cambridge, Cambridge University Press.

Brothwell D (1981): *Digging Up Bones*. Ithaca, Cornell University.

Campillo D (1977): *Paleopatologia del craneo. en Cataluna, Valencia Y Baleares*. Barcelona, Editorial Montblanc-Martin.

Correia AM, Teixeira C (1949): *A jazida pré-histórica de Eira Pedrinha*. Lisbon, Publicações do Serviço Geológico de Portugal.

Crubézy E, Bruzek J, Guilaine J, Cunha E, Rougé D, Jelinek J (2000): 'The antiquity of cranial surgery in Europe and in the Mediterranean Basin'. *Compt Rend Acad Sci*.

Ferembach D, Schwidetzky I, Stoukal M (1980): Recommendations for age and sex diagnosis of skeletons. *Human Evol 9*: 517–549.

Lisowski FP (1967): Prehistoric and Early Historic Trepanation. In: Brothwell D, Sandison AT (eds.) *Diseases in Antiquity*. Springfield. Il., C.C.Thomas, pp. 651–643.

Masset C (1882): *Estimation de l'age au décès par las sutures crânnienes*. Thèse Doctoral. Lab. Anthropologie Biologique, Université de Paris VII.

Ortner DJ and Putschar W (1981): *Identification of Pathological Condition in Human Skeleton Remains.* Smithsonian Contribution to Anthropology nº 28, Washington D.C.

Roberts C, Manchester K (1995): *The Archaeology of Disease*. 2nd edition. New York, Cornell University Press.

Silva AM (2001): Trepanation in the Portuguese Late Neolithic Chalcolithic and Early Bronze Age Man (this volume).

Chapter 9
New Cases of Cranial Trepanation

GASPARE BAGGIERI AND MARINA DI GIACOMO
Ministero per i Beni e Le Attività Culturali-Servizio Tecnico, Ricerche Antropologiche e Paleopatologiche, Roma, Italy

Abstract

We deal here with two skulls showing alterations on the bony table of the cranium with a loss of bony substance. We can also observe a manual intervitam likely to be a cranial trepanation. The two skulls, belonging to male subjects, derive from ancient southern Etruria, 100 kilometres north of Rome. They belong to the seventh-sixth centuries BC, along with another skull that is still being examined of a female dating to the seventh century BC. These three skulls represent the most original and ancient evidence of the neurocranial surgery in the regions inhabited by the Etruscans.

Keywords: Trepanation, Etruscan, Surgery

The First Trepanation

The specimen was found in the necropolis of Osteria (Vulci) in a so called "dado tomb" excavated in 1986 under the supervision of Dr. A.M. Moretti, of the Archaeological Superintendency of Southern Etruria. The tomb, previously looted, can be dated to the second half of the sixth century BC from the scanty grave goods found, a bucchero cup, a fragmented oinochoe and remains of an iron spear. Lying on one of funerary beds of the second chamber of the tomb, the skeleton of an adult individual was found.

The Anthropological Specimen

The skull (Fig. 1) is almost complete; the occipital squama is not present, except for a small portion close to the right parietal and temporal sutures, and also the zygomatic processes of both the temporals and the left condyle of the mandible are missing. The specimen is fairly well preserved; the calvarium and the mandible have the cortical bone eroded almost on the whole surface. The mandibular teeth are complete, while the maxillary lacks the left third molar (lost intra vitam, as it is shown by the remodelling and partial closure of the tooth socket) and the left canine (post-mortem loss). The teeth show in some cases (5 out of 30) enamel hypoplasia. The skull belongs to a male individual with an age at death that can be calculated between 25 and 35 years, from the degree of dental wear present (Brothwell, 1981), and around 40 years from the obliteration of cranial sutures (Meindl and Lovejoy, 1985).

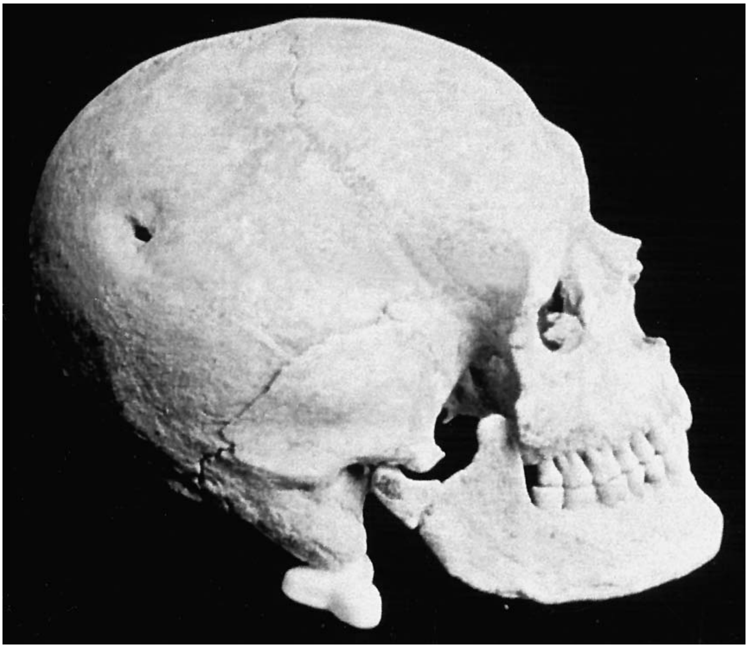


Figure 1. A cranial lesion of the upper right parietal bone.

The Lesion

On the right parietal bone, just above the eminence, a lesion or loss of substance can be observed: its shape is roughly elliptical and its longer axis is slightly oblique (from posterior left to anterior right). The dimensions of the lesions are 10 x 8 mm. It is surrounded by a shallow area of 23 x 21 mm (Fig. 2). The edges of the hole are smooth, not sharp and show small bony spurs due to the healing: the diploe is obliterated because of the cicatrization process, and the shape of the injury is made irregular by the presence of a healed bone fragment that partially closes the hole. On the radiologue, one can observe a sclerotic margin (Fig. 3).

Interpretation

From the observations made, the lesion has to be interpreted as a cranial trepanation performed on a living subject (there are traces of survival after the traumatic event). It was probably made by the scraping method with a flat implement used with a rotary movement on the surface, which was eroded to the formation of a complete hole (Campillo, 1977). This could explain both the elliptic shape of the trepanation hole and the presence of the hollow area around it. The presence of the small bone that partially fills the lesion is particularly interesting: it is the cicatrized result of a bone spur created

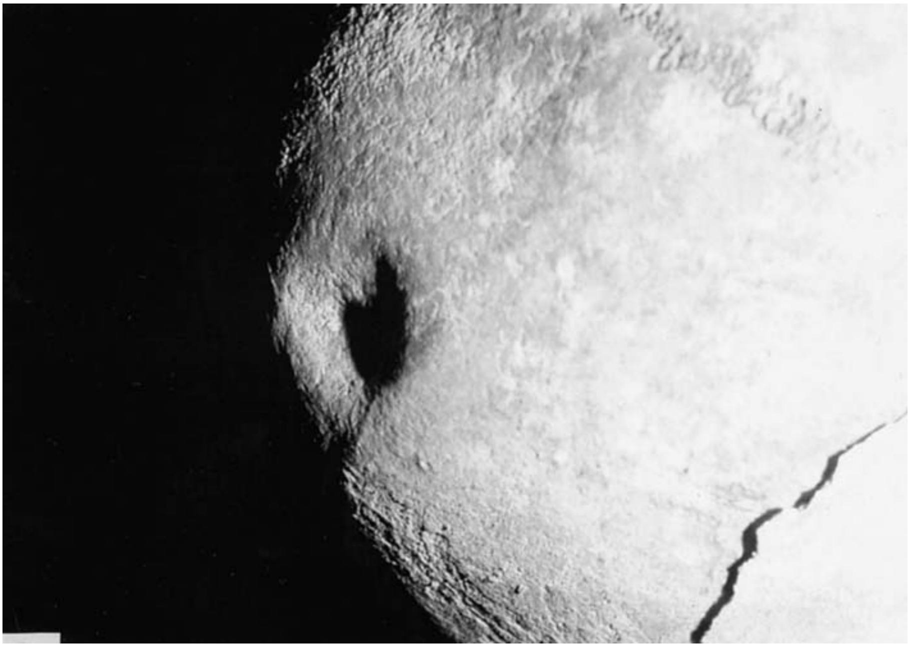


Figure 2. Particular to the trepanation, a cicatrized hollow on the hole. The cavity is made by a burin, or by a small curette, through a circular movement. The hollow is homogeneneous and harmonious on the surface. This suggests there were good medications provided during the cicatrization.

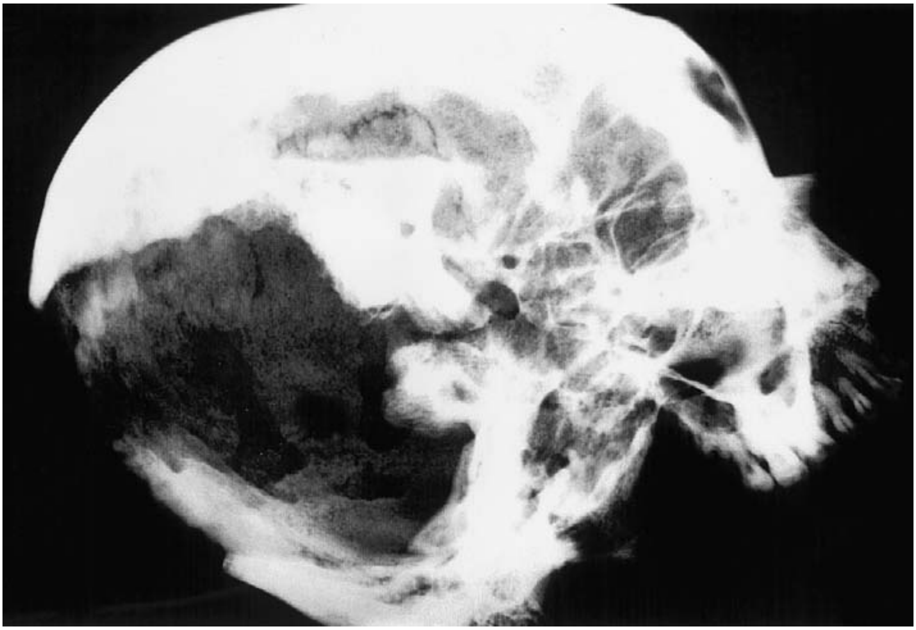


Figure 3. X-ray: Bony reaction on the cavity.

during the intervention that was not removed during our analysis and healed particularly well. The trepanation event was followed by a quite long survival period, probably at least one year.

Second Case

The Barucci Skull

This skull, conserved with the mandible, was given along with its sarcophagus to the Archaeological Superintendency of the Meridional Etruria by the Barucci family, at the same time as other local archaeological finds of great value. At first this specimen was considered not as important as the sarcophagus, made in piperine stone, therefore, it had been kept unstudied for decades in the Etruscan National Museum of Tarquinia. From the stylistic execution of the sarcophagus, we can suppose it belong to the fourth century BC. We do not know the place of origin exactly, but can imagine it was a burial coming from the ancient Etruscan necropolis of Monterozzi, near Tarquinia. The small town of Tarquinia is located in the middle of the Tyrrenian coast of Italy and it had been an Etruscan centre of great commercial importance since the Orientalizing Period (800–600 BC) (Torelli, 1990; Pallottino, 1968).

The Anthropological Specimen

We have only the skull, and no additional information about post cranial bones (Fig. 4). The bony condition of the skull, lacking in right frontal, temporal and mastoid bones, is fairly well preserved. The esocranial surface does not present any porotic pathology. The endocranial surface clearly shows marks of the meningeal vessels. This is a brachio-cephalic skull; its horizontal index is 77.48 (Olivier, 1960). The skull's geometrical shape is sphenoid in accordance with Sergi. The surface of the frontal bone extends to the orbital torus defining, together with the mastoid process, the male sex of the subject. The calvarium surface permits, in posterior view, a good view of the sagittal suture and the lambda sutures. On the right lambda suture there are some small bones, whereas on the left lambda suture there is the asterion bone, considered discontinuous features (Berry and Berry, 1967). The age of death is calculated according to the resorbence status of cranial sutures, averaging between 43 and 50 years under the cranial vault system and between 35 and 49 under the anterior lateral system (Meindl and Lovejoy, 1985). Both the maxillary and the mandibular teeth are incomplete due to post-mortem loss. The maxilla jaw presents five molar teeth: 16–17–26–27–28, with a wear degree of respectively: 4+–4–5+–5–3 (Brothwell, 1981). Whereas the mandible jaw presents four teeth (45–46–36–38) with an average wear degree: 5+, the vacant dental alveola do not show lesions due to infection or inflammation. From these observations we can suppose an age of death averaging between 35 and 45 years (Brothwell, 1981).

Figure 4. Right view of the trepanation on the upper right parietal bone.

The Lesion

Part of the sagittal suture runs alongside the lesion. The latter has a geometric shape, almost hexagonal on the right side of the parietal bone, under a normo-posterior vision. The cavity extends along the parietal bone surface for 2.7 cm in the maximum diameter, and for 2.3–2.4 cm in the minimum diameters (Fig. 5). The edges of the hole are basically rounded and show a slight introflexion inwards. The internal angles are also rounded. On microscopic examination (28x), we can see a protruding bony reaction, such as the sawtooth on the inside edge of the lesion. Moreover, we observe an obliquity of 2 mm between exocranial and endocranial surface. This suggests there was a bony reaction previously. Radiological examination portrays a moderate bony reaction (Fig. 6).

Interpretation

The lesion site near the suture, the geometrical shape, the bony reaction at the edge level, and the radiological valuation induces us to consider this lesion as a cranial trepanation with a short survival (less than one month). The geometrical shape of the lesion lead us to suppose that the trepanation was performed with the sampling technique. Appropriate points were identified for perforation and were joined through an incision, resulting in the withdrawal of the sample, perhaps in combination with the Inca cross hatch technique. This is a hypothesis, and it is important to demonstrate the intervention of the human hand. It has been maintained that one may use the definition of cranial

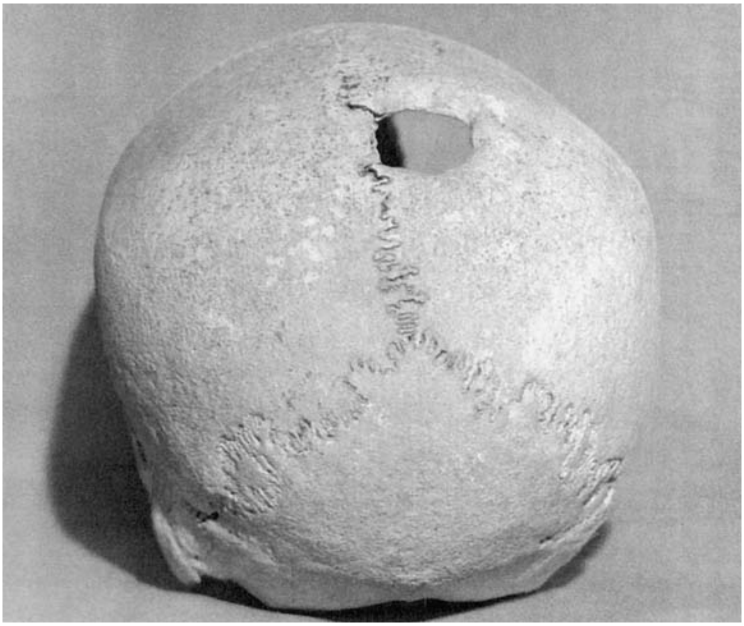


Figure 5. A posterior view. The hole might have been made through compounded incisions with the Inca cross cut technique.

Figure 6. The trepanation cavity.

trepanation, even if it was only a surgical intervention following a trauma or the removal of a bony splinter (Germanà and Fornaciari, 1992).

Other Trepanations in Italy

These specimens complement a good number of cases of cranial trepanations recorded in Italy until the present, even if we have to keep in mind that the actual number of cases could be biased by the fact that in the past not all cases were recorded. For a chronological framework, it belongs to the group of trepanations of the historical period, and from a geographical point of view, it is the only one discovered until now in Southern Etruria, while other cases of trepanation, coming from Lazio, are ascribed to the Neolithic periods “Cerveteri” (Patrizi, 1950) and “Casamari” (Genna, 1930–32).

The Italian Environment

Numerous skulls exhibiting cranial trepanation have been located in Italy during the last few years. We can surmise that this type of lesion exceeds 45 cases, including the trepanations belonging to the Renaissance period. The evidence, from the Neolithic period to the modern age, presents quite an interesting historical continuity. Some trepanned skulls, belonging to the Late Bronze Age, were found in the province of Grosseto, Grotta dello Scoglietto (Messeri, 1962), not very far from the retrival area of the skulls in question. About ten skulls, also belonging to the Late Bronze Age, were found in Sardinia. This region had a strong cultural exchange with the regions from which the two trepanned skulls derive. Moreover, some Nuraghic small bronzes were found in Etruscan areas and belong to the Etruscan period. These facts lead us to imagine that there was probably an exchange between these two cultures in therapeutic treatments and neurosurgical rituals.

Considerations and Hypothesis of Study

Taking into consideration the geographical distribution of Italian trepanned skulls, it is interesting to notice that Sardinia and Tuscany show a high concentration of these cases, especially of those dated to the Bronze Age. It is therefore possible to suppose a cultural linkage between the two regions, as it is shown also by the finding of Nuraghic votive figurines in Etruscan tombs. About the sample analysed, the short distance (a few kilometres) between the site of recovery and Scoglietto cave (from where many cases of cranial trepanation dated to the Early Bronze Age originate) could suggest the hypothesis of a sort of continuity of this cultural tradition from the Prehistoric to the Etruscan ages in the same geographic area, even if we face a scanty fossil record. The most important thing in all these cases is to ascertain if human intervention is due to medicine, magic or religion.

In both of the new cases of cranial trepanation, we would lean toward the first hy-

Figure 7. The three Etruscan skulls (seventh–sixth centuries BC) probably showing cranial trepanation. These are unique specimens in Italy and in the world.

pothesis; especially if we suppose that an Etruscan medical school existed, and generated intense medical activity in that very period (Baggieri, 1999). There is a lot of convincing evidence to support the hypothesis of the medical school, such as dental therapies, a rich collection of archaeological finds that show a perfect imitation of internal organs, and various surgical and cosmetic instruments utilized in medicine. In this connection, we can mention the existence of the clay votive heads, showing an expression of melancholy. These kinds of clay heads might evidence a focus on brain illnesses, such as depression or organic disease.

Some skulls have been recently discovered and are still being researched. For instance, another Etruscan skull, originating from the necropolis of Ferrone, in the northern area 50 km from Rome (Orientalizing Period), would lead us to suspect cranial trepanation (work in progress) (Fig. 7). We may suspect that the cranial trepanations deriving from the Etruscan areas and originating from the Etruscan period, were practised on aristocratic individuals, belonging to the elite. In fact, all these burials show stylistic and architectural characteristics that lead us to suppose they belonged to the elites.

References

Alciati G, Fedeli M, Pesce Delfino V (1987): *La malattia dalla Preistoria all'Età antica.* Bari, Laterza.

Baggieri G, Allegrezza L, Capasso L (1995): *Un nuovo caso di trapanazione cranica.* Volterra, Atti del XIX Convegno di Studi Etruschi ed Italici.

Baggieri G (1997): Antichi pazienti...in neurochirurgia. *Archeologia Viva XVI*: 76–79.
Baggieri G (1999) : Les objets votifs des Etruscques, Dossier Pour La Science. *Sci Amer*, October 1999.
Berry AC and Berry RJ (1967): Epigenetic variation in the human cranium. *Journal of Anatomy*.
Brothwell DR and Sandison AT (1967): *Disease in Antiquity*. Springfield, Illinois, Charles C. Thomas.
Brothwell DR (1981): *Digging up Bones*. Oxford, Oxford University Press.
Genna G (1930–32): La trapanazione del cranio nei primitivi. Contributo alla sua conoscenza alla preistoria italiana. *Riv Antropol*, *29*: 139–159.
Germanà F and Fornaciari G (1992): *Trapanazioni, craniotomie e traumi cranici in Italia.* Collana di Studi Paletnologici dell'Università di Pisa, Giardini Editori e Stampatori in Pisa.
Lo Schiavo F (1994): *Bronzi Nuragici della I Età del Ferro a Pontecagnano.* La Presenza Etrusca nella Campania meridionale, Firenze, Olschky.
Messeri P (1962): Aspetti abnormi e patologici nel materiale scheletrico umano dello Scoglietto. *Arch Antrop Etnol 92*: 129–159.
Olivier G (1960) : *Pratique Antropologique,* Paris, Vigot.
Patrizi S, Radmilli AM, and Mangili G (1950): Sepoltura ad inumazione con cranio trapanato nella grotta Patrizi, Sasso-Furbara. *Riv Antropol, Roma*, *41*: 3–68.
Pallottino P (1968): *Etruscologia*. Milano.
Torelli M (1990): *Storia degli Etruschi*. Laterza.
Steinbock RT (1976): *Paleopathological Diagnosis and Interpretation*. Springfield, Illinois, Thomas.
Ubelaker DH (1984): *Human Skeletal Remains*. Washington, Smithsonian Institution.

Chapter 10
Celtic Trepanations in Austria

RUPERT BREITWIESER
Institute for Ancient History, University of Salzburg, Salzburg, Austria

Abstract

Within the area of today's Austria, as well as in many other parts of the world, a rather large number of trepanned skulls have been discovered. Twenty-eight ante-mortem trepanations have been identified. Most trepanations, about 15, were undertaken during the La Tène period. We have the traditional scraping technique and also a method of operation that so far has always been usually restricted to the Mediterranean world. From the cemeteries on Durrnberg/Hallein, near Salzburg, as well as from several in Guntramsdorf and Katzeldorf near Vienna, we have the only known trepanations within the Celtic world that were perforated with a drill. Thus far, no trepans made of iron have been found in the region, so it is assumed that the drills used were made of hard wood, possibly from the wood of the elder-tree. New finds on the Durrnberg raise the possibility of the surgery by a female. In the middle of a grave circle there is the burial place of a woman. Outstanding gifts, amongst them medical instruments, signify her high social status. She is surrounded by three other persons who had been trepanned in their lifetime.

Keywords: Austria, Dürrnberg, Guntramsdorf, Katzeldorf, drill trepans, female surgeon

As in other countries, a number of trepanned skulls were found within the boundary of what is modern day Austria. We know of about 28 people who had trepanations during their lifetime, and in addition, we know of three postmortem trepanations (Urban et al., 1985). For the thousands who were buried in cemeteries within Austria, and who have been scientifically examined, this number – only 28 – is rather low. This is not surprising, as the primary interest of the previous generations of archaeologists was with the grave structures and goods therein. Moreover, the anthropological material was examined in order to define a certain racial type. Thus, miscellaneous paleopathological features were lost.

Two burials with trepanations date back to the Neolithic, six to the Early Bronze Age, one to the Late Bronze Age and three go back to Late Antiquity. Most trepanations were done within the La Tène period. So far, 15 trepanations, carried out during the lifetime of the individual, have been verified for that period.

The main technique used for the operations was the scraping technique. From finds in Germany, Swizerland, and France we know that the cutting technique was also used, although this method has not yet been detected in Austria. There is one technique, drilling, which has, as yet, only been attested in the Mediterranean during Greek and Roman antiquity. Recently, drilled trepanations were also discovered within the Celtic area, exclusively in Austria. From the burial-fields on the Dürrnberg near Hallein in the Land

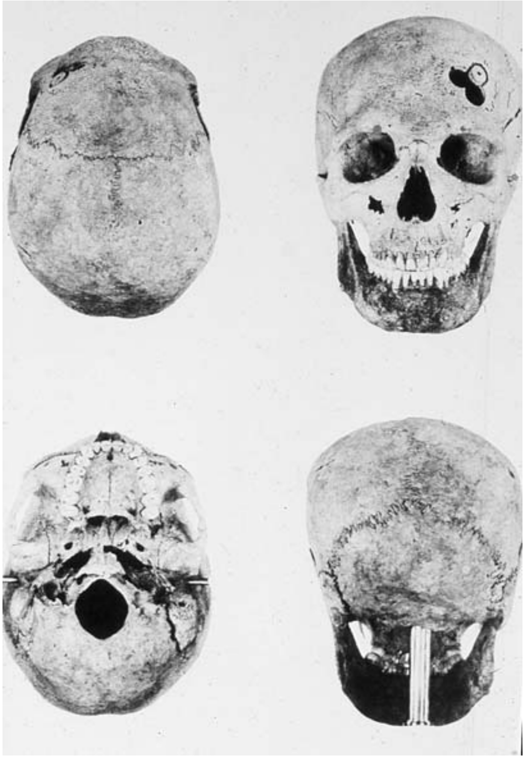


Figure 1. Trepanned skull from La Tène, Grave 1 in Katzelsdorf. Copyright by Naturhistorisches Museum Wien/Abteilung für Archäologische Biologie und Anthropologie.

of Salzburg and from the burial places at Guntramsdorf and Katzelsdorf near Vienna, have emerged the only trepanations done with a drill within the Celtic world (Urban et al., 1985).

The three skulls of Guntramsdorf show a total of five drilled trepanations. Two fragments of Grave number 5 (unfortunately lost) had one simple circular drilling, and one had two or maybe three drillings. The skull of Grave 6 shows a scrape-trepanation plus one simple and one triple clover-like drill trepanation. On the skull from Grave 29 is a double drill-trepanation. In Katzelsdorf, we have another clover-like drill trepanation that was not completed (Fig. 1).

Three of the six operations reveal a more or less advanced healing process. These include the trepanation of a 30 to 35 year-old man from Grave 6, and the lost skull fragments of Grave 5 in Guntramsdorf, which were found in 1930. According to the grave-goods, the remains were those of a warrior. The top of his skull had changed due to a post-operative inflammation around the trepanation site. We can deduce from the healing process that the patient lived for at least several days if not for weeks. Two trepanations (Guntramsdorf Grave 29, and Katzelsdorf, La Tène Grave 1) do not show any post-operative changes of the bones. We can assume that they died following the operation. La Tène, Grave 1 in Katzelsdorf also contains the remains of a warrior who died at the age of about 30 years. Grave 29 in Guntramsdorf contained a youth, and was most probably a person of high social rank.

How was the trepanation performed? First, the cranium was uncovered in order to determine the kind of injury or illness to be treated, thus locating the trauma. Then a decision on the number of drillings was made, and the diameter of the drill selected. The exact spot for the drilling was measured, and the skull-bone drilled open, down to the lamina interna. The bone-circle was taken, or broken, out. The meninges were not to be injured in any case. Hence, haematomas, bone splinters, inflamed bones and even tumours could be removed. Finally, the wound was covered with medicinal herb, and probably bandaged.

Unfortunately, no circular drills have yet been found. We may assume that Celtic drills were made of organic material, in contrast to the trepans made of iron in Greek and Roman times. They were probably made of hardwood, preferably from elder wood. The finding of centrepieces prove the use of such drills from Neolithic times onwards, when they were used to produce stone tools. Technically, Celtic blacksmiths were able to produce bronze or iron trepans.

How was it that the drilling technique, already described in detail in the Hippocratic corpus, could have been used in an area on the edges of the Mediterranean world, a place that must have seemed absolutely barbaric to the contemporary Greeks? Why should it happen just there, and not, for instance, in Gallia, where closer contacts existed between the Greek and the Celtic world, since the founding of the Greek colony Massilia? The assumption was that the drill trepanations were a local speciality in the southern part of the Viennese basin, perhaps an area of temporary settlement, as the graves are clustered together and date from the first half of the third century BC. The excavators of the cemeteries were of the opinion that it was due to the amber trade route, which was known and had been used from Neolithic times onwards. The route became important for the migration of the Celts into the Mediterranean and to Asia Minor. These migrations started around 400 BC, and culminated in the destruction of Delphi in 279 BC. During that first cultural exchange between the Mediterranean and the Celtic world, it was possible that a Celt might have learnt the technique in Greece and then returned home; or a Greek captured by Celtic raiders, or a travelling Greek physician, may have transferred this new method of surgical wound treatment to such a remote region. In other Celtic settlements, the traditional scraping technique was still in use, and compared to the drill trepanation, the patient had a 75% chance of survival. The new method could not succeed as it offered less chance of survival.

A fundamental new assessment of these questions came about with the new findings from Dürrnberg near Hallein. The Dürrnberg is one of the most important and richest settlements of the La Tène period in Europe. Halfway up the Dürrnberg, near the entry to the salt mine at the northwest, below the Putzenkopf, there is a small necropolis where the most interesting discoveries were made. As early as 1930, the grave of a man was opened who had been trepanned (Klose, 1920–33). The burial gifts and the skeleton were brought to the museum in Salzburg. Unfortunately, an air raid in the 1939–1945 war destroyed them.

Afterwards, archaeological fieldwork all over the region at the Dürrnberg intensified. Fascinating new findings came to light, and the former interest for the little necropolis at

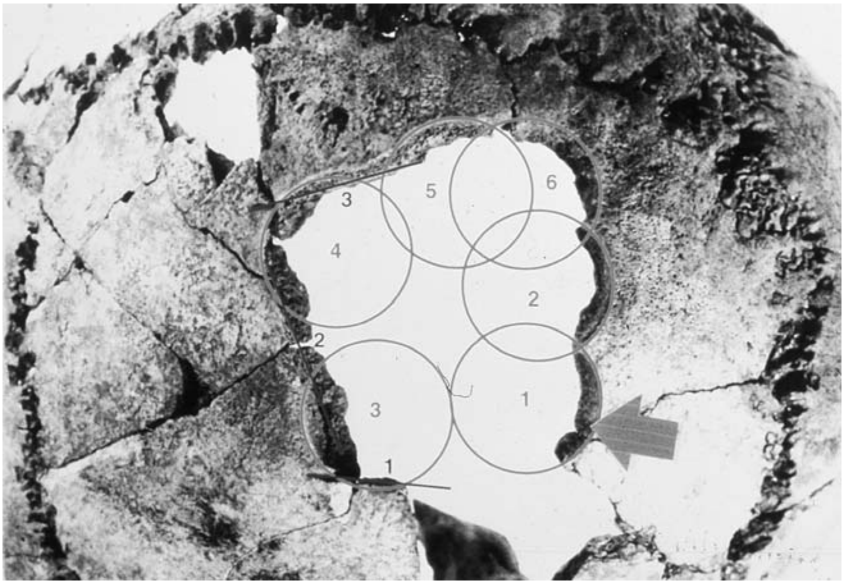


Figure 2. Six-time drill trepanation from the Putzenkopf necropolis at the Dürrnberg. Copyright by Österreichisches Forschungszentrum Dürrnberg.

the Putzenkopf faded. It was only in the eighties that excavations were resumed there again. During the course of the new excavations in 1981, the skeleton of a man was uncovered. According to his grave goods, he dated back to La Tène A (about the first half of the fourth century BC). His skull revealed a sixfold trepanation performed with a drill. This is the earliest known drill trepanation in Middle Europe (Fig. 2). This group of trepanned individuals was completed in the summer of 1999, when a grave was uncovered with a man who had a single scrape-trepanation at the back of the skull. That grave also dates to La Tène A. The skeleton had not been in its original position: the bones had been placed in a pile with the trepanned skull on top. The excavations continued in 2000. The grave of a child was uncovered, which contained amongst the gifts a roundel that originated from a trepanned person. It was apparently used as an amulet.

Results of the osteological examination are not yet available. Therefore, no details are known about the health status or the cause of death of the individuals. At first sight it seems that all have survived the trepanation.

Each one of the respective graves was placed in a regular distance at the periphery of the cemetery. The centre is dominated by a tumulus 9 m in diameter (Fig. 3), which covered a grave-chamber of 2.5 by 2.5 m^2. In it were the skeletons of a man and a woman, their bodies separated by gifts that consisted of five clay pots and several animal bones, probably from a meal.

At an opening of the grave, the man’s skeleton had been disturbed with the exception of the lower limbs, which were still *in situ*. Some of the extremities were broken, probably on purpose. Amongst the bones of the man were a bronze fibula and several objects, from which we might learn something about his profession and social status. There is an

Figure 3. Tumulus grave of a female healer from the Putzenkopf necropolis at the Dürrnberg. Copyright by Österreichisches Forschungszentrum Dürrnberg.

Figure 4. Gifts from the tumulus grave. Copyright by Österreichisches Forschungszentrum Dürrnberg.

iron rod with a handle made of horn, decorated with circles, an oval disc with a dent in the middle, made of white quartzite, and the point of an antler with a drilling hole. In addition we have two parts of sharpened ribs (Fig. 4).

The woman in the grave was undisturbed, her right arm slightly bent. She was located at the southern wall of the chamber. She had an expanding necklace in seven parts, made of bronze. There were also ten fibulae used to fasten the clothing and partly for ornament. Worthy of particular note was a figured fibula, most probably portraying a dog. In the religious belief of the Celts, dogs were the messengers of the gods and leaders into the world of death. The waist of the woman was surrounded by a belt. On each forearm she had a bracelet made of rolled-up bronze plate. On the lower legs there were simple rings, made of bronze.

Placed at her feet, this wealthy lady had an organic container with several amulets, and an iron sickle-like object, sharpened on both sides. Amongst the amulets there was a bronze wheel, the pierced tooth of a boar, two pieces of limestone with natural holes, and a bone-needle.

The iron equipment, as well as the iron rod mentioned before, and the disk, might possibly belong to a set of surgical instruments. The iron rod with the horn-handle, and the oval disk, might have been parts of a drill. There was also a fragment of a slender steatite blade in the grave that could very well have been used for surgical purposes.

The very impressive grave construction right in the centre of the cemetery, and the imported grave-goods, demonstrate the high social status of the deceased. They were most probably buried around 400 BC. The medical equipment and the magical amulets allow the conclusion that the buried pair belonged to an elite. We cannot decide what their function in life really was. The Celts did not have professional doctors. According to Pliny the Elder (Pliny, *Nat Hist* 16: 249–251), medical help was to the duty of the Druids, although it must be taken into consideration that "classical" Druids were limited to Gallia (Caesar, *Gal* 6: 13–14).

In any case, healing played a most important part in the life of the buried pair. Medical help was always combined with magical and religious practice: the antlers, being renewed every year, and the limestone pebbles were just as much symbols for the renewal of life in the world of the Celts as the snails and the shells we know of from other Celtic graves. The tooth of the boar symbolises the power of the animal.

We can assume that the former "patients" of the pair were buried around them. Probably, there were other social connections with them as well. Whether any family-relations existed can only be verified with analysis of the aDNA.

The archaeological and anthropological evaluation of the new finds is not yet concluded. Nonetheless, the excavations at the small cemetery on Dürrnberg open new perspectives of healing in Celtic times. Apart from the fact that we have the earliest grave of a female healer in Celtic territory, the development in the technique of trepanation will have to be defined afresh. We know now that drill trepanations are no longer restricted to the Mediterranean but they have also been used, at a very early time, in the Celtic world. We cannot exclude completely that Celtic healers have had knowledge of Greek techniques, but it seems much more realistic to think of an original Celtic development that is, so far, limited to three local findspots in Austria. We hope and trust that more discoveries will help to solve these problems.

Acknowledgement

I should like to express my special gratitude to the leading excavator and director of the "Forschungszentrum Dürrnberg", Kurt Zeller. He let me examine the material of his excavations and offered every possible assistance.

Note

All trepanations encountered in Austria until 1991 are to be found in: Hahnel B, Grosschmidt J, Winkler E (1991): *Trepanation einst und jetzt in: Kunst des Heilens. Aus der Geschichte der Medizin und Pharmazie.* Wien, Niederösterreichische Landesausstellung, Kartause Gaming, p. 329.

References

Klose O (1920–33): *Fundberichte aus Österreich 1*: 132.

Urban O, Teschler-Nicola M, Schultz M (1985): Die latènezeitlichen Gräberfelder von Katzelsdorf und Guntramsdorf in Niederösterreich. *Arch Aust 69*: 55–104.

Chapter 11

A Bregmatic Ossicle Resembling a Trepanation from an Eleventh-Century Skeleton Excavated from a Cemetery Area Now Within the Prague Castle, Czech Republic

MARSHALL JOSEPH BECKER
Department of Anthropology, West Chester University, West Chester, Pennsylvania, USA

Abstract

An apparent trepanation in the area of bregma of a fragmentary skull of a woman was discovered during the 1928 archaeological excavations in a cemetery of the tenth through thirteenth centuries at the Prague Castle, Czech Republic. The human skeletal remains were studied as part of a comprehensive program of archaeological review now being conducted at this site. The supposed "trepanation" in the skull of this women from Unit 993, who died at age ca 60 years, is identified as a bregmatic bone, a rarely reported type of cranial ossicle.

Keywords: Bregmatic bone, Intersutural ossicle, Pseudo-trepanation, Prague Castle, Early Czech State

Introduction

Since 1911, archaeological excavations in various areas of the Prague Castle have revealed several ancient cemeteries submerged beneath constructions of later dates. As part of a review of the archaeological record of the Prague Castle, Dr. Jan Frolík located the human skeletal remains from these several excavations in a series of storage areas where they had been deposited over the years. The outstanding archaeological recovery and effective curation of these remains is a tribute to the uniformly high quality of Czech archaeological research. These human remains were evaluated to provide basic age and sex information to the archaeologists in order to enhance the interpretation of the field record. Early archaeological and biological data from this urban center in Bohemia, especially dating from the important period at the beginning of the Czech state (Frolík, 1994), enable comparisons to be made with contemporary medieval rural developments in this region. In turn, these developments in transitional Prague can be compared with parallel processes of urbanization and state formation along the Middle Danube (see Christie, 1996) and elsewhere in this region.

Materials

The distribution and extent of the burial areas within the Prague Castle zone suggests that at one time or another a great deal of the surface had been used for burials. The focus of this report is the human skeletal material recovered from Grave 3 within a single excavation unit (993) located in the Courtyard III zone as identified by Bohácová et al. (1988: 180, Fig. 6). This large open plaza lies to the south of the impressive Cathedral of St. Guy (also known as St. Vitus). The important excavations in this plaza have revealed the complex architectural history of this area and development of the Prague Castle complex from its beginnings, probably as an ancient hill fort (Frolík, 2000). The second oldest known Christian structure in the Czech Republic, the Virgin Mary Church, was built toward the western end of the area now considered as the Prague Castle complex. The body of Prince Spytihnev, who ruled from 895 until his death in 915, was interred within the Virgin Mary Church and represents one of the earliest known in-church burials from any location in the Christian world.

Unit 993 identifies the location of the grave of a woman who was buried beneath the area that now is Courtyard III at some time during the tenth to thirteenth century. Her grave was among a number listed in the (non-inclusive) series 851–1,586 in which approximately 275 individuals are well represented. Frolík now notes that Unit 993 is part of a relatively isolated group of eight graves situated to the south of the residence next to the cathedral that had been the seat of the Bishop of Prague. The eight graves from this location appear to be stratified, with Unit 993 located in the third of the four levels defined. Artifact analysis of earlier levels suggests that Unit 993 possibly dates from the eleventh century.

At least 200 other units represent disturbed graves from which incomplete skeletons have been recovered (Becker, 2001). A number of important tombs on the periphery of Courtyard III are associated with the nearby architectural features. Perhaps the most notable of these graves is that of Prince Vratislav, who reigned from 915 until his death in 921. Prince Vratislav, the younger brother of Prince Spytihnev, is buried in the St. George Basilica at the Prague Castle.

Prince Vratislav was the father of Svaty Vaclav, who is known in the English speaking world as St. Wenceslas. Svaty Vaclav ruled this early Czech state from 921 to 935 CE, when he was murdered by his brother, Boleslav, in Stara Boleslav. The body of Svaty Vaclav was buried in Stara Boleslav, but in 938 these remains were relocated to the St. Guy Church, which later became the Cathedral of St. Guy. An elaborate enclosure within the present Cathedral of St. Guy now features the Tomb of St. Wenceslas (Svato Vaclav). The church, or "rotunda" of St. Wenceslas, built around 926 AD, also held the grave (K3) identified as that of Podiven (ca 935 AD), who was an important warrior or knight who served St.Wenceslas (Vlcek, 1997, pp. 56–57, Fig. VIII/6 on p.143).

The numbers by which the bones from these graves are identified derived from the archaeological excavation units. Most of these unit numbers were assigned by Borkovsky, an early excavator who began his enumeration with the *theoretical* number 10,000.

Thus Borkovsky Unit 993, for example, actually represents number 10,993 and includes primarily the material relating to what appears to be a single grave. This report uses the term “Unit” only where clarification may be needed, but for the most part each of these burials will be identified solely by their field number only (e.g. “993” or 993). The storage system for those human remains that are held by the National Museum, one of several locations, provides their box number for each container, indicated by the prefix “Ao.” In identifying the materials held in the National Museum storage the field number will be followed by the Museum box storage number always indicated by the “Ao” prefix.

Methods

The difficulties for analysis presented by skeletal materials recovered by different excavators using different standards, together with all the different problems of curation, amplify the challenges offered by remains recovered from cemeteries that have been used for centuries. The bones from ancient cemeteries often suffer multiple types of disturbance, presenting the analyst with a fundamental challenge in the recognition of specific individuals. The excavators in 1928 compounded this problem by having the bones washed. The washing was followed by a labor- intensive effort to assemble bone pieces using thick glue, possibly derived from animal hide. This glue has aged to a dark amber color and the quantities involved obscure features such as cranial sutures. This glue also locked into surrounding osseous tissue, thereby exaggerating the brittleness of the bone. In a few cases this old glue was mechanically removed and replaced with a PVA solution.

The multiple non-standard methods of analysis used in this study are described in the earlier work at Prague Castle (Becker, 2000). These techniques derive from previous programs that have had success in providing data useful to archaeologists (Becker and Salvadei, 1992). In general the field recording procedures follow the standards set by Buikstra and Ubelaker (1994). Where cranial material is all that survives, age estimates derive from the state of suture closure (cf. Jackes, 2000, pp. 438–442), coupled with an analysis of dental wear. The realization that this latter technique may be population and class specific has led to plans being made to implement further studies addressing these specific issues.

Findings from Unit 993: (24 IV 1928) Ao 974

Female, age 60 ± 10 years (Stature = 155.864 ± 3.72cm.; Becker, 2001)

The skull of this woman is represented by much of the calotte and both temporal bones. All the recovered fragments are eroded and earlier attempts to restore this skull, probably in 1928, created part of our analytical problem. A metopic suture can be identified.

What was believed by the excavators to be a trepanation on this skull, located on the frontal bone and only slightly off center, was found on close inspection to have been the location of a large bregmatic ossicle. There is no sharp margin nor “healed” area outlining what had been described in the archaeological field notes as a trepanation. A cut would be evident had a surgical event taken place shortly before death. Furthermore, there is no evidence of either diploe healing and rounding, or beginning to extend bone tissue out into the open area from which a piece of bone might have been removed surgically. Although the normal denticulate outlines of the sutures defining the perimeter of this bregmatic bone are slightly blurred by general deterioration of the bone, sufficient evidence survives to demonstrate that this opening clearly was the location of an ossicle at bregma.

Traces of the sutures surrounding and delineating the ossicle survive, but the actual bregmatic bone was not positively identified and either did not survive or was not recovered by the excavators. A small cranial fragment that was recovered may be a good candidate. The sutures evident along the bones surrounding the opening generally appear normal, and similar in configuration to those involved in the metopism that also is evident in this skull. Note may be made that much of the right coronal suture has been largely obliterated, possibly by disease. No correlation is known between any disease process and the formation of bregmatic bones or any other intersutural ossicles.

The deteriorated mandible in Unit 993 appears to be part of this woman's skeleton and provides information that supports the evaluation of age at death. The mandible reveals considerable ante-mortem dental loss, which in this population is associated with advanced age. At least seven and possibly eight teeth were in place at death. The loose mandibular 2M and 1M can be fitted within their original sockets. Left third molar agenesis appears evident and may reflect a general pattern. Third molar agenesis is noted frequently among females in this population, but less frequently among males (Becker, 2000). The crown of a canine and a very worn premolar have survived, but damage to them and their sockets prevents them from being restored to their specific locations.

Post-cranial remains include shafts of both humeri and one head fragment, a fibula, and the left femur. The distal ends of the left femur do not directly join the shaft, but enable us to make a good estimation of length (412 mm) and to measure the midshaft diameters (22/24). The length permits a calculation of stature (cf. Becker, 1999). A very eroded right femur is represented only by a shaft section that is 14 cm long. Also noted among these remains of this woman are a left clavicle fragment, a bit of scapula, two pieces of pelvis which include a broad sciatic notch, a left tibia shaft plus much of the head and distal ends that are not connected, both talus, fragments of both calcaneus, four other tarsals, and both large metatarsals and bits of three others.

Discussion

The study of skeletons from the Iron Age site of Osteria dell'Osa in central Italy (Becker and Salvadei, 1992) revealed that the post-cranial remains were far more reliable in sexing skeletons than were skulls at this site. This finding holds true for the entire region south of the Alps, and applies to a lesser degree in the Czech Republic. The person in Unit 993 was evaluated as "female" based primarily on an evaluation of the post-cranial skeleton, with the cranial characteristics also found to be in agreement with this evaluation of sex.

Trepanation is rare among these early medieval people who were in the process of forming the first Czech State, but not unknown. At least one example has been identified. Study of the remains of Prince Spytihnev I (Becker, 2000, p. 342) revealed the presence of a healed trepanation on the right side of the occipital. Since the Prince died at approximately 65 to 70 years of age, based solely on skeletal data and not the historical record, this trepanation reflects activity when he was a much younger man, but certainly a mature adult. Gender differences in the presence of trepanation are not commonly emphasized in most reports, but those examples associated with traumatic injury are predominantly associated with males. Examples of trepanation tend to be almost entirely on the parietals, temporals, and occipital, with examples at or around bregma being uncommon.

Lovell, as do most modern authors, directs readers to Hauser and De Stefano's (1989) compendium on epigenetic traits. Lovell (2000, p. 236) discusses epigenetic traits (also called discontinuous or non-metric traits) such as metopism and bregmatic bones under the rubric of "pseudopathology." This example of bregmatic bone from Prague had been misinterpreted as a trepanation, but Hauser and De Stefano (1989, p. 93) suggest that more commonly they are believed to be the result of a trauma.

Metopic sutures are relatively common in this Czech population (cf. Unit 880: Becker, 2001). Some 100 years ago Fischer (1902) noted that the incidence of metopism in a series of populations ranged from 0.3% to 10.8% and that variation by sex could be demonstrated. Hauser and De Stefano (1989, p. 43) provide an updated listing of occurrences. The presence of a metopic suture in a person interred in Prague Castle Unit 996A, near Unit 993, may reflect the presence of a relative. At this stage in the ongoing analysis of this large cemetery population, no statistical compilation of these data on metopic sutures or other non-metric traits has been made. Specific attention was directed in this study toward the search for bregmatic ossicles in the crania of individuals buried in the immediate area of Unit 933, with the assumption that these people might be kin to the woman in question. No others were found, leaving the case of the woman identified from Unit 993 as a unique example in this population.

Ossicles at bregma, or in the bregmatic (great) fontenelle, are rare in adults (Hauser and De Stefano, 1989, pp. 46–47). Hauser and De Stefano illustrate only two examples (1989, Pl. XVc and XVd), of which one is a small example running along a short section of the sagittal suture and the other, in an adolescent with metopism, is a two-part, squarish example. They also depict one by a drawing, on an overlay (1989: p. 25, Pl. II), as a relatively small intersutural bone. The relevant paragraph from Hauser and De Stefano (1989, p. 92) is worth quoting in its entirety:

> **Within population variation.** *Ossicle* at bregma: There is general similarity in incidence between the sexes, and tendencies are not consistent (Berry 1975, Perezonius 1979a, Cesnys 1982a). Perizonius (1972a) reported no change with age in adulthood, and Cesnys (1982a) a tendency to decrease with age. The ossicle at bregma is significantly correlated with the sagittal ossicle, and the ossicle at lambda (Hauser and Bergman, 1984).

Examples of the bregmatic ossicle remain rare in the published literature despite considerable attention directed toward various aspects of cranial sutures (Berry and Berry, 1967; cf. Jackes, 2000, pp. 438–442). A study of "100 male adult middle Europeans" (Hauser and De Stefano, 1989, p. 88) found no ossicles at bregma. Barnes (1994: also Fig. 4.3f) specifically identifies the ossicle at bregma as being an anterior fontanelle bone, with the implication that it disappears along with the closure of the normal sutures. Schultz's (1929) study of the metopic fontenelle and suture addressed the question of the *ossiculum fonticuli maioris* and found that its borders normally were absorbed in an invisible fusion, similar to that of the mandibular midline (cf. Becker, 1986). Bregmatic ossicles are unknown from other people in this Czech population of the tenth–thirteenth centuries and no examples have been seen elsewhere in any Czech archaeological context. Of interest is the fact that bregmatic ossicles are rarely reported from archaeological contexts anywhere in the world. Barnes (1994) lists, by catalogue number, three examples that all were found among individuals from Pueblo-Zuni contexts of the American southwest and are all in storage at the National Museum of Natural History in Washington, DC. Other examples remain elusive.

Conclusions

1. The apparent "trepanation" of this woman's skull actually is the site of a large bregmatic ossicle.
2. This woman does not appear to be of high status, as indicated by her average stature (Becker, 2000) and the location of her grave within this cemetery.
3. No maxillary dentition was recovered, so we cannot evaluate the presence of the Lateral Incisor Trait (LIT, see Pinto-Cisternas et al., 1995) or incisor "shoveling." However, the LIT is common in this population, indicating that it is far from limited to central Italian populations (see also Becker and Salvadei, 1992).
4. Suture closure or fusion is not a reliable indicator of age in this population, although it can be employed to provide a general indicator of age at death.

Acknowledgements

Thanks are due to Dr. Jan Frolík for arranging for this study to be conducted, for providing all the support needed for working on site, and for his careful review and corrections of this text. Thanks also are due to Prof. Zdenek Smetánka for his important work in initiating this general program of research. My sincere thanks also are due to my colleagues in the Archaeological Institute as well as the Anthropological Institute in Prague, to Dr. Deborah Anne Smith (GlaxoSmithKline) for aid in processing data on site, to Prof. Nancy Rumfield for aid with illustrations, and to Peter Halvorson.

Funding for the fieldwork during three periods of research in Prague was provided by grants from the Archaeological Service of the Czech Republic. A small grant for equipment used during the August 2000 season was awarded by the College of Arts and Sciences of West Chester University of Pennsylvania. This manuscript was produced while the author was a Visiting Fellow in Anthropology at the University of Pennsylvania. My thanks are due to Professor Gregory Possehl for his continued support and encouragement of this research. The ideas presented and all interpretations of the data are, of course, solely the responsibility of the author.

References

Barnes E (1994): *Developmental Defects of the Axial Skeleton in Paleopathology*. Miwot, Colorado, University Press of Colorado.

Becker MJ (1986): Mandibular Symphysis (Medial Suture) Closure in Modern *Homo sapiens*: Preliminary Evidence From Archaeological Populations. *AJPA 69*: 499–501.

Becker MJ (1999): Calculating stature from *in situ* measurements of skeletons and from long bone lengths: an historical perspective leading to a test of Formicola's hypothesis at 5th century BCE Satricum, Lazio, Italy. *Riv di Antropologia (Roma) 77*: 225–247.

Becker MJ (2000): Human skeletal remains from Excavations in the Area of the Church of the Virgin Mary, Prague Castle, Czech Republic. In: Frolík J, ed., *Nejstarší Sakrální Architektura Pra•ského Hradu. Výpoved' archeologických pramenu*. Prague, Nakladatelství Peres, pp. 289–353.

Becker MJ (2001): Human skeletal remains from Various Excavations Within the Area of the Prague Castle, Czech Republic. Manuscript in process.

Becker MJ, Salvadei L (1992): Analysis of the Human Skeletal Remains from the Cemetery of Osteria dell'Osa. In: Bietti Sestieri AM, ed., *La Necropoli Laziale di Osteria dell'Osa*, Anna. Rome, Quasar, pp. 53–191.

Berry AC (1975): Factors affecting the incidence of non-metrical skeletal variants. *J Anat 120*: 519–535.

Berry AC, Berry RJ (1967): Epigenetic variation in the human cranium. *J Anat 101*: 361–379.

Boháčová I Frolík J, Tomková K, Žegklitz J (1988): Předbežné výsledky výzkumu Pražkého hradu v letech 1980–1987. *Archaeologia Historica 13*: 173–198.

Buikstra JE, Ubelaker DH, eds. (1994): *Standards for Data Collection from Human Skeletal Remains*. Arkansas Archeological Survey Research Series No. 44. Fayetteville, Arkansas: Arkansas Archeological Survey.

Cesnys G (1982): Relation of non-metric cranial traits to sex and age in the 1st–2nd millenium A.D. Lithuanian craniological materials. *Human Biol Budapest 10*: 19–24.

Christie N (1996): In: Christie N, Loseby ST, eds., *Towns in Transition: Urban Evolution in Late Antiquity and the Early Middle Ages.* Brookfield, Vermont, Ashgate.

Fischer E (1902): Zur Kenntnis der Fontanella metopica und ihrer Bildungen. *Zeitsch Morph Anthrop 4*: 17–30.

Frolík J (1994): Prague Castle and Its Hinterland. Comments on Its Beginnings and Initial Development of, "Prague Castle, Vyšehrad Castle and the Prague Agglomeration." Památky Archeologické Supplementum 1: *25 Years of Archaeological Research in Bohemia*, pp. 158–162.

Frolík J, ed. (2000): *Nejstarší Sakrální Architektura Pražského Hradu. Výpoved' archeologických pramenů.* Prague, Nakladatelství Peres.

Hauser G, Bergman P (1984): Some biological and methodological problems of asymmetrical development illustrated with reference to sutural bones. *Anthrop Anzeiger 42*: 101–116.

Hauser G, De Stefano GF (1989): *Epigenetic Variants of the Human Skull* (in co-operation with A. Bastianini, V. Capecchi and A. Guidotti). Stuttgart, E. Schweizerbart'sche Verlag.

Jackes M (2000): Building the Bases for Paleodemographic Analysis: Adult Age Determination. In: Katzenberg MA, Saunders SR, eds., *Biological Anthropology of the Human Skeleton*. New York, Wiley-Liss, pp 417–466.

Lovell NC (2000): Paleopathological Description and Diagnosis. In: Katzenberg MA, Saunders SR, eds. *Biological Anthropology of the Human Skeleton*. New York: Wiley-Liss, pp 217–248.

Perizonius WRK (1979): Non-metric cranial traits: sex differences and age dependence. *J Hum Evol 8*: 679–684.

Pinto-Cisternas J, Moggi-Cecchi J, Pacciani E (1995): The Lateral Incisor Trait. In: Moggi-Cecchi J, ed., *Aspects of Dental Biology: Palaeontology, Anthropology and Evolution*. Florence: pp 333–339.

Schultz AH (1929): The metopic fontanelle, fissure and suture. *Amer J Anat 44*: 475–499.

Vlcek E (1997): *Nejstarší Premyslovci. Fyzické osobnosti eských panovniku I. díl. Postavy českych dejin očima antropologa.* Praha, Sazba Vesmir.

Chapter 12

Prehistoric Trepanations in Russia: Ritual or Surgical?

MARIA MEDNIKOVA
Institute of Archaeology, Moscow, Russia

Abstract

The study of ancient trepanned skulls attracts specialists by its mystery. Palaeopathologists study apertures that show traces of healing and describe various traumatic conditions. Archaeologists provide information about ancient cults of different parts of the body, for instance: skull cult, the distribution of post-mortem masks, the mummification traditions, manipulations of defeated enemy, neutralisation of buried spirits, decapitation and scalping. On the one hand, skill is needed to describe apertures in human skulls, formed as a result of external influence. On the other hand, there is the historical context of skeletal finds, the interlacing of ancient cultures, the distribution of religions and ideas, war and colonisation of new countries. The main goal of this study was the observation of trepanation cases from Russia in connection with then-common skull operation tendencies and the archaeological context of finds. Crania from various parts and epochs of Russia were investigated. The trepanning practice in Russia probably began in the Mesolithic period. The Bronze Age trepanations were mainly localised in the European part of Russia; the centre of Early Iron Age skull openings was in southern Siberia; the early Mediaeval operations were once more concentrated in the European part of Russia. Funeral patterns sometimes give evidence that suggests the skull operations were more magical than medical.

Keywords: Russia, geographical and spatial distributions of perforated crania, funeral rites, ritual or therapeutic purposes of trepanning

Studies of ancient trepanned skulls have long attracted investigators because of their mystery. These studies can be undertaken within the framework of different sciences. For instance, palaeopathologists provide analysis of apertures with traces of healing and describe various traumatic conditions. Unfortunately, many palaeopathological works did not place skeletal finds within a historical context. Only the geographical place of a find and the approximate date were of traditional interest for palaeopathologists, although other details are also useful. For example, it is important to look at burial rite features when interpreting trepanning cases. And archaeologists want information about ancient cults of different parts about a body. Included are skull cults, distribution of after-death masks, embalming and mummification traditions, the treatment of defeated enemies, neutralisation of buried spirits, decapitation, and scalping. So, on the one hand, there is the need to describe apertures in human skulls formed as a result of external influences, and on the other hand, there is the need to know the historical context of the skeletal finds, interlacing of ancient cultures, migration of the peoples, distribution of religions and ideas, war and colonisation of new countries, and so forth.

The trepanation research in Russia has been going on for at least 120 years, but it is not well-known to the international scientific community. The main goals of this paper are: 1. To give information about prehistoric trepanations studied in Russia; 2. To describe main geographical and long-term tendencies of skull opening distributions; and 3. To determine whether the most ancient trepanations in Russia are ritual or surgical in their nature.

The study of prehistoric trepanations in Russia started in the 1870s. Archaeologist and anthropologist Dmitrij Anuchin, who particularly had been educated in France and was deeply influenced by Paul Broca's investigations, first discussed these ancient trepanations (Anuchin, 1895). Looking for trepanned samples, he investigated about 5,000 skulls collected at Moscow University. Only two trepanation cases were found in that collection, both without clear archaeological attribution.

The first skull belonged to a female, and was found during excavations on the River Dniepr. It was trepanned in the centre of the frontal bone, after death. The second skull was of undetermined sex and was taken from Khulam in Northern Caucasus. The centre of the left parietal bone had an described oval lesion, which had not affected the inner compact layer. It was interpreted to be an unfinished operation. In the present day this case can be included among those operations called symbolic trepanations by Bartucz (1950).

The first impression of anthropologists was that prehistoric trepanations were not as common in Russia as in other parts of the ancient world. But by the end of the nineteenth century, all kinds of trepanations were discovered in Russia. There were openings made on the skulls of living persons, amulets created from cranial bones, and after death skull perforations connected with specific mummification practices. In one case, an ancient operation was performed on the skull roof of a living person that did not affect the inner compact layer of bone.

In the twentieth century, trepanation studies in Russia were undertaken by clinicians, who were interested in palaeopathology and in medical history (Rokhlin, 1965), and by physical anthropologists with an interest in medicine (Gokhman, 1989).

The most famous trepanations were the Mesolithic and Neolithic skulls found in the Dniepr River region, now in the Ukraine (Goichman, 1966). The oldest Mesolithic operation was made about 10,000 years ago, and was done by drilling in the centre of the left parietal bone (burial site Vassilyevka III, Grave 31). The lesion observed on the skull of an old man, had round borders. The external diameters of the perforation were 16 x 18 mm. On the inner, endocranial side, the hole was smaller: 8.2 x 9.3 mm. With palpation, microscopically, and with the X-ray method, the borders of the hole showed clear evidence of regeneration and bone callus development. On the anterior and lower sides of the lesion, the diploe was invisible. The three bone layers joined in a common compact structure.

According to the investigators of this skull, the surgical intervention was performed after a depressed fracture of the bone. It can be supposed that this operation was provided for treatment of post-traumatic, localised headache syndrome (Goichman, 1966: Figs 4, 6; pp.112, 115).

Only a summary of the trepanning regions can be given within the framework of this report. If we look at a Russian map, the Bronze Age trepanations were mainly localised in the European region; the centre of early Iron Age skull openings involved the south of Siberia including the Minussinsk Basin and the Altai-Sayan Highland; and the early Mediaeval operations were again concentrated in European part of Russia.

The Bronze Age

In the Early Bronze Age, during the fourth and the third millennia BC, trepanations were intra-vital, made with the scraping technique. The majority of perforated skulls were found in the low Don River flow, inhabited by cattle-breeding tribes in that period. Locations of trepanation holes were on parietal and occipital bones, anatomically in the obelion and lambda areas. The largest diameter for a perforation was about 50 mm.

It is difficult to differentiate between magical or therapeutic purposes underlying such a practice. In a collective grave excavated in a Rostov-upon-Don town, 5 out of 7 individuals were trepanned (Elena Batieva, personal communication). The burial belonged to the Eneolithic Maikop culture or to the Early Bronze Age. In all cases, the trepan holes were observed in the parietal-occipital area, and were made well before death.

The group includes three adult males and two females, one juvenile, and a child about 2 years old. One female, 30–35 years old at death, had a lesion on the obelion area; another female, 25–30 years old at death, had a round opening on the sagittal suture; the sub-adult (female?), 14–16 years old, had an opening in the obelion area; the first male, 35–40 years old, had a round perforation in the lambda area, and the second male, 30–35 years old, also had an oval opening in the lambda area. It should be stressed that trepanning activity of the operators crossed genders and ages. It would be strange if each of these people needed to be trepanned for medical reasons.

The unusual posture of these skeletons indicates that the bodies were disarticulated and then bound after death. The pit grave contained a lot of red ochre, often used for magical purposes.

In the Middle Bronze Age, the first half of the second millennium BC, the location of trepanned holes was mostly in the occipital area. The majority had indications of vital reactions. In this period, the skull opening practice was found in the Upper and in the Middle Volga River flows. Some of the skulls had many trepanation holes, mostly localised on the parietal and occipital bones (Gokhman, 1989).

Were the Middle Bronze Age skull perforations ritual or surgical? The archaeological context of the skeletal finds sometimes gives an answer to this question (Mednikova and Lebedinskaya, 1999). For example, in the Volga River region not far from the city of Cheboksary a large collective funeral was excavated, dated from the eighteenth century BC (Pepkino). In the long grave there were the remains of 27 adult males buried simultaneously.

The skeletons were found in good anatomical order with two exceptions. Two skulls were separated, and both were trepanned on the parietal bones in the bregma area by the scraping technique (Fig. 1). The first trepanned skull was found in the chest area of the skeleton in an upside-down position. There was a ceramic vessel in its normal anatomi-

a

b

Figure 1. Trepanation made by the scraping technique on the left parietal bone of an adult male. Traces of healing are not present. Volga river region, Pepkino mound. (Photos: a. A.Maurer, b. R.Wieland.).

cal place. The second trepanned skull was found on the feet of another individual.

Different skeletons from the same grave showed unhealed cranial traumas, cut-marks, and artificial damage to the skulls and long bones (Mednikova and Lebedinskaya, 1999). Those buried in the mound could certainly be victims of a Bronze Age battle. But it is also possible to consider some traits of specific rituals, especially in connection with those persons who had been trepanned.

Moreover, amulets made from the cranial bones, dating from the third-fourth centuries BC, were excavated in this small district. The amulets were discovered in layers of an Iron Age settlement (Anuchin, 1895; Bader, 1951). The roundels had drilled perforations that were used for hanging them. The burial tradition of the first millennium BC in the European woody part of Russia called for burning. Such a practice has obscured our knowledge about more trepanations.

The Early Iron Age

The absence of cremation in other areas may be why the centre of Early Iron Age skull openings appears to be in the south of Siberia, including the Minussinsk Basin and the Altai-Sayan Highland. The Minussinsk Basin of the upper Yenisei region was mentioned in an excellent review of ancient trepanations by Lisowski (1967). But it is important to highlight that skull perforations in this place were part of a funeral tradition. The inhabitants of the Southern Siberia were experienced in specific kind of mummification.

The first investigator of these palaeoanthropological materials was Gorosh'enko. In 1899, he reported to the Empire Archaeological Commission about the artificial damages on the human remains excavated in mounds, dated at the end of the first millennium BC. He described large perforations in the temporal bones, and classified the manipulations as after death procedures for removing the brain. The rite was connected with the creation of death masks. Some perforated skulls were coated by clay, and then by gypsum over clay (Fig. 2). The skulls did not have to have the soft tissues removed before the gypsum masks could be created.

Among the 400 Siberian skulls, we have about 80 artificial perforated crania. The majority of trepanned individuals were buried during the last period of the Tagar culture, in the third-second centuries BC. The earlier periods of the Tagar culture have shown a relative absence of trepanation. Some cases, however, belong to the later Tashtyk culture (second century BC – first century AD).

Generally speaking, the openings were made on fresh skulls by cutting with sharp, flat-bladed instruments. Traces of healings or inflammatory reactions are not represented. In all cases no signs of vital reaction are observable, and the margins are sharp. The outer borders of the openings were larger than the inner, and this differentiates these damages from traumas (Berryman et al., 1996). But in most cases the size differences between the perforations of external and of the inner compact layers were not so clear as with the typical scraping procedure (Lisowski, 1967). It seems that the operators did not try to be especially careful and were not afraid to destroy the dura mater or the brain itself. The original unchanged structure of the spongy substance is visible, and there are

Figure 2. An after-death trepanned skull of an adult female. The wide oval perforation is in the left parietal bone. The defleshed skull was coated with clay and then by a gypsum mask. Southern Siberia, Tagar culture. (Photo: M.Mednikova).

no traces of new bone formation. Consequently, it can be hypothesized that the operations took place after death.

The lesions were classified according to location and extent (Mednikova, 1997; 1999, in press):

Type 1: Skulls with large symmetric perforations on parietal and temporal bones. The occipital bone and facial skeleton were not destroyed. Some skulls were plastered. As a result, red-coloured clay sometimes filled the orbital cavities.

Type 2: Skulls with bilateral, wide destructions. The facial skeleton and cranial base are absent. As a rule the parietal bones are completely removed.

Type 3: Skulls with large holes in parietal regions alone.

Type 4: Skulls that demonstrate both large perforations on parietal, and small oval or round lesions in the occipital area.

Type 5: Skulls with large lesions of the occipital bone and/or small holes on parietal. The small openings were made with a typical scraping technique. This type was later, and associated with the Tashtyk culture, which started from the second century BC. Such

Figure 3. An after-death trepanned skull of an old female. The perforation is localised in the occipital bone. On the face was a gypsum mask with solar symbols. Southern Siberia, Tashtyk culture. (Photo: A.Nagler).

skulls were found with carefully made death masks, which covered the facial part of the skull (Fig. 3).

The perforations were found among adults, juveniles, and little children. It seems the first type was more common in males, but in general there is an absence of gender differences. The other techniques were probably done on small children. The infants from different sites were operated on in a similar manner after death (Type 4 and 5). Hence the skulls of ancient South Siberians were mainly opened after death. And the artificial apertures are more varied in form and location than thought earlier.

The regions of north-western Mongolia, Tuva, Kazakhstan, and Altai had to be included into the study. The data of different authors show the sporadic appearance of trepanning cases on these territories. The finds of opened skulls of the Saglynskaya culture in Tuva (Grach, 1980) and Pazyryk culture in Altai (Polosmak, 2000) were undoubtedly interpreted as sequences of embalming. The mummies with clear evidence of skull perforations were discovered not only on Russian territory. During the last planting season in the highland part of Kasakhstan, the mummy of a male was excavated under layer of permafrost. The skull was opened in the parietal bone (Gorbunov et al., 2000).

The Mongolian Ulaangom (Chandman) trepanned skulls and one case from Kazakhstan may be intra-vital and post-mortem (Naran and Tumen, 1997; Boev and Ismagulov, 1962; Mednikova, 1997; in press). But the place of the apertures and probably techniques have commonalities with some South Siberian cases, especially with the last Type

5 (small oval apertures). The finds from Mongolia may occupy an intermediate position, combining locations of apertures both in Tuva (on parietal bones) and in Kazakhstan (on the border of parietal and occipital bones). Similarly, the cases from Tuva are a lot like some variations of the apertures in the Minusinsk basin.

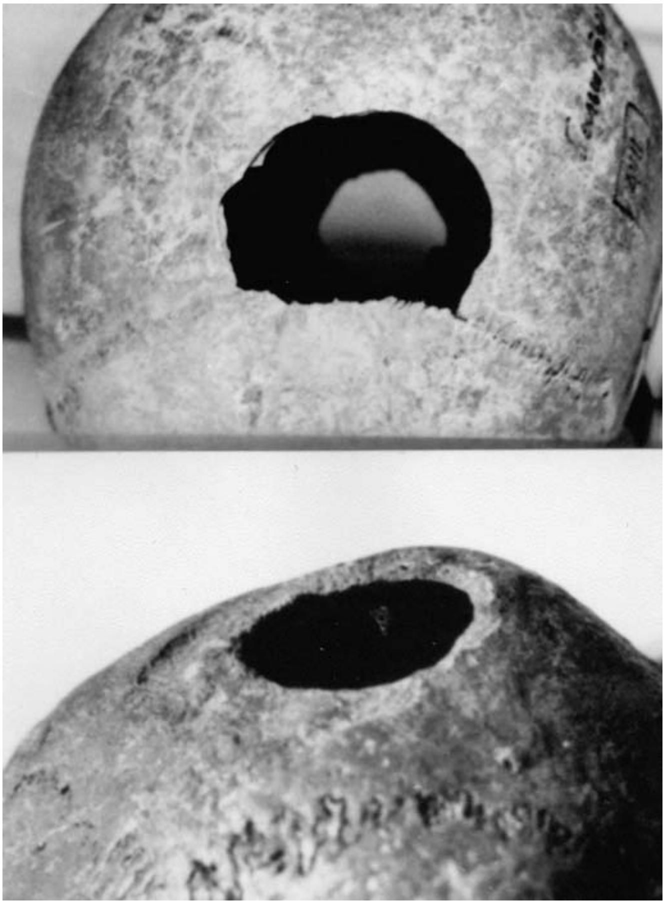
The ritual skull perforations were probably also distributed in West Siberia. Artificial skull destructions were reported for the burial site from the Upper Ob" region, dating by the Early Iron Age (Shpakova and Borodovski, 1998). The damage looks similar to the openings and damage found in the late Tagarians.

We think that the area of ritual and after death trepanation in Central Asia can be wider. Perhaps it was characteristic for the population at the end of the first millennium BC. It seems very possible that palaeopopulations practised such rites and had common genetic origins. And this is shown by craniological methods and in studies of epigenetic traits. South Siberians had more craniological similarity with Scythian time inhabitants of Tuva and with Saka from Central Kazakhstan (Kosintsev, 1977). The cultural and ethnic relations between groups from Altai, Tuva, and northwest Mongolia are also strong (Novgorodova et al., 1982; Grach, 1980). Therefore, the data from trepanning research in general supports the hypothesis of moving from the south through Tuva into the Minussinsk Basin. The migrations of these nomadic peoples took new funeral traditions and different techniques of skull perforations with them.

Figure 4. Symbolic trepanation at bregma on the skull of a female 20–29 years old. Diameter of lesion, 13 mm; its depth, 1.5 mm. Metopic closure is present. Middle Volga region, seventh-ninth centuries. Bulgars, burial site Bolshye Tarkhany. (Photo: M.Mednikova).

The Mediaeval Time

The Early Mediaeval operations are concentrated in the European part of Russia again. They were distributed among nomadic tribes on the Middle Volga, on the Middle Don, and in the Northern Caucasus – Dagestan and Osetia. The majority of cases from the eighth-ninth centuries belong to the kind of symbolic intra-vital trepanation. They only affected the tabula externa and did not open the cranial cavity. They were scraped or cut in bregma area and along the line of sagittal suture. Symbolic trepanations in Russian material are more often single, characterised by round and oval outlines (Fig. 4). The



a

b

Figure 5. Intra-vital trepanations on the skulls of mediaeval nomads. Bolshye Tarkhany site. a. A male, 20–29 years old. The wide artificial perforation in the bregma area was cut by sharp instrument. On the left side the hole shows a slight widening in the endocranial direction. On the frontal bone there is a healed depressed fracture. b. A male, 35–39 years at death. A well-healed artificial perforation is in the left parietal bone in the eminentia area. (Photo: M.Mednikova).

individuals, “symbolically signed” during life, were buried in ordinary graves, not notably rich or remarkable by other features. Both males and females could be symbolically trepanned.

As was shown earlier, symbolic trepanations were widely distributed in mediaeval Hungary and Bulgaria, especially during the so called conquest period when nomadic tribes migrated from the more Eastern steppes of the Volga region (Nemeskery et al., 1960).

Hungarian anthropologists Nemeskeri, Kralovanski and Harsanyi (1965) wrote about both the medical and ritual goals of symbolic trepanation. The Bulgarian anthropologist Boev (1970) discussed medical purposes. But such operations were forbidden in the eleventh century by King Stephen of Hungary, who changed the state religion in Hungary from pagan to Christian. These trepanations might, therefore, be connected with magic. Some skulls from the Volga region of the seventh century also demonstrate large perforations on parietal bones, often with healing (Fig. 5).

The first millennium AD was the period of great migrations. It started in the northern part of China and finished 1,000 years later in Europe. It seems that the distribution of trepanning cases in this historically complicated period reflects the spiritual aspects of different nomadic tribes and indicates the ways of their migrations.

Conclusions

- The trepanning practice on Russian territory might have had early Mesolithic roots. During the Bronze Age, trepanations were mainly concentrated in the European part of Russia and were made by the scraping technique. The human remains associated with trepanned skulls were often found in atypical anatomical positions or with cut marks and artificial destruction.
- During the Early Iron Age in the European woodlands amulets were created from cranial bones. In the Central Asian part there was embalming and mummification with skull perforations. Some skull operations in this region were intra-vital.
- In early Mediaeval times, trepanations were distributed among the nomadic tribes of the European part of Russia: in the Volga and the Don regions, and in the Northern Caucasus. The majority belong to the kind called symbolic trepanations.
- It seems that prehistoric skull operations in Russia were more magical than medical, but more research is needed for a more definitive statement to be made.

Acknowledgements

I am glad to thank the Bioanthropology Foundation for financial support, and to all people who consulted with me and gave me information: Dr. Nikolai Leontyev (Minussinsk), Dr. Galina Lebedinskaya (Moscow), Dr. Herbert Ullrich (Berlin), Mrs. E.Batieva (Rostov-upon-Don).

References

Anuchin DN (1895): Amulet iz chelovecheskoi kosti i trepanaziya cherepov v drevnie vremena v Rossii. In: Graf. Uvarova, Sluzki SS, eds., *Trudy X Archeologicheskogo S'ezda v Vilne*, v. 1., Lisner, Roman Moscow, pp. 283–297 (Amulet from human skull and cranial trephination in prehistoric Russia. In: Countesse Uvarova, Sluzki SS, eds., *Materials of X Archaeological Meeting in Vilno*, v. 1. Lisner, Roman Moscow, pp. 283–297.

Bader ON (1951): Gorodish'a Vetlugi i Unzhi. *Materialy issledovaniy po arkheologii SSSR (MIA)*, *22*: 110–159. (Settlements on Vetluga and Unzha rivers).

Bartucz L (1950): Adatok a koronyalekeles (trepanacio) es a bregmasebek kapcsolatanak problemajahoz magyarorszagi nepvandorlaskori koronyak alapjan. *Annales biologicae universitatis Scegediensis*. Tomus I, Redigit A.Abraham: pp. 389–435.

Berryman HE, Jones Haun S (1996): Applying Forensic Techniques to Interpret Cranial Fracture Patterns in an Archaeological Specimen. *Int J Ost 6*: 2–9.

Boev P (1970): Symbolische Trepanationen. *XXII Congres International D'Histoire De La Medicine*, Bucarest – Constanza, pp. 123–124

Boev P, Ismagulov O (1962): Trepanirovannyi cherep iz Kazakhskoi SSR. *Sovet Etno 2*: 131–132 (Trepanned skull from the Kasakhstan Republik).

Gokhman I (1989): Paleoantropologiya i doistoricheskaya medicina. In: Alexeeva TI, ed., Anthropology for medicine. Moscow, Moscow University, pp. 5–15 (Palaeoanthropology and prehistoric medicine).

Goichman VA (1966): O trepanazii cherepa v epochu mesolita. *Voprosy Antropol 23*: 111–118. (About cranial trephination in the Mesolithic Age).

Gorbunov AP, Samashev ZS, Severski EV (2000): *Birel. Vechnaya merzlota – khranilishe drevnostei*. Alma-Aty (Birel. Perpetual frost – preserver of antiquities).

Grach AD (1980): *Drevnie kochevniki v zentre Asii*. Moscow, Nauka. (Ancient nomads in Centre of Asia).

Kosintsev AG (1977): *Antropologicheskij sostav i proiskhozdenie naseleniya tagarskoi kultury*. Leningrad, Nauka. (Anthropological composition and origin of the Tagar culture population).

Mednikova MB (1997): K voprosu o rasprostranenii posmertnoi trepanazii cherepov v Zentralnoy Asii. *Ross Arkheol 4*: 130–140 (About the spread of postmortem trepanations in Central Asia).

Mednikova MB, Lebedinskaya GV (1999): Pepkinskij kurgan: dannye antropologii k rekonstrukzii pogrebenij (Pepkino mound: anthropological data to reconstruction of the funeral). In: Gulyaev V, Kamenetzki I, Olkhovski V, eds., *Burial rite*. Moscow, Vostochnaya Literatura, pp. 200–216.

Mednikova M, Lebedinskaya G (1999): A Bronze Age battle in European Russia: palaeopathological evidence. *J Paleopath 11*: 80.

Mednikova M (in press): *Post-mortem trepanations in Central Asia: types and trends*.

Naran B, Tumen D (1997): Travmaticheskie povrezhdeniya na cherepakh Chandaman'skogo mogilnika. *Ross Arkheol 4*: 122–130 (Traumatic injuries on the skulls from the Chandman burial ground).

Nemeskery J, Ery K, Kralovansky (1960): Symbolically trephined skulls in Hungary. *Kulolenyomat az Antropoloiai Kozlrmenyek 4*: 1–22.

Nemeskeri J, Kralovansky A, Harsanyi L (1965): Trephined skulls from the tenth century. *Acta Arch Acad Sci Hung 17*: 343–367.

Novgorodova EA, Volkov VV, Korenevskij SN, Mamonova NN (1982): *Ulangom – ein*

Graberfeld der skythischen Zeit aus der Mongolei. Wiesbaden, Otto Harassowitz.
Polosmak NV (2000): The balming operation among the Pazyrykians of Ukok. In: Gulyaev V., Olkhovskiy V., eds., *Scythians and Sarmatians in the 7th – 3rd centuries BC: Palaeoecology, Anthropology and Archaeology*. Moscow, Staryi Sad, pp. 67–72.
Rokhlin DG (1965): *Bolezni drevnikh ludey (kosti ludey razlichnykh epokh – normalnye i patologicheski izmenennye*). Moscow-Leningrad, Nauka. (Diseases of ancient peoples (bones of peoples of different epochs – normal and pathologically changed).
Shpakova E, Borodovski A (1998): Fakty iskusstvennogo povrezdeniya cherepov iz Novosibirskogo Priob'ya v epochu rannego zheleza. In: V I Molodin, ed., *Sibir* v *panorame tysyacheletij*. Materialy symposiuma. Novosibirsk, Institute of Archaeology and Ethnograpy, pp. 685–692. (Facts of artificial damage to skulls from Novosibirsk Ob" region in Early Iron Age Siberia: panorama over millennia. Abstracts of meeting).

Chapter 13

Cranial Surgery: The Epipalaeolithic to Neolithic Populations of Ukraine

DR. MALCOLM C. LILLIE
Wetland Archaeology and Environments Research Centre, Department of Geography, University of Hull, Hull, England

Abstract

Recent increased access to skeletal materials housed in the former Soviet Union has enabled western researchers to evaluate the extensive archives that exist for the prehistoric period of Eastern Europe. In the current study 310 crania housed in Kiev and St. Petersburg were initially studied for palaeopathology and dietary markers in order to assess the evidence for significant dietary shifts at the Mesolithic to Neolithic transition. The cemeteries studied cover the period ca 10,000–3,500 cal BC, equating to the Epipalaeolithic through to Eneolithic/Copper ages in Ukraine.

During this study, new radiocarbon determinations, literature survey and palaeopathological analyses revealed evidence that attests a low level of cranial surgery being carried out from as early as 10,000–9,000 cal BC at the Epipalaeolithic cemetery of Vasilyevka III. At the end of the Mesolithic period at ca 7,000–6,000 cal BC healed trepanation is identified at the cemetery of Vasilyevka II. Subsequently during the earlier Neolithic period at ca 5,500–4,800 cal BC an identical form of trepanation to that identified at Vasilyevka II, although in this case unhealed, is reported from the Vovnigi II cemetery.

The significance of the cases reported lies in the fact that while the areal extent of the trepanned area on the vault is very limited, when compared to examples such as that recorded by Alt et al. (1997) from Ensisheim, Alsace, the trepanation from Vasilyevka II would appear to be the earliest evidence for healed trepanation recovered to date from the European mainland.

Keywords: Ukraine, fisher-hunter-gatherer, trepanation, Epipalaeolithic, Mesolithic, Neolithic

Introduction

Consideration of the skeletal archive from the cemeteries of the Dnieper Rapids region of Ukraine (Fig. 1), located ca 400 km to the south-east of Kiev, has resulted in the "re-discovery" of evidence for cranial surgery in the prehistoric period of Ukraine. The trepanations discussed below were first recorded by Gokhman (1966) in Russian language, and subsequently the Vasilyevka II and Vovnigi II examples were reported by the present author after completion of extended study visits to Russia and Ukraine between 1993–5 (Lillie, 1998a).

As noted previously (Lillie, 1998a), the evidence reported here represents one facet of a multi-disciplinary investigation into the chronology, dental pathology and diet of the human population living in the Dnieper Rapids region during the Mesolithic and Neolithic periods (Lillie, 1998b). Two key reasons for the relative "ignorance" of the existence of this material can be identified. Firstly this lies in the limited access to the skeletal collections housed in Eastern Europe. Secondly, until recently and in the absence of publication in western language journals many of the earlier developments and discoveries in eastern European anthropology and archaeology have had a somewhat limited exposure in the west.

In the current context, the lack of associated settlement evidence at the Dnieper Rapids sites makes them cemeteries in the "true" sense (*sensu* Brinch Petersen and Meiklejohn, in press) in that they are areas specially delimited and set aside for burial purposes. However, *contra* Brinch Petersen and Meiklejohn (in press) these cemeteries exhibit:

- chronological partitioning of the cemeteries with multiple burials
- the Dnieper Rapids (Mariupol-type) cemeteries represent a Mesolithic phenomenon that has clear evidence for continuity into the subsequent Neolithic period

and

- these cemetery sites overshadow Olenii Ostrov in Karelia and Zvejniecki in Latvia in terms of their duration as a discrete phenomenon, spanning the period 10,000–4,500 cal BC as a minimum estimate, and their internal continuities which in the case of sites such as Nikolskoye can be seen to span in the region of 3000 radiocarbon years from ca 6–3,000 BP.

Until recently (e.g. Jacobs, 1993, 1994; Lillie, 1996, 1998b, c; Zvelebil and Lillie, 2000) the chronological partitioning of the Mesolithic and Neolithic cemeteries in this region of Ukraine was based on Telegin's (1968, 1982, 1987) and Telegin and Potekhina's (1987) seriation. This chronology was originally based on a limited number of absolute dates, typological seriation and cross-cultural correlations to the Tripolye culture.

Recent research has shown that many of the criteria used to define sites as "Neolithic", such as the rite of extended burial, characterise both Epipalaeolithic and later Mesolithic cemeteries in this region. Early on in his research Lillie (1996) highlighted considerable inconsistencies in the typological seriation. This led to the extended dating program outlined in 1998 (Lillie, 1998c), and has culminated in the obtaining of in excess of 60 radiocarbon determinations for this cemetery sequence. All dates used in this paper are calculated at the 2 sigma level using the OxCal programme of Stuiver et al. (1998).

The revisions to the cemetery sequences developed on the basis of the investigations outlined above has enabled a more considered investigation of the skeletal database across the period 10,000 to ca 3,500 BC (Lillie, 1998c). To date, evidence for cranial surgery has been obtained from three cemeteries within the Dnieper Rapids sequence. These sites are:

- Vasilyevka III dated to 10,230–9,035 cal BC (OxA-3807, 3808, and 3809)
- Vasilyevka II dated to 7,300–6,220 cal BC (6,900–6,250 BC when recalibrated, see below) (OxA-3804, 3805, and 3806)
- Vovnigi II dated to 5,470–4,783 cal BC (OxA-5938, 5939, and 5940)

They occupy what are effectively Epipalaeolithic, late Mesolithic and earlier Neolithic chronological positions in the Holocene evolution of the cultures that exploited the rich riparian zone of the Dnieper River system.

The region under consideration has been the subject of continued analyses into the general pathology and diet of these populations across the period ca 10,000–4,500 BC (Lillie, 1998b). To date, the study of 310 individuals from the cemeteries spanning the Epipalaeolithic through to Eneolithic/Copper Age periods in the Dnieper Rapids region has been carried out. During the analysis of the palaeopathology of these populations a range of dental pathologies such as caries levels, dental calculus expression and rates of enamel hypoplasia were investigated on the intra- and inter-cemetery levels of analysis.

The analysis of the incidence of dental pathologies such as dental caries and dental calculus (which, in turn, reflect the relative frequencies of carbohydrates versus proteins in the diet), ante-mortem tooth loss and abscesses, coupled with general systemic stress indicators such as enamel hypoplasias and the more specific stress indicator, porotic hyperostosis (indicative of an anaemic disorder), have been used in numerous investigations of the transition from food extraction to food production economies. These analyses have been carried out in both archaeological and modern ethnographic contexts (Alexandersen, 1988; Angel, 1966; Frayer, 1987; Goodman et al*.,* 1984; Larsen et al*.,* 1991; Littleton and Frohlich, 1993; Lubell et al., 1994; Macchiarelli, 1989; Meiklejohn et al*.,* 1988; Meiklejohn and Zvelebil, 1991; Molnar and Molnar, 1985; y'Edynak, 1978, 1989). The pathologies studied can be used to enhance the general picture of the dietary spectrum exploited by the human populations of the Dnieper Rapids region across both Mesolithic and Neolithic periods (Lubell et al., 1994).

The available evidence has shown that these populations exploited protein-rich dietary pathways with little evidence to suggest a shift towards food production societies. In essence we are looking at a continuation of a fisher-hunter-gatherer lifestyle across the Lateglacial and much of the earlier part of the Holocene from at least 10,000 BC through to 4,500 BC as a minimum estimate.

Support for these observations is found in recent stable isotope research by (Lillie, 1998b), and Lillie and Richards (in press). This research has suggested that fish formed a significant part of the subsistence economy. Indeed, the location of numerous, large, early to mid-Holocene cemeteries on the high loess terraces of the major rivers such as the Pripyat and Dnieper would support this observation. In addition, the inclusion of fish tooth pendants in the burial inventories, and other artefactual evidence such as finds of bone used as harpoons, fish-hooks and stone net sinkers (Telegin and Potekhina, 1987), all attest the role of fishing in the economy of the populations that exploited the Nadporozhe region. Telegin (1987) has often emphasised the role of fishing in this region, and reports that the Dnieper (prior to the construction of six major reservoirs, [Kiev, Kanev, Kremenchug, Dniprodzerdzin, Zaporozhie and Kakhovka] along its course) was resource-rich in terms of such freshwater species as carp and pearl roach.

Further support for the dietary spectrum comes from sites such as Dereivka (Telegin, 1986), which provides some valuable insights into the potential range of fish and animal species that were available for exploitation by the indigenous populations of the region. As noted by O'Connell et al. (2000, p. 307), in addition to horse and dog, species such as waterfowl, otter, beaver, European pond terrapin (*Emys orbicularis*), European catfish (*Siluris glanis*), asp (*Aspius aspius*), pike (*Esox lucius*), zander (*Lucioperca lucioperca*), rudd (*Scardinius erhythropthalamus*), mussel (*Unio*) and river snail (*Viviparus* sp.) are all attested in Telegin's faunal report from this site.

From a dietary perspective, Nuzhnyi (1998, p. 103–3) suggests that at the Pleistocene-

Holocene boundary, the populations of this region followed a hunting strategy focussed on the "mass drive hunting" of bison (*Bison priscus*) in the late Pleistocene, with a shift to auroch (*Bos primigenius*) (amongst others) in the Mesolithic period. The focus on large herd animals, which resulted in a degree of technological continuity across these periods, also left these populations susceptible to an economy that was both seasonally and climatically determined (ibid., 1998). According to Nuzhnyi these populations experienced periodic food "crises" that resulted in episodic phases of intensive exploitation of aquatic resources (1998, p. 104).

There is considerable evidence from the cemeteries of this period, sites such as Voloshkoe, Vasilyevka I and III, for conflict in the region of the Dnieper Rapids, where access to fish resources resulted in what Nuzhnyi terms "possessive competition" (1998, p. 104). While the evidence for such conflict does not persist into the later Mesolithic and subsequent Neolithic periods, the emphasis on fishing as an integral element of the dietary spectrum does (Lillie and Richards, in press). In fact, the available evidence would suggest that fishing is a primary food resource. If Nuzhnyi (1998) is correct in asserting the existence of periodic food "crises" and a concomitant emphasis on fish as a more stable resource, albeit periodically, then the stable isotopic evidence for the later Mesolithic and Neolithic periods would indicate that this element of the economy had come to dominate food procurement strategies within the Mesolithic period. This stable resource base may provide an insight into the occurrence of such large cemeteries from the Late Pleistocene onwards in the Dnieper Rapids, in that such sites will have provided ancestral legitimisation to the access of these resources.

Given this background, the Dnieper Rapids cemeteries have provided a considerable, and quite unique resource, for use in the study of the populations exploiting this region of Ukraine. Over 1,000 individuals were interred in these cemeteries across the Late Pleistocene and Holocene periods up to at least ca 3,500 BC. Consideration of the pathologies in evidence on the skeletal remains of these fisher-hunter-gatherers by the current author and Professor I.I. Gokhman of the Museum of Anthropology and Ethnography, St. Petersburg, Russia has resulted in the identification of a number of trepanned crania from three of the cemeteries of this region. The details of these analyses are presented below, with a consideration of the earliest through to youngest cemeteries spanning the Epipaleolithic through to Neolithic undertaken, in order to outline the evidence chronologically.

Vasilyevka III

The earliest example of trepanation in the Dnieper Rapids region has been identified by Gokhman on individual 31 from Vasilyevka III. This particular site was uncovered by Danilenko in 1953. It is located on the left bank of the Dnieper, on the slope of the third terrace (Konduktorova, 1974:9). Excavations by Telegin in 1957 and 1962 led to the discovery of 44 graves at this cemetery. Thirty seven of the graves at this site were in the crouched (flexed) position while seven were extended. As extended burial originally characterised "Neolithic" burial rituals in the periodisation of these cemeteries, the extended burials were recorded as such. This led to individual 31 being interpreted as being of Neolithic age. New radiocarbon dates obtained by Jacobs (1993) have allowed us to refine this chronological position. Individual 33, buried in the same group as individual 31 has been dated to 10,060±105 uncal BP (OxA-3807). When calibrated, this gives an age range of 10,212–9,047 cal BC for the extended burials at this cemetery site.

In this example, the trepanation (Plate 1a) is located on the left side of the vault on the parietal, ca 20 mm above the junction of the temporal/lamboid sutures (Asterion) (Plate 1b). Gokhman (1966, p. 25) asserts that this is undoubtedly an artificially produced opening. The aperture is 9 mm in diameter, and it appears to have originally formed a circular opening, with some suggestion of ante mortem damage having occurred at the upper limits of the aperture resulting in a more rectangular outline similar to that from Vasilyevka II (Plate 3). The limited evidence for remodelling around the margins of the trepanation led Gokhman to suggest that the surgery was performed immediately prior to the death of the subject (1966, p. 25). Arguing against the aperture having been formed by a projectile point, Gokhman notes the completely level, regular way in which the area has been cut in from the outer margins of the vault (ibid., 1966). This aperture is thus formed in a similar way to the conical shape occurring in the later examples from Vasilyevka II and Vovnigi, as outlined below.

Vasilyevka II

The second example considered here consists of a healed trepanation occurring on the cranium of a male individual from the site of Vasilyevka II in the Dnieper Rapids region (Fig. 1). The Vasilyevka II cemetery is situated on the left bank of the Dnieper, near the village of Vasilyevka. This cemetery was originally investigated by Stolyar in 1953, at which time 27 graves were unearthed (Konduktorova, 1973, p. 13). On the basis of typological considerations, this cemetery had previously been assigned a Neolithic periodisation by Telegin (1987).

Research by Jacobs (1994) originally indicated that the actual age of the cemetery spanned the period 7,300–6,220 BC. In Telegin's (1987) scheme this would make Vasilyevka II a fully Late Mesolithic cemetery. Allowing for the possibilities of a "reservoir effect" in the ageing of the skeletal remains from Vasilyevka II (cf. Cook et al., nd, Lanting and van der Plicht, 1998), the radiocarbon ages were recalculated using a 300 year offset. This was undertaken due to the fact that the consumption of freshwater fish by the populations of the Dnieper region at this time may result in age estimations that are between 300–500 years too old. It should be noted at this juncture that despite the consumption of freshwater fish, we can not assume *a priori* that these dietary patterns immediately create this "reservoir effect" without associated faunal or charcoal materials for use in comparative dating (*contra* Lanting and van der Plicht, 1998, p. 160–1). However, for the purpose of confirming the "real" antiquity of the healed trepanation as reported, the calculations are undertaken here for Vasilyevka II.

Even when allowing a 300 year offset, the calibrated determinations for Vasilyevka II indicate an age range of 6,900–6,250 BC, i.e., still well within the Late Mesolithic period. If calculated with a 500 year offset, Vasilyevka II remains predominantly within a Late Mesolithic periodisation at 6,510–5,800 BC. This would confirm the conclu-

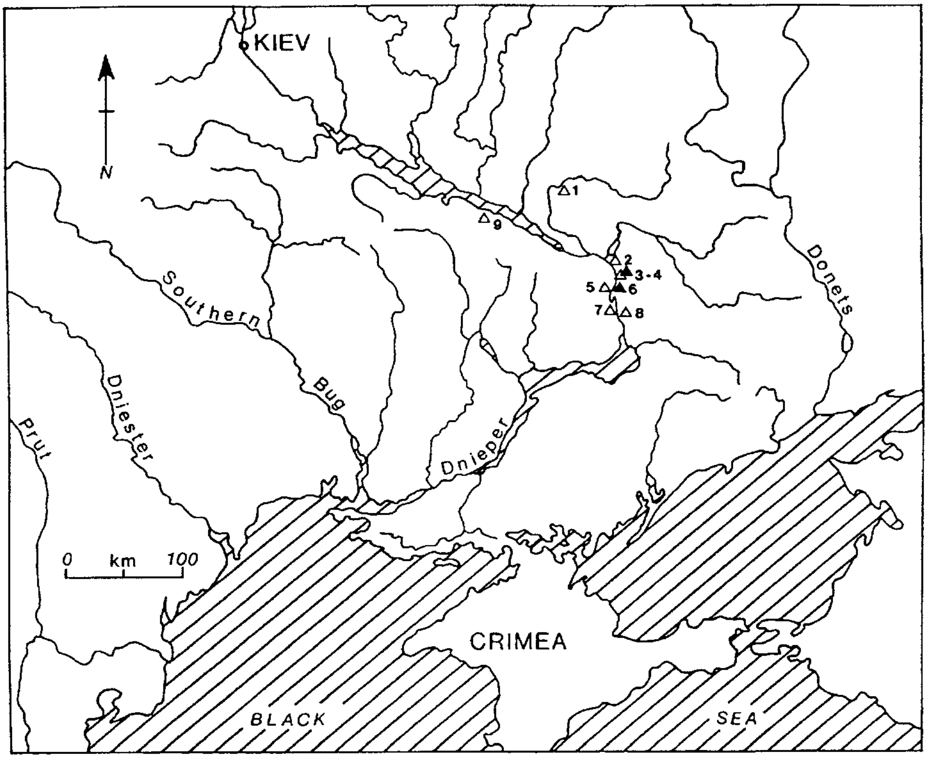


Figure 1. The Dnieper Rapids region, showing location of cemeteries discussed in text. 1. Osipovka, 2. Igren VIII, 3. Vasilyevka V, 4. Vasilyevka III and II, 5. Nikolskoye, 6. Marievka, 7. Vovnigi II, 8. Yasinovatka, 9. Dereivka I and II. ▲ = Mesolithic, △ = Neolithic.

Plate 1a. Trepanation on the left side of the cranium of individual No. 31, an adult male, from the cemetery site of Vasilyevka III (Gokhman, 1966). Used with permission of the author.

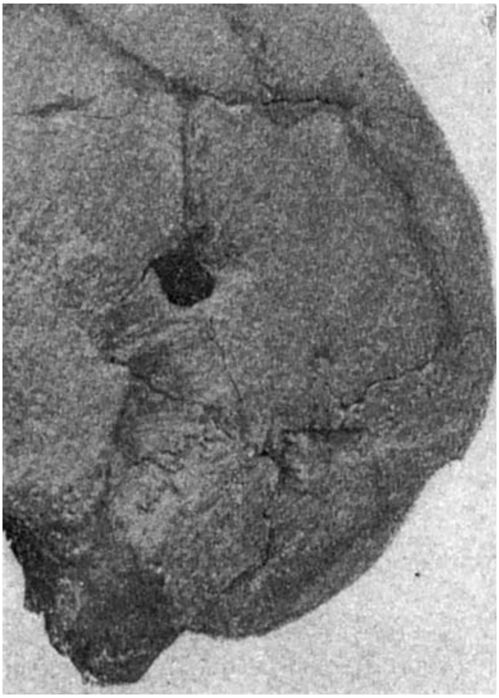


Plate 1b. Close-up of aperture on the cranium of individual No. 31 from the cemetery of Vasilyevka III (Gokhman, 1966). Used with permission of the author.

sions of Lillie (1998a), that this particular example represents the earliest known example of an healed trepanation identified to date from the European mainland.

The individual in question (Plate 2a) is identified as a male (No.6285–9), aged ca 50 years at death. The trepanation is a healed lesion located on the left side of the frontal at a point ca 15 mm anterior to the coronal suture and 30 mm to the left of the sagittal suture. As can be seen from the photograph (Plate 2b), the aperture has a pronounced raised border of remodelled bone, and "stepping" in the central area of the aperture. The central area of the depression is in the region of 6 mm in diameter. The remodelled bone that closes the innermost portion of the aperture is less than 1 mm in thickness.

Whilst the remodelling on skeleton No.6285-9 serves to obscure the evidence for the method used to remove the bone, it appears likely that drilling using a worked flint point would have been the method employed (cf. Lisowski, 1967). That this method was in fact employed is supported by an example from the later, Neolithic, trepanation at the cemetery of Vovnigi II, described below.

An additional trepanation is reported by Gokhman (1966, p. 98–9) as occurring on the left side of the vault of individual No.6285-10, an adult male (Plate 3). This example is visible in the centre of the radiograph as an aperture described by Gokhman as being on the left side of the vault and ca 5 mm in diameter (1966, p. 98). No photograph of this example is available for comparison, and while this individual was not available for study in 1993–5, the description appears to contrast with that outlined above for individ-

Plate 2a. Front view of the healed trepanation on individual No. 6285–9, an adult male, from the cemetery of Vasilyevka II (Lillie, 1998). © Macmillan Magazines Ltd (used with permission).

Plate 2b. Superior-lateral view of area of remodelled bone on individual No. 6285–9 from Vasilyevka II. Note the complete closure of the aperture and the "stepperd" nature of the progressive stages of healing (Lillie, 1998). © Macmillan Magazines Ltd (used with permission).

Plate 3. Radiograph of the trepanation on individual No. 6285–10, an adult male from the cemetery of Vasilyevka II.

ual 6285-9. In light of the fact that 6285-10 was unavailable for analysis, and until this can be investigated, the irregular form of this "large" aperture as described by Gokhman remains to be confirmed, and as such no further interpretation of this particular trepanation can be offered here.

Vovnigi II

This cemetery, located on the right bank of the Dnieper, is one of the largest cemeteries in the Dnieper Rapids region containing some 130 burials. Of the original 130 burials recovered during excavation, burials 2–43 are currently housed in St. Petersburg, and were investigated by the present author. The trepanned individual, reported by Gokhman (1966, p. 142) is that of an adult male (Plates 4a and 4b) from a cemetery complex that is dated to between 5,480–4,700 BC (6,320±80 to 6,090±100 BP – OxA-5938 and 5940).

As can clearly be seen from Figure 4, the trepanation on individual No.54 is an unhealed example occurring on the sagittal suture about 20 mm above the coronal suture (Lillie, 1998a). The bone defect on the outer part of the vault is a relatively regular, circular shape. It is 14 mm in diameter, and on the internal plate the hole is irregular in plan, resembling a rhombus. According to Gokhman (1966), the diploë is completely closed around the aperture and the edges of the internal plate are thin, exhibiting the scratches made during the drilling operation (ibid., 1998a).

An additional value of this later trepanation lies in the confirmation of the duration

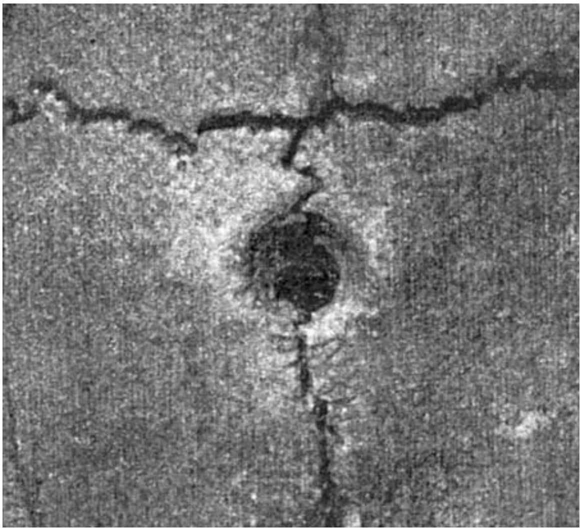


Plate 4a. Superior view of the unhealed trepanation on the cranium of individual No. 54, an adult male, from the cemetery of Vovnigi II (Gokhman, 1966). Used with permission of the author.

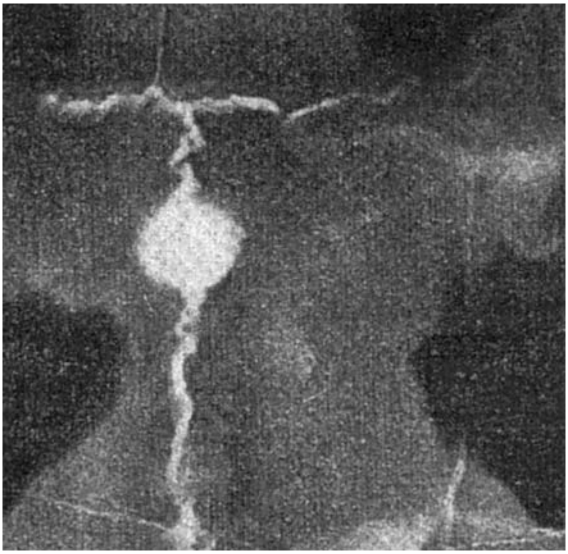


Plate 4b. Radiograph of the trepanation from individual No. 54 from the cemetery of Vovnigi II, highlighting the absence of remodelled bone (Gokhman, 1966). Used with permission of the author.

of the use of this particular procedure across the later Mesolithic and Neolithic periods in this region, with the evidence from Vasilyevka III suggesting an even earlier genesis. While also lending support to the earlier observations from Vasilyevka II, the Vovnigi II lesion does not exhibit the same degree of remodelling as evidenced by individual No.6285–9 from Vasilyevka II, suggesting that the individual did not survive for any great length of time after the surgery was carried out.

Discussion

The trepanations presented in this paper represent the accumulation of evidence over more than three decades, with the preliminary reporting of this material in the Russian literature being carried out by Gokhman in 1966. More recently Lillie (1998a) highlighted the fact that the new dating for the cemeteries of the Dnieper Rapids region (Jacobs, 1993, 1994; Lillie, 1996, 1998b,c) would make the healed trepanation from the cemetery of Vasilyevka II the earliest example from the European mainland. In addition it is clear from the available evidence that considerable continuity in methodology with regards the *intra vitam* surgical operation is attested by the examples presented in this outline.

A study of the available literature on trepanation identifies numerous reasons behind the performance of the operation, with cranial fractures and intracranial blood clots (both epidural or subdural haematoma), occurring as legitimate medical reasons. Alternatively surgery could have been for more spiritual reasons such as the exorcism of the evil spirits associated with brain disorders (e.g. Bennike, 1985; Grmek, 1989; Lisowski, 1967; Margetts, 1967). Lisowski (1967, p. 651–72) cites examples of trepanation from 26 European, five Asian and four African countries, with a similarly extensive range of evidence being presented by Stuart Piggott as early as 1940.

There are few examples of the extensive, and healed cranial surgery outlined by Alt et al. (1997, p. 360) from the site of Ensisheim (Alsace) in the anthropological record. Indeed, the evidence from Vasilyevka II, presented above is in no way comparable to the scale of healing in evidence from Alt et al.'s Neolithic example. However, the significance of the Vasilyevka II trepanation lies in its chronological position at 7,300–6,220 cal BC. Even where a correction factor is employed in order to allow for the possibilities of a "reservoir effect" in the ageing of skeletal remains of humans consuming high freshwater fish diets, the radiocarbon dating places this example at 6,900–6,250 BC with a 300-year offset, and 6,510–5,800 BC with a 500-year offset. These dates remain in excess of 700 years earlier than the dates of 5,100–4,900 BC given by Alt et al. for the Ensisheim example, as a minimum estimate (1997, p. 360).

The intrusive surgery in evidence on the skeletal remains from Vasilyevka III, and particularly Vasilyevka II, is also of note due to its having been carried out by earlier Holocene populations exploiting fisher-hunter-gatherer lifeways. Even at Vovnigi, these populations remain in a similar food extraction mode, but unusually they adopt a surgical procedure that has its genesis at the Lateglacial-Holocene transition site of Vasilyevka III. The technique of drilling the aperture using a flint borer, which produces a hole parallel to the surface of the vault, with a bevelled cross section and very similar internal diameter displays considerable internal continuity in approach across some 4,000 radiocarbon years between ca 10,000 and 4,700 BC.

Conclusions

Cranial surgery has been carried out on the populations of the Dnieper Rapids region of Ukraine since the Epipalaeolithic period at 10,000 BC. At the end of the Mesolithic period at ca 7–6,000 BC cranial surgery was carried out on an adult male from the cemetery site of Vasilyevka II. This particular individual is currently exceptional in the European skeletal record as the earliest evidence for the fact that the patient clearly survived the surgery, with complete closure of the aperture in evidence, and lived to ca 50 years of age prior to his death. While the surgery is of relatively small extent, especially when compared to the example presented by Alt et al. (1997, p. 360), the continuities in methodology indicated by comparisons between the cemeteries of Vasilyevka III, Vasilyevka II and Vovnigi II, are remarkable.

As noted by Lillie (1998a), in the absence of absolute dating for numerous skeletal remains from the European mainland, it is not unrealistic to suppose that even earlier examples await "discovery". New dating of the skeletal remains from the Dnieper Rapids region by Jacobs (1993, 1994) and Lillie (1996, 1998b,c), led to the identification of the examples reported here. Were it not for this dating, these examples, and in particular the healed trepanation from Vasilyevka II, would have remained in a "Neolithic" periodisation, thereby subsuming their significance to our understanding of the age and genesis of Holocene cranial surgery procedures.

Acknowledgements

The author would like to extend his considerable gratitude to Professor Dimitri Telegin and Dr. Inna Potekhina of the Ukrainian Academy of Sciences, Kiev, Ukraine. Also, Professor Gokhman, and Dr. Alexander Kozintsev, Museum of Anthropology and Ethnography and Professor Dimitri Timofeev, Department of Palaeolithic Studies, St. Petersburg, Russia for invaluable assistance during his research visits to eastern Europe. In addition, Professor Gokhman is thanked for giving permission for the use of the following plates: 1a and b, 3, 4a and 4b. Any errors and/or omissions are solely the responsibility of the author.

References

Alexandersen V (1988): Description of the Human Dentitions from the Late Mesolithic Grave-Fields at Skateholm, Southern Sweden. In: Larsson L, ed*., The Skateholm Project: Man and Environment*. Sweden, Almqvist & Wiksell Int, pp. 106–63.

Alt KW, Jeunesse C, Buitrago-Téllez CH, Wächter R, Boës E, Pichler SL (1997): Evidence for stone age cranial surgery. *Nature 387*:360.

Angel JL (1966): Porotic Hyperostosis, Anemias, Malarias, and Marshes in the Prehistoric Eastern Mediterranean. *Science 153*:760–3.

Bennike P (1985): *Palaeopathology of Danish skeletons: A Comparative Study of De-*

mography, Disease and Injury. Denmark, Akademisk Forlag, pp. 65–90.

Brinch Petersen PS, Meiklejohn C (in press): Paradigm Lost? Intensification, Sedentism and Burial Practice in Southern Scandinavia: Some Questions and Suggestions. In: Janik L, Kaner S, Rowley-Conwy P, eds., *From the Jomon to Star Carr: Holocene Hunyters and Gatherers in Temperate Eurasia.*

Cook GT, Bonsall C, Hedges REM, McSweeney K, Borneant V, Pettitt PB (nd): A Freshwater Diet-Derived ^{14}C Reservoir Effect at the Stone Age Sites in the Iron Gates Gorge. Paper presented at the 17th International Radiocarbon Conference held 18–23 June, 2000 at Judean Hills, Israel.

Frayer DW (1987): Caries and Oral Pathologies at the Mesolithic Sites of Muge: Cabeço Da Arrunda and Moita Do Sebastião. *Trab Antropl Etnol 27* (fasc. 1–4):9–25.

Goodman AH, Armelagos GJ, Rose JC (1984): The Chronological Distribution of Enamel Hypoplasias from Prehistoric Dickson Mounds Populations. *Am J Phys Anthropol 65*:259–66.

Grmek MD (1989): *Disease in the Ancient Greek World* (English Translation). London, John Hopkins University Press, pp. 63–5.

Gokhman II (1966*): Naselenie Ukrainy v Epokhu Mezolita I Neolita: Antropogicheskiy Ocherk.* Nauka, Moscow.

Jacobs K (1993) Human Postcranial Variation in the Ukrainian Mesolithic-Neolithic. *Curr Anthropol 34*:417–30.

Jacobs K (1994): Reply to Anthony "On Subsistence Change at the Mesolithic-Neolithic Transition". *Curr Anthropol 35*:52–9.

Konduktorova TS (1974): The Ancient Populations of Ukraine: from the Mesolithic Age to the first Centuries of our Era. *Anthropologie BRNO XII* (1&2): 5–149.

Larsen CS, Shavit R, Griffin MC (1991): Dental Caries Evidence for Dietary Change: An archaeological context. In: Kelley MA, Larsen CS, eds., *Advances in Dental Anthropology*. New York, Wiley Liss, pp. 179–202.

Lanting JN, van der Plicht (1998): Reservoir Effects and Apparent 14C Ages. *J Irish Archaeol IX*: 151–65.

Lillie MC (1996): Mesolithic and Neolithic Populations of Ukraine: Indications of Diet from Dental Pathology. *Curr Anthropol 37*: 135–42.

Lillie MC (1998a): Cranial surgery dates back to Mesolithic. *Nature 391*:854.

Lillie MC (1998b): *The Dnieper Rapids region of Ukraine: a consideration of chronology, dental pathology and diet at the Mesolithic-Neolithic transition*. Sheffield University: Unpublished PhD thesis.

Lillie MC (1998c): The Mesolithic-Neolithic transition in Ukraine: new radiocarbon determinations for the cemeteries of the Dnieper Rapids region. *Antiquity 72*:184–88.

Lillie MC, Richards MP (2000): Stable Isotope Analysis and Dental Evidence of Diet at the Mesolithic-Neolithic Transition in Ukraine. *J Archaeol Sci*.

Lisowski FP (1967): Prehistoric and early Historic trepanation, In: Brothwell D, Sandison AT, eds., *Diseases in Antiquity: A Survey of Diseases, Injuries and Surgery of Early Populations*. Illinois, C.C. Thomas, pp. 651–72.

Littleton, J, Frohlich B (1993): Fish-Eaters and Farmers: Dental Pathology in the Arabian Gulf. *Am J Phys Anthropol 92*:427–47.

Lubell D, Jackes M, Schwarcz H, Knyf M, Meiklejohn C (1994): The Mesolithic-Neolithic Transition in Portugal: Isotopic and dental evidence of diet. *J Archaeol Sci 21*:201–16.

Macchiarelli R (1989): Prehistoric "Fish-Eaters" Along the Eastern Arabian Coasts: Dental variation, morphology, and oral health in the Ra's al-Hamra community (Qurum, Sultanate of Oman, 5th-4th Millennia BC). *Am J Phys Anthropol 78*:575–94.

Margetts EI (1967): Trepanation of the skull by the medicine-men of primitive cultures, with particular reference to present-day native East African practice. In Brothwell D, Sandison, AT, eds*., Diseases in Antiquity: A Survey of Diseases, Injuries and Surgery of Early Populations*. Illinois, C.C. Thomas, pp. 673–701.

Meiklejohn C, Zvelebil M (1991): Health Status of European Populations at the Agricultural Transition and the Implications for the Adoption of Farming. In Bush H, Zvelebil M, eds., *Health in Past Societies: Biocultural Interpretations of Human Skeletal Remains in Archaeological Contexts.* Oxford: B.A.R. (Int. Ser.) 567:129–44.

Meiklejohn C, Baldwin JH, Schentag, CT (1988): Caries as a Probable Dietary Marker in the Western European Mesolithic. In Kennedy BV, LeMoine GM, eds*., Diet and Subsistence: Current Archaeological Perspectives*. Calgary Univ. Press, Proc. 19th. Chacmool Conf., pp. 273–9.

Molnar S, Molnar I (1985): Observations of Dental Diseases Among Prehistoric Populations of Hungary. *Am J Phys Anthropol 67:*51–63.

Nuzhnyi D (1998): The Ukrainian steppe as a region of intercultural contacts between Atlantic and Mediterranean zones of European Mesolithic. In: Domanska L, Jacobs K, eds., *Beyond Balkanisation*, Poland. *Baltic-Pontic Studies 5*: 102–19.

Piggott S (1940): A trepanned skull of the Beaker period from Dorset and the practice of trepanning in Prehistoric Europe. *Proc Prehist Soc 6:* 112–32.

O'Connell TC, Levine MA, Hedges REM (2000): The importance of fish in the diet of central Eurasian peoples from the Mesolithic to the Early Iron Age. In: *Late Prehistoric Exploitation of the Eurasian Steppe II*. Cambridge, McDonald Institute for Archaeological Research, pp. 303–27. (Conference Abstracts).

Stuiver M, Reimer PJ, Bard E, Beck JW, Burr GS, Hughen KA, Kromer B, McCormac G, Van der Plicht J, Spurk M (1998): INTCAL98 Radiocarbon Age Calibration, 24000–0 cal BP. *Radiocarbon 40*: 1041–83.

Telegin DYa (1968): *Dnipro-Donetska Kultura* (The Dnieper-Donets Culture). Kiev, Naukova Dumka, pp.248–54.

Telegin DYa (1982): *Mesolithichni Pamyatki Ukraine (9–6 tisyacholitta do n.e.)* [Mesolithic monuments of Ukraine]. Kiev, Naukova Dumka.

Telegin DYa (1968). *Dnipro-Donetska Kultura* (The Dnieper-Donets Culture). Kiev, Naukova Dumka, pp.248–54.

Telegin DYa (1987): Neolithic cultures of the Ukraine and adjacent areas and their chronology. *J World Prehist 1* (3): 307–31.

Telegin DYa Potekhina ID, (1987*): Neolithic Cemeteries and Populations in the Dnieper Basin.* B.A.R. Int. Ser., *383*.

y'Edynak G (1978): Culture, Diet, and Dental Reduction in Mesolithic Forager-Fishers of Yugoslavia. *Curr Anthropol 19* (3):616.

y'Edynak G (1989): Yugoslav Mesolithic Dental Reduction. *Am J Phys Anthropol 78*: 17–36.

Part 3: Trepanation in Africa, Asia and The Americas

"*There is no doubt that trepanations occurred by the Iron Age in Mongolia, but where did the surgical influence come from?*"

N. Bazarsad (this volume)

"*A significant percentage of Peruvian skulls show evidence of healing, indicating survival following the procedure*"

J.W. Verano (this volume)

Chapter 14

Perforating Skull Trauma in Ancient Egypt and Evidence for Early Neurosurgical Therapy

ANDREAS G. NERLICH[1], ALBERT ZINK[1], ULRIKE SZEIMIES[2], HJALMAR G. HAGEDORN[3] AND FRIEDRICH W. RÖSING[4]
[1]Pathologisches Institut, Ludwig-Maximilians-Universität München, München, Germany; [2]Institut für diagnostische Radiologie, Ludwig-Maximilians-Universität München, München, Germany; [3]Klinik für HNO-Kranke, Ludwig-Maximilians-Universität München, München, Germany; [4]Institut für Humangenetik und Anthropologietätsklinikum Ulm, Ulm, Germany

Abstract

Trauma sequelae of the skull are frequent findings in ancient Egyptian human remains. In contrast, there exists as yet no previous convincing evidence that the ancient Egyptians practised “neurosurgery“ or trepanation either for medico-therapeutical or for religious reasons. In two large series of mummies and skeletons originating from the necropoles of Thebes-West and Qubbet-el-Hawa/Elephantine in Aswan we observed a total of 10 examples of perforating osseous skull lesions due to severe external impact. Four cases were recovered from the Theban necropolis; six came from the cemeteries of Aswan. Nine of those cases provided evidence for a longer survival after the trauma. In one example, we provide additional evidence that a neurosurgical intervention may have removed fracture fragments from the defect.

The four Theban cases showed osseous defects of the skull (twice affecting the occipital region, twice the parietal region) with round to oval defects and infundibular widening at the inner skull tabula. One case revealed an intact covering layer of subcutaneous connective tissue with reddish coloration suggesting bleeding residues, but without signs of osseous healing. Two cases presented extensive reactive new bone formation indicating survival for a considerable period of time. The fourth case showed in computed tomography and endoscopy a larger osseous defect of the left parietal bone, which was covered intracranially by an intact layer of adherent dura mater and an intact outer layer of connective tissue, hair and intact linen bindings. Since there were signs of osseous remodelling, we suppose that this was an intravital traumatic lesion. The lack of any osseous fragment suggests their therapeutic removal. This may indeed have been therapeutically justified, because the trauma might have otherwise led to epidural haematoma.

We thus provide initial evidence that the ancient Egyptians practised “neurosurgery”. The lack of cases with clear evidence for trepanation suggests that this procedure was not performed in ancient Egypt due to ethical, practical or religious reasons; there might have been professional counter-indications: the medical Papyri show that the ancient Egyptian practitioner well knew success rates and therefore often decided not to treat an ailment. Much of this knowledge, however, was only theoretical, traces of factual surgical interventions remain very rare.

Keywords: Ancient Egypt, trepanation, skull trauma

Introduction

The palaeopathological analysis of skeletal material from various historical populations provides evidence for traumata *(residue ist ein Rückstand oä und nicht ein Beleg oä)* even dating back to very early human populations, such as the Neandertal individuals. In addition, previous studies suggest that the sequels of trauma were not infrequent findings in various historic populations. This holds particularly true for ancient Egyptian and Nubian skeletal material, where fractures of various skeletal regions have been recorded (Wood and Jones, 1908; Chamla 1967; Winkler and Wilfing 1991; Molleson 1993; Nunn, 1996; Nerlich 1997; Alvrus, 1999; Nerlich et al., 2000).

Our own previous investigations on the human remains of one of the largest necropoles of the period, between the New Kingdom and the Late Period (ca 1,500–500 BC), revealed frequencies of 10–25 % of healed trauma lesions that had manifested in bone (Nerlich et al., 2000). Similar frequencies have been observed in other ancient populations, e.g. 18% in a Nubian population of comparable time (Alvrus, 1999). A comparably high frequency has also been recorded for the largest ancient Egyptian population analyzed so far (Rösing 1990), from the necropoles of Assuan (Qubbet-el-Hawa and Elephantine), where a total of 116 posttraumatic lesions in more than 1,000 individuals was identified. Furthermore, the hitherto most extensive study of human remains in Nubia – published in 1908 by Elliot Smith and Warren Dawson – described 200 healed fractures in 6,000 individuals. However, since this study had been performed at the beginning of palaeopathology, it remains unsure whether all diagnoses were established correctly and whether all small injury traces were found. Furthermore, not included in those observations are non-healed traumatic lesions that are difficult to be distinguished from postmortal fractures, e.g. by grave robberies. Such fresh fractures are best recognizable when therapeutic measures are found, e.g. wooden splints (Smith and Dawson, 1924).

Traumatic lesions of the skulls comprise a considerable proportion of those pathological alterations. As with the other healed fractures, there exists only limited data on the frequency of these skull lesions, in particular those with perforations of the skull vault. However, due to the more robust and more complicated structure of the skull, perimortal injuries are much easier to distinguish from artificial postmortal destruction. The previous few studies on this subject reported frequencies of 7.5 % of all trauma traces (Smith and Jones, 1908). We therefore focus in the present paper on the occurence and frequency of traumatic skull lesions in well-defined and well-studied populations of ancient Egypt, with particular reference to the necropoles of Thebes, the capital of ancient Egypt during one of its most prosperous times, and Aswan, the border city of the core of the ancient Egyptian kingdom.

In addition, we provide the first evidence that beyond the theoretical knowledge of skull trauma – as deduced from the Smith Papyrus (Breasted, 1930) – the ancient Egyptians occasionally practised "neurosurgery", such as the removal of fracture fragments from an open skull wound. Thereby, the therapy of skull injuries can be assumed to have ranged at a higher standard, highlighting ancient Egyptian medical knowledge.

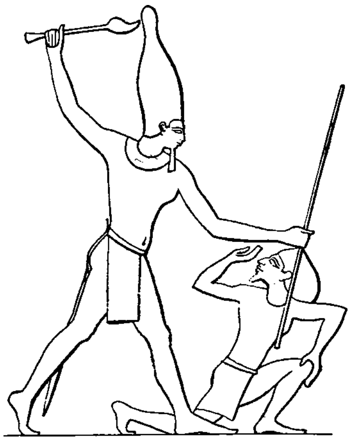


Figure 1. “The Pharaoh beats the enemy”. Drawing of a typical temple wall scene (Medinet Habu, Thebes-West) showing the typical mechanism leading to perforating skull injuries.

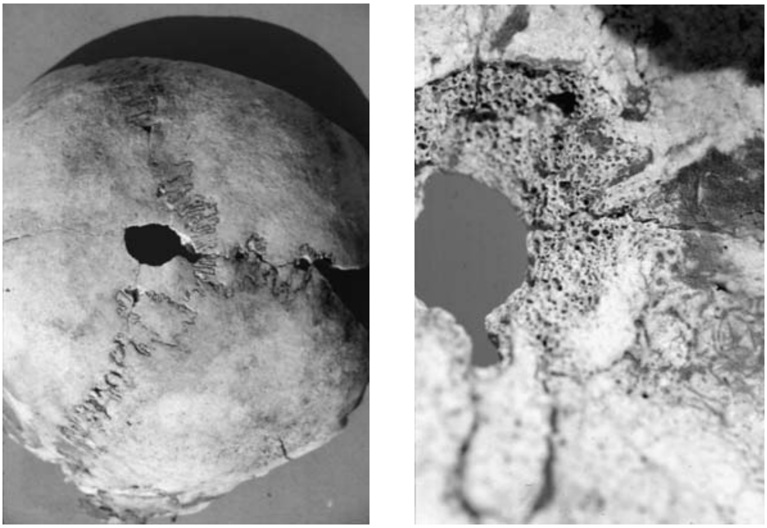
Material and Methods

Study Populations

The present study is composed of two parts: 1. estimation of the frequency of osseous defects due to severe skull trauma on the basis of two ancient Egyptian populations, including the morphology and type of lesion; 2. evidence for vitality of those defects, including signs of possible therapeutic intervention.

The two study populations come from major necropoles of ancient Egypt that harbour the human remains from Thebes-West and from Assuan. In detail, the first population represents the inhabitants of a capital of ancient Egypt, Thebes, that have been buried in the “tombs of the nobles” and comprise a socially upper-class population. This necropolis was mainly used during the period of the New Kingdom and subsequent periods (ca 1,500–500 BC). Several tombs have been excavated from this necropolis, comprising a total of at least 566 reconstructed individuals (Nerlich et al., 2000). A fairly balanced sex ratio was recorded for this study population. In addition, the age ratio suggested a relatively low life expectancy, with most individuals dying between 20 and 30 years of age (Nerlich et al., 2000). To this study population we added one case where the skull had previously been brought from the Theban necropolis to Germany in the 1960s. This skull is now housed in the Franz-Parsche-collection of Egyptian mummy remains of the Institute of Pathology of the Ludwig-Maximilians-University, Munich. There exists no further archaeological information on the individual.

The second study population comes from the human remains of the necropoles of Qubbet-el-Hawa and Elephantine, two large cemetaries containing the burials of upper and middle class people of the province capital of Assuan from the Old Kingdom until the late period (ca 3,000–500 BC). A total of 1,482 individuals has been identified, which nonetheless represents just a small fraction of the individuals that have been



a b

Figure 2. Occipital defect in a skeletonized mummy skull fragment of a male individual. a. The external surface reveals an ovoid defect with sharp margins. b. The internal aspect in contrast shows infundibular widening of the defect and new bone formation at the defect margins.

buried in those necropoles (Rösing, 1990). Out of this over all study population, 982 skulls were available for evaluation. The demographic parameters of the Assuan population was similar to the Theban one with particular respect to the age and sex distribution. After correction for deaths in infancy, life expectancy amounted to 26 years.

Trauma Diagnosis Criteria

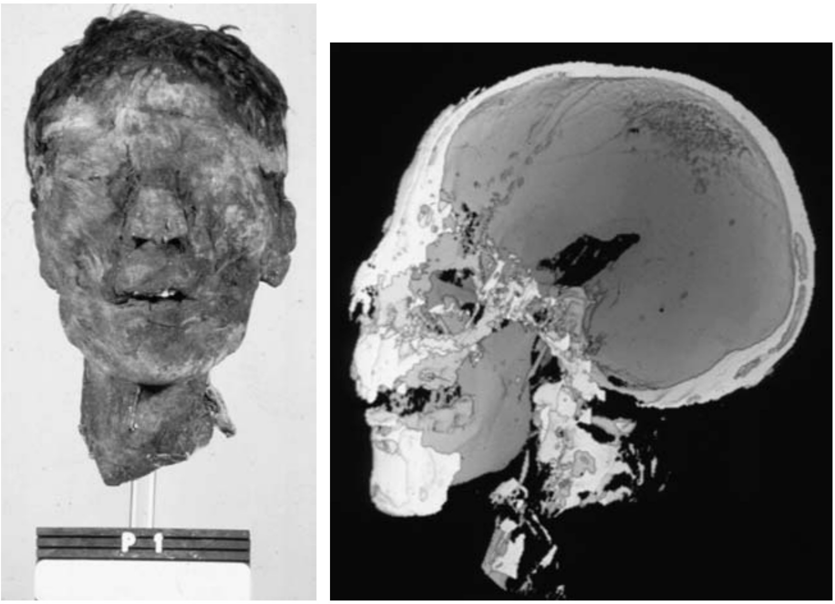
In order to establish the proper diagnosis, distinct criteria had to be applied. Thereby, several major different diagnoses – apart from general differential diagnostic considerations – had to be excluded. These comprised:

1. benign/malignant tumoral lesions
2. inflammatory lesions
3. biparietal thinning

A tumoral lesion was ruled out by the lack of the frequent multiplicity of tumoral processes (in particular in secondary malignant tumors which cover the most frequent tumor lesions), the massive internal and external appositional new bone formation induced by the (benign or malignant) tumor cells, and form and localization of tumoral lesions (mostly symmetric transosseous lesions with internally and externally irregular margins).

Methods for Analysis

In addition to the determination of general anthropological data as described in more detail in Rösing, 1990 and Nerlich et al., 2000, the material from these two populations



a b

Figure 3. Skull defect in an intact mummy head. a. The outer appearance shows an intact surface made up by soft tissue and few linen bindings. b. On CT scans, however, the left parietal zone reveals a defect with missing bone fragment(s). The defect margins are again infundibularly widened and show some minor bone reaction indicating an intravital lesion.

was carefully analyzed by macroscopy and all lesions suggestive of traumatic origin were recorded. In the Theban material, we also applied radiological and CT scan analyses in diagnostically unclear cases.

Results

Traumatic Skull Lesions In The Two Ancient Egyptian Populations

Skull lesions with perforation of the bone were observed in both populations. In the population from the Theban necropolis, four cases were identified, while in the Assuan population, six cases were recorded. On a populational basis this signifies in the Theban group approximately 0.7% and in the Assuan population 0.6% cases of perforating skull trauma defects in the analyzed population. This small difference is of course not significant (χ^2=0.0506, P=82%).

In addition to the perforating osseous skull defects, further types of healed skull trauma traces have been noted. These include non-perforating posttraumatic lesions of the skull and traumatic lesions of facial bones, such as nasal and zygomatic bones and others. Likewise, in the Assuan population of 982 skulls available for evaluation, 15 non-perforating lesions of the skull mostly due to severe external impact, 15 healed traumatic lesions of the nasal bones, and 12 of the zygomatic bones, were noted. In addition, three traumatic lesions of other types were recorded. Thus, the overall trauma rate in this population stood at 51 cases (5.2%). In the Theban population several findings suggested skull trauma without perforation of the skull bone. Thus, we noticed in this population four cases with healed fractures of the nasal bone, one fracture of the zygomatic arch, two cases with partial defects of the external tabula (such as caused by a sword beat), one small roundish impression farcture of the frontal skull (0.8 cm in diameter) and one case with a severe, though healed fracture of the mid-face (type LeFort III), thus yielding a population frequency of 1.6%

Types and Morphology of the Perforating Skull Trauma Lesions

The six Assuan cases with perforating skull lesions may be broken down according to the following anthropological and morphological observations: Four out of the six cases affected males, one lesion was seen in a female skull, and the sixth case was more likely to be male than female. Four cases (all males) were seen in young adults (20 – 35 years) and two affected mature adults (approx. 50–60 years) – here including the female case. According to the archaeological findings, most affected individuals belonged to an advanced social status.

Two cases (one large impression fracture of the occipital bone and one right parietal) represented large defects without evidence of healing reaction, while three further cases (three left parietal bones) showed marginal healing, smoothing of the defect margin, and focal but superficial new bone reaction. One additional left parietal defect revealed a large osseous defect without osseous reaction. However, since the superficial linen bindings protruded at the lesion site into the skull, it is fair to assume a perimortal lesion.

In the Theban population, all four cases showed osseous defects of the skull, twice affecting the occipital region and twice the parietal region, with round to oval defects and infundibular widening at the inner skull tabula. One case revealed an intact covering layer of subcutaneous connective tissue with redish coloration suggesting bleeding residues, but without signs of osseous healing (Case DAN 93.11-8). This lesion affected a mature male individual (Parsche et al., 1996). Two further cases presented typical lesions, one of the occipital (Case TT95-142), one of the parietal region (Case DAN 95.1-24). Both revealed smooth margins of the defects, a sensible infundibular widening and extensive reactive new bone formation at the inner table, indicating survival for a considerable period of time, amounting to several weeks. In one case a young female of about 20–25 years was affected; the other individual was approximately 30–40 years old, the individual's sex could not be determined (Nerlich et al., 2000).

Description of the Case with Evidence for Neurosurgical Therapy

This particular case was that of a mummified complete skull with intact external soft tissues that were largely covered by linen bindings (the case from the Franz-Parsche-

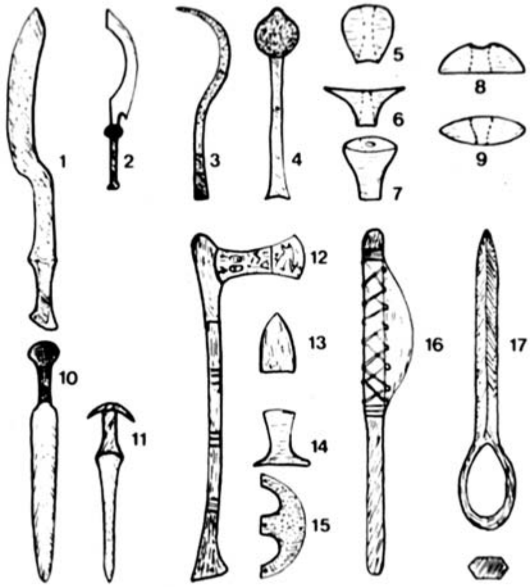


Figure 4. Some examples of the repertoire of ancient Egyptian weapons that may have been used for lethal strikes towards the skull.

collection, Case P1). In a pilot study for the application of CT scan for the investigation of mummies and mummy fragments, this sample had been subjected to an extensive analysis (Szeimies et al., 1999). This surprisingly showed an extensive osseous defect of the left parietal bone that was covered by an intact external layer of connective tissue, hair and linen bindings. The bone fragment(s) was (were) missing. At the defect margins, smoothening and focal slight new bone formation (signs of osseous repair) were seen. In addition, there was a fracture line running from the upper end of the defect into the parietal bone, and there was evidence for a fracture of the petrous bone. In order to evaluate these findings further, an additional examination of the endocranial space by endoscopy was performed. Hence, a small endoscope was inserted into the open nostrils through a small defect in the lamina cribrosa. These defects are typically seen in mummies from the New Kingdom (ca 1,550 BC) and later periods. They have been set during the embalming process in order to remove the brain (Smith and Dawson, 1924). On internal inspection, the left middle cranial fossa was partly covered by a thin brown layer, appearing to be a residue of the dura mater. There was no evidence for a bone fragment and there was also no evidence for other residues of organic material, except for a dark brown gluey material adhering to the occipital bone, such as the pitch used for embalming in later Egyptian periods. The endoscopic inspection of the external and middle ear showed a complete loss of all ossicles on the left side, whereas the ossicular chain was present and arranged in normal position on the right side. A more detailed description of this case, including further extensive investigations, will soon be presented in a separate paper.

Discussion

The identification of perforating skull trauma in historic populations is interesting for at least three reasons: First, skull lesions of traumatic origin with perforation of the skull vault may present typical lesions indicating severe, frequently lethal trauma due to external impact. Hence, cases suffering possibly from severe interpersonal conflict may be identified. Secondly, these lesions have to be distinguished from trepanations. Thirdly, a therapeutic management may be recorded when evidence is seeen for surgical intervention. This sheds particular light on ancient medical practice and its development.

In the present report, we present the data on this topic from two large populations of mummies and skeletal remains originating from large necropoles. These cemeteries date back mainly to the time period between the New Kingdom and the Late Period (ca 1,500–500 BC; Theban material) or cover a long time period from the Old Kingdom to the Late Period (ca 3,000–500 BC, Aswan material). Thereby, material from two major cemeteries of ancient Egypt have been investigated, comprising approximately 1,700 individuals for analysis. Although this number of individuals is still limited, we were able to identify a total of 10 cases with perforating skull trauma, with almost equal frequencies between the two different populations and without obvious significant differences betwen various time periods. In this regard, an overall frequency of approximately 0.6% of cases with this type of lesions can be recorded for ancient Egypt. This rate is rather high – in particular for the Theban population –, since it can be assumed from archaeological findings that the individuals buried in those tombs belonged to a more advanced social status and had civil occupations (Rösing, 1990; Nerlich et al., 2000).

Thus, the cases described here indicate an unexpectedly high ratio of skull trauma. The vault distribution and the morphology of these lesions is typical for conflict-associated lesions, rather than those from accidents – an unexpected finding in a presumably socially higher class population without a considerable military function. The differential diagnosis of those perforating skull lesions comprises primarily trepanation and tumors. The latter may be distinguished by their morphology, since they often occur as multiple lesions – particularly when a malignant, metastasizing tumor is present – and mostly present with a typical destructive morphology with irregular osteolysis and/or osteosclerosis. In contrast, benign tumors and trepanation sites are in most instances distinct. Benign tumors and trepanation defects do not show infundibular widening and mostly reveal significant chronic bone adaptation. Trepanation defects may be identified by the morphology of the defect margins, which is characterized by signs of cutting, sewing, or scrutching in the trepanned skulls.

Post-traumatic consequences have a variable morphology. Thus, "early" lesions show irregular and sharp margins without evidence for osseous reaction. More advanced lesions reveal resorption of the bone and smoothing of the defect margins. In this regard, there are no major differences in the healing pattern between skull bones and long bones in these stages (Nerlich, 1998). However, while long bone healing finally results in a (more or less stable) junction, the skull bones may remain at the defect stage. This seems to be due to differences in the biomechanical requirements between the weight-bearing long bones and the less mechanically "loaded" skull; for optimal healing process slight movements between the parted bones is necessary. However, major difficulties in diagnosis may occur in those cases where a traumatic defect was treated by trepanation, so both conditions may be intermingled.

Besides the surprisingly high rate of trauma conditions with skull perforation, we observed one particular case that provided evidence for intravital perforating skull trauma. It seemed to have been treated surgically by removal of the fracture fragments from the fracture zone. In this case, the vitality of the lesion can be deduced from a rounding of the defect margins and slight new bone formation in the defect zone. This is typically seen in fractures of various bones after a period of one to several weeks (Nerlich, 1998). Furthermore, this type and extent of lesion is typically seen in cases with severe impact to the skull by sharp force, e.g. by an axe or a sword. This resulted in a severe perforating cranial defect with a typical fracture line running from the superior edge into the skull bone, as well as a fracture of the petrous bone at the affected left side. As a further consequence of this trauma, the ear ossicles of the left side were absent, while they were still in their position on the right side. This suggests that the severe trauma luxated the ossicles which may have been lost from the ear peri- or postmortally.

The most unexpected observation in this case was the lack of any fracture fragment within the trauma zone. This zone was covered externally by a complete layer of soft tissue and multiple linen bindings, so that the defect was not visible on the outer appearance of the head. In addition, the inspection of the endocranial space by endoscopy through a typical perforation defect of the nasal cribrous lamina made by the embalmer did not provide evidence for any skull bone fragment intracranially. We even observed an intact layer of a brown organic material covering the defect zone of the left middle cranial fossa. It is fair to assume that this material represents the remains of dura mater that adhered to the exocranial soft tissue. The missing fracture fragments thus raise the question of where this bone material disappeared. The most plausible explanation is that the bone fractures were removed after the trauma by medical treatment i.e. surgical removal. Furthermore, the observations suggest that the trauma was survived for one or several weeks. It would not have made sense for the embalmers to have opened an obviously healing wound for removal of one or several skull bone fragments after death. A more detailed description, including the associated soft tissues, will be provided in a forthcoming report.

Our present study thereby clearly indicates that severe, perforating defects of the skull bones as a result of severe impact are not rare events in two socially higher-class population samples from ancient Egypt. This suggests that interpersonal conflicts may have led to frequent use of weapons, although the type of weapons may have been highly variable. Furthermore, we present initial evidence that traumatic skull lesions have been treated (neuro-)surgically by removal of fracture fragments from the defect zone. This makes particular sense in the case described here, since the parietal region of fracture is prone to develop a severe epidural haematoma, which usually leads to rapid death due to cerebral compression. It may be speculated that the ancient Egyptians knew (from empirical observations?) about this association, so they tried to remove the overlying skull fragments thus mimicking therapeutic trepanation. This assumption is furthermore corroborated by written sources where in the Smith Papyrus perforating skull traumata are described. These descriptions indicate a concise assessment and prognosis of various conditions, and suggest distinct therapies including wound wrappings, etc. (Breasted, 1930). We can thus conclude from our observations that the ancient Egyptian medical doctors performed surgery not only for ethical/religious reasons.

On a higher, cultural level, however, it should be noted that invasive medical interventions were very rare in ancient Egypt. Theoretical knowledge, as put down in the medical papyri, is not frequently found. This may be deducted from an inspection of two ailments where treatment is urgent and easy: long bone fragments and apical abscesses of the teeth; most cases found in Aswan were not treated (Leek, 1967, 1969; Rösing, 1980, 2000). The present presentation does not challenge this general picture. Obviously there is a large gap between written evidence and factual evidence for medical service in ancient Egypt.

Acknowledgements

The studies on the human remains of both necropoles have been supported by grants from the Deutsche Forschungsgemeinschaft (DFG; Ro475/2 – /5 and Ne 575/3–3). The authors thank the collaborating egyptologists (in particular members of missions of the German Archaeological Institute, Cairo) and also the Egyptian authorities for their invaluable help. In particular, we want to thank Dr. A. Gnirs, Dr. H. Guksch, E. Grothe-Paulin, Prof. Dr. D. Polz and Prof. Dr. R. Stadelmann for their continuous collaboration and support of this research.

References

Alvrus A (1999): Fracture patterns among the Nubians of Semna South, Sudanese Nubia. *Int J Osteoarcheol 9*: 417–429.

Breasted JH (1930): *The Edwin Smith surgical papyrus*. University of Chicago Press, Chicago.

Chamla MC (1967): *Aksha III. La population du cimetière méroïtique*. Librairie Klincksieck, Paris.

Leek F Filce (1967): Reputed early Egyptian dental operation, an appraisal. In: Brothwell D and Sandison AT, ed., *Diseases in Antiquity*. Springfield, IL, C.C. Thomas, pp. 702–705.

Leek F Filce (1969): Did a dental profession exist in ancient Egypt? *The Dental Delineator*, Spring 1969: 1–4.

Molleson TI (1993): The Nubian pathological collection in the Natural History Museum, London. In: Davies WV, Walker R, eds., *Biological Anthropology and the Study of Ancient Egypt*. London, British Museum Press, pp. 136–143.

Nerlich AG (1998): Pathomorphological and pathophysiological aspects of fracture healing and their application to historic fractures. *Homo 49*: 156–171.

Nerlich AG, Zink A, Szeimies U, Hagedorn H, Weyss C (2000): Anthropological and paleopathological analysis of the human remains from three "tombs of the nobles" of the necropolis of Thebes-West, Upper Egypt. *Anthrop Anz 58*: 321–343.

Nunn JF (1996): *Ancient Egyptian medicine*. London, British Museum Press.

Parsche F, Betz P, Nerlich AG (1996): Possible evidence for homicide in an Egyptian mummy head. *Int J Osteoarcheol 6*: 326–332.

Rösing FW (1980): Medical papyri and medical treatment – a contradiction. *Antrop contemp 3*: 1–7.

Rösing FW (1990): *Qubbet el Hawa und Elephantine – Zur Bevölkerungsgeschichte von Ägypten*. G. Fischer Verlag.

Rösing FW (2000): Die Behandlung von Knochenbrüchen in vormoderner Zeit. In Zichner L, Rauschmann MA, Thomann K-D (Hrg) *Geschichte operativer Verfahren an den*

Bewegungsorganen. Dt Orthop Geschichts- und Forschungsmuseum, Jb 2, Steinkopff, Darmstadt, pp. 3–14.

Smith GE, Jones WF (1908): Report on the human remains. Archaeological survey of Nubia. Bulletin 2.

Smith E, Dawson WG (1924): *Egyptian Mummies*. London, Unwin.

Szeimies U, Hagedorn HG, Nerlich AG (1999): Spiral CT of a 3000 year-old Egyptian mummy with different 3D rendering techniques. In: Teupser D, Enders G, Demant T, Seidel D (Hrsg.), *Research Festival 99*. München, MMW Verlag, p. 477.

Winkler EM, Wilfing H (1991): *Tell el-Dab'a VI. Anthropologische Untersuchungen an den Skelettresten der Kampagnen 1966–69, 1975–80, 1985*. Wien, Akad. der Wiss, Verlag der Österr.

Chapter 15

Four Cases of Trepanation from Mongolia, Showing Surgical Variation

NARAN BAZARSAD
Department of Anthropology, Institute of Biology, Mongolian Academy of Sciences, Mongolia

Abstract

This paper considers four trepanned skulls from the Chandman burial ground of Western Mongolia, dating back to the Late Bronze and Early Iron Age, that can be found in the paleoanthropological collection of the Department of Anthropology, Institute of Biology, Mongolian Academy of Sciences. Four cases with holes in the cranium (numbers: 10-2, 47-4, 33-6, 31-1) have therefore been identified in the Chandman group in Mongolia, each skull having from one to seven trepanned holes in different conditions. Two of them show healing, but the others did not have signs of inflammation, which is evidence of trauma in the process of healing.

Keywords: Mongolia, trepanation, Chandman group

Mongolia is a vast country, three times the size of France, and placed between the developing civilizations of Western and Eastern Asia. Its history is perhaps best known in Europe during the expansion of the Mongol Empire, under the Great Khans, but the archaeology of Mongolia extends back into prehistory.

Between 4,000 and 1,500 BC, the area had connections with populations to the east and west of it in the development of early pastoral societies. Between 1,500 and 1,000 BC, Bronze Age communities were becoming distinctive, and there was a mixing of peoples, with influences from both China and Central Asia. Within the first millennium BC, mounted nomadic peoples, of Scythian and other cultures, became dominant groups over a wide area. These are centuries of considerable change, and this continued into the next millennium, when, during the next few centuries, the first nomad empire was established in Mongolia, with the Huns later becoming a dominant force. Later still, the Mongol Empire of the Khans became a major force.

In this paper, I wish to concentrate on the evidence for some form of cranial surgery associated with the Late Bronze Age and Early Iron Age peoples of Western Mongolia. Cultural influences in this area, and at that time, are likely to have been with the Altai and Tuva peoples. In considering the cases of trepanation, it is therefore worth asking whether they suggest any links with populations to the west of the Chandman area.

I also specifically wish to consider four trepanned skulls from the Chandman burial ground of Western Mongolia, which dates back to the Late Bronze and Early Iron Age. Two types of burials were uncovered during archaeological excavation of this burial ground: timber and stone box graves. Small size stone boxes contained single and multiple burials. Timber graves, which are larger in size than the stone boxes, contained from two burials to a dozen.

As yet, these are the only archaeological cases of trepanation from Mongolia, and are from the north western corner of the country. They are particularly important because surprisingly few cases are known from Asia, and this therefore raises the question of where the surgical influence originated.

Material and Methods

The paleoanthropological collection of the Department of Anthropology, Institute of Biology, Mongolian Academy of Sciences, which contains 156 skeletons, has been examined macroscopically and radiologically for the evaluation of pathological data. The processing of information on trepanation in these Mongolian skulls was included.

Case-histories

The trepanned skulls date from the fifth-third centuries BC and were found in the Chandman burial ground in Western Mongolia.

Inventory Number 10-2; Stone Box Grave

Two lesions were noted on this male adult skull. In the centre of the frontal region was evidence of trauma, about 5 x 5 mm in extent. Apparently, this was the result of a blow from a blunt instrument. At the outer margin of the wound is evidence of inflammation and healing. Another lesion in the skull was noted on the left side of the sagittal suture, about 14 mm from the coronal suture and about 37 mm from the temporal suture. This trepanation opening is oval in form, with maximum dimensions of about 63 x 25 mm. Probably there was healing after trepanation by scraping (Fig. 1).

Inventory Number 47-4; Timber Box Grave

Seven holes were noted in this skull of an adult male. On the left side of the midline, three trepanned holes were noted. One of the holes was made in a circular form and was about 23 x 23 mm, being in the left frontal region, about 20 mm from the orbit. On the left side of the frontal region, about 10 mm from the first case, was another circular form about 15 x 15 mm. Twenty-five mm from the second case was a third hole of 10 x 10 mm square (Fig. 2). There are two holes on the lambdoid suture in the occipital region, one being about 10 x 10 mm, the other on the right being more rounded and 20 mm on diameter. On the occipital, about 20 mm from the lambdoid suture, is a square form of opening about 10 x 10 mm. On the right parietal is the seventh hole, which is about 10 x 5 mm in size (Fig. 3).

The form and character suggest that the same sharp instrument was used in all seven trepanned holes. In my opinion the trepanations were executed in stages, and probably indicate different states of healing. There are no signs of an inflammatory process which would be evidence of the lesions not having healed.

Figure 1. Endocranial photo of Chandman 10–2 showing the trepanned shape and healing.

Figure 2. General facial view of Chandman 47–4 with the three trepanned holes in the frontal bone.

Figure 3. Posterior view of Chandman 47–4 displaying the other four trepanned holes in the occipital region.

Ortner and Putschar (1981) suggest that four basic responses can occur in trepanation. First, in those cases where trauma preceded the trepanation procedure, death may be due to the initial trauma. Second, the surgical procedure itself may cause death. Third, the surgical procedure may not directly cause death but may introduce disease organisms that cause infection and possibly death. Fourth, there may be no complications resulting from surgery, in which case the individual survives with varying degrees of repair to the surgically-induced defect. If there is no healing, as evidenced by the lack of remodelling of the cut edges or diploic spaces, the reasonable assumption is that death occurred at the time of, or shortly after, surgery. A zone of porous, reactive bone surrounding the surgical area suggests survival for some time after surgery, but with the possibility of infection complicating the healing process and causing death. Partial to complete remodelling of the surgical defect is indicative of recovery and long-term survival after surgery.

Inventory Number 33–6; Timber Box Grave

This was again a male adult. A round trepanned hole on the left side of the temporal region was noted, about 25 mm in diameter, with no reaction present on the edges (Fig. 4).

Inventory Number 31–1; Timber Box Grave

In the occipital region of this male adult there is a hole about 7 x 8 mm, with no healing or of infectious changes present on the edges (Fig. 5).

The last two cases (nos 33–6 and 31–1) showed no reaction present on the edges, and

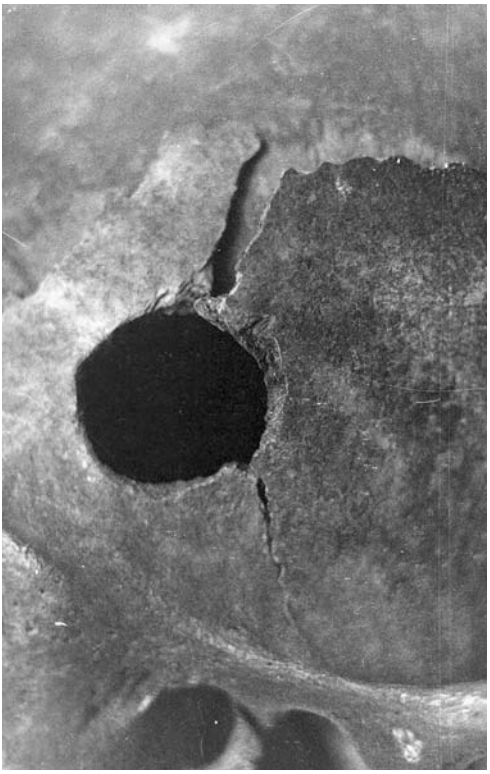


Figure 4. Chandman 33–6 displaying a bund trepanned hole in the right side of the temporal bone.

Figure 5. Chandman 33–1 showing an unhealed trepanned hole on the occipital bone.

this kind of trepanation cannot be distinguished from post-mortem ritual removal. These skulls could therefore represent cases of the symbolic trepanation, in order to obtain bone roundels.

Discussion

Trepanation is a practice known since Neolithic times. From a paleopathological point of view, trepanation represents a special traumatic lesion of bone, caused by a sharp instrument (Rokhlin, 1965; Derums, 1979; Ortner and Putschar, 1981).

The question arises, was the cutting done before or after death? That is, whether we confronted with the product of a surgical procedure or with the result of some post-mortem ritual (symbolic trepanation)? If signs of healing are present, the cutting is a result of a surgical trepanation. It is possible, however, that the patient died during the operation or soon after it. In this case the surgical trepanation cannot be distinguished from post-mortem ritual removal (cult trepanation) (Farkas and Marcsik, 1986).

Rokhlin (1965) suggested a trepanation case from the fourth century BC in North Kazakhstan. Boev and Ismagulov (1962) studied further remains from the fifth-third centuries BC period in Kazakhstan. There are suggestions that the neighbouring Tureg tribe used trepanation for various purposes. Gokhman (1989) wrote about the Bronze Age in Central Asia. One of the individuals was noted to have five healed trepanation holes. Grach (1980) described trepanation in two skulls, from Sagli-Baji II and Sagli culture in Tuva. Grach suggested further trepanation in cases of early nomadic people of Central Asia. In particular, trepanation for surgical purposes was practised in Tuva and Kazakhstan.

Conclusion

Four cases with holes in the skull (numbers: 10-2, 47-4, 33-6, 31-1) have been identified in the Chandman group in Mongolia, each skull having from one to seven trepanned holes in different conditions. Two of them healed, but the others did not have signs of inflammation, which is evidence of trauma in the process of healing. Simultaneous finds of healed and unhealed trepanation holes on one skull suggest that the bearers of the Chandman culture practised trepanation for surgical and perhaps symbolic purposes. There is no doubt that trepanation occurred by the Iron Age in Mongolia, but where did the surgical influence originate? Probably the influences appeared from Central Asia, but we need to discover more cases before more certain conclusions can be made.

References

Boev P, Ismagulov O (1962): A case of a trephination skull from Kazakhstan. *Jo Russ Ethnog*.

Derums VJ (1979): Extensive trepanation of the skull in ancient Latvia. *Bull Hist Med*: 53.

Farkas GY, Marcsik A (1986): Further trephined skulls in Hungary (case-history). *Acta Biol Szeged*: 32.

Gokhman II (1989): *Paleoanthropology and prehistoric medicine*, Moscow, Nayyka.

Grach AD (1980): *Early nomadics from Central Asia*, Moscow, Nauka.

Ortner DJ, Putschar WGJ (1980): *Identification of Pathological Conditions in Human Skeletal Remains*. Washington, Smithsonian Institution Press.

Rokhlin D (1965) *Diseases of Ancient Men*. Moscow, Nauka.

Chapter 16

Trepanations and Perforated Crania from Iron Age South Siberia: An Exercise in Differential Diagnosis

EILEEN M. MURPHY
School of Archaeology and Palaeoecology, Queen's University Belfast, Northern Ireland

Abstract

The cemetery complex of Aymyrlyg is located in the Ulug-Khemski region of the Autonomous Republic of Tuva in southern Siberia. Recent osteological research on a corpus of approximately 800 Iron Age skeletons from the cemetery has revealed evidence for a number of crania displaying human-induced perforations. A female displayed a perforation on the left side of her frontal bone which was probably due to a trepanation. It is considered that the procedure may have been undertaken for medicinal purposes a substantial period of time ante-mortem. An adolescent displayed an oval perforation on the coronal suture immediately to the right of the bregma. In this case the perforation appears to have been made post-mortem, possibly for ritual or trophy purposes. A large number of Scythian period individuals, of a variety of ages and of both sexes, displayed one or more circular perforations on their crania. These perforations have been interpreted as injuries that were caused by chekany, a class of battle axe used throughout the Scythian World. The evidence for the different forms of cranial perforations apparent in this population group will be presented and their interpretation will be discussed.

Keywords: Aymyrlyg; Siberia; Iron Age; ante-mortem trepanation; post-mortem cranial incision; battle axe trauma

Introduction

Recent osteological research on a corpus of approximately 800 skeletons from the cemetery complex of Aymyrlyg, Tuva, southern Siberia, has revealed evidence for a number of crania with human-induced perforations (Murphy, 1998). Merbs (1989) has provided a comprehensive overview of the possible aetiologies for cranial perforations, which includes weapon injuries, genuine and practice surgery, taphonomic processes and various palaeopathological conditions. It can, however, be extremely difficult to interpret the cause of a particular cranial perforation and both healed and unhealed trepanations, for example, may be confused with other phenomena. Bearing this in mind, the following paper will present the osteological characteristics associated with each of the different categories of cranial perforation evident among the Scythian period population from the cemetery of Aymyrlyg. In addition, a number of interpretations will be proposed to explain each class of perforation evident in this population.

The Aymyrlyg Cemetery Complex

The cemetery complex of Aymyrlyg is located in the Ulug-Khemski region of the Autonomous Republic of Tuva, south Siberia (Fig. 1). It was excavated in the period between 1968 and 1984 by archaeologists of the Sayano-Tuvinskaya expedition team from the Institute for the History of Material Culture of St. Petersburg. The director of the expedition for the period between 1968 and 1978 was Dr AM Mandelshtam, and Dr EU Stambulnik continued the research until the mid 1980s. The majority of the burials from the excavations undertaken by Mandelshtam were from the Uyuk Culture of the Scythian period (ca seventh–second century BC), with most of the burials dating to between the third and second centuries BC. A preponderance of the burials from the later years of the excavation programme, under the direction of Stambulnik, originated from the Hunno-Sarmatian period (ca first century BC–second century AD). The most characteristic interior structure used in the Scythian period funerary monuments was the rectangular log house tomb. Invariably the numbers of individuals buried within an Aymyrlyg log house tomb was considerable, with as many as 15 skeletons being recovered from individual tombs. The stone cist was the second form of Scythian period funerary monument which was commonly encountered at Aymyrlyg (Mandelshtam, 1983).

Artefacts recovered from Scythian period funerary monuments in Tuva indicate that the economy of the highland-steppe peoples was based upon a semi-nomadic form of pastoralism, which was combined with land-cultivation, hunting and gathering. The Scythian period tribes of the mountain-steppe regions of Tuva are thought to have made seasonal migrations (Vainshtein, 1980). This form of economy would have involved regular repeated seasonal movements between the mountains and the steppes (termed "vertical shifts") within the borders of a relatively defined territory (Mandelshtam, 1992). The distribution of large tribal burial grounds in Tuva from both the Scythian and Hunno-Sarmatian periods indicates that cyclic migration, with fixed routes and set winter camp sites, existed amongst these populations (Vainshtein, 1980). Presumably, herds would have been pastured in the mountains during the summer and in the more low-lying land during the winter (Bokovenko, 1995).

Case Study 1: Ante-Mortem Trepanation

Numerous examples of ante-mortem trepanations are known from the palaeopathological record, with the earliest cases dating to Mesolithic times (Rokhlin, 1965). In addition, the practice of trepanation has been widely observed by modern anthropologists throughout the populations of the world (Ackernecht, 1967). Trepanation of the cranium involves the removal of a section of the calvarium without damaging the underlying blood vessels, meninges and brain (Lisowski, 1967). At least five forms of trepanation have been identified in archaeological human remains throughout the world (Culebras,

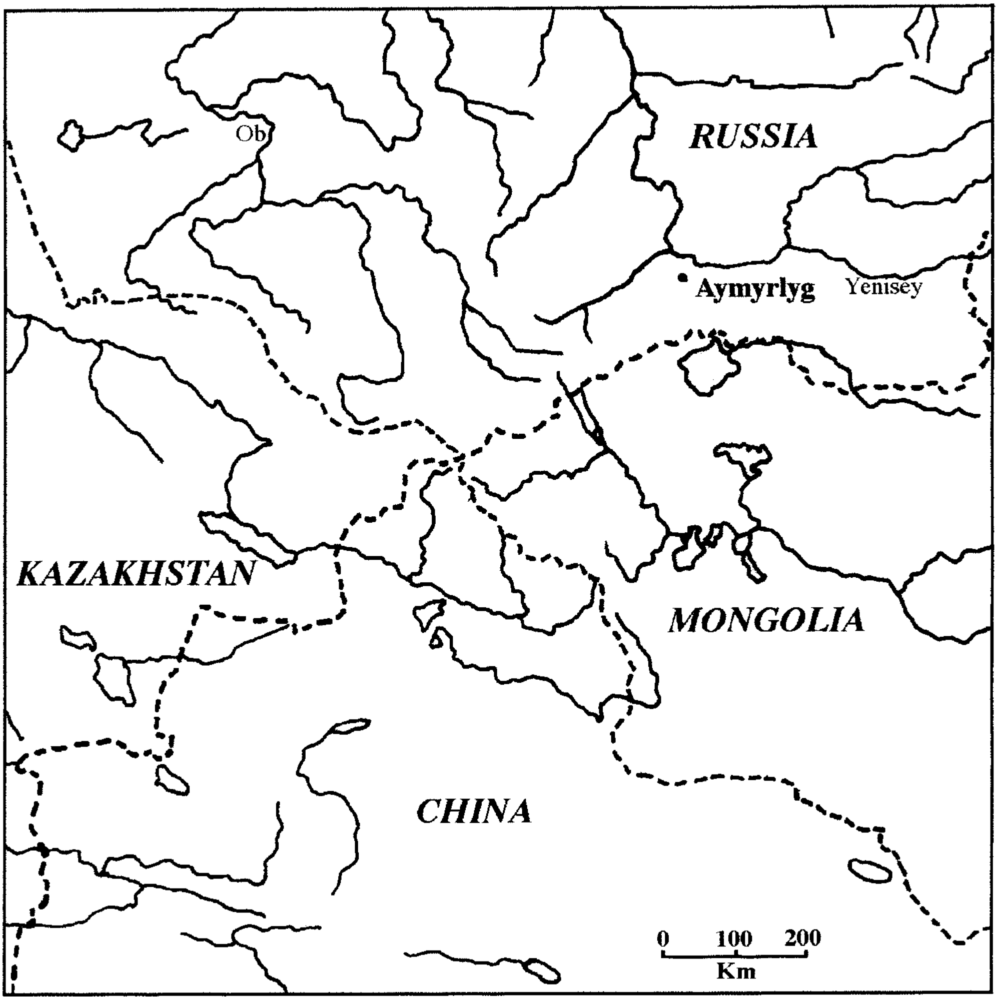


Figure 1. Location map of the cemetery complex at Aymyrlyg, Tuva, southern Siberia.

1993). Trepanation can be undertaken by 1. scraping – possibly using a piece of flint or a shell, 2. gouging, 3. boring and sawing – using a drill-like implement, 4. sawing alone, and 5. drilling, using a trephine. Lisowski (1967) has summarised the motives behind trepanations into three categories. The operations may have been undertaken for a therapeutic reason to treat head injuries, including fractures and scalp wounds. The trepanation could also have been carried out for magico-therapeutic motives whereby the cause of symptoms, such as headaches, neuralgia or epilepsy, may have been regarded as a consequence of possession by evil spirits. The third of Lisowski's categories of motivation is magico-ritual, in which the trepanation was undertaken purely for ritual or magical purposes.

Skeleton VIII. 21. Sk. 3, a 35–45 year-old female, displayed a well-healed perforation

Figure 2. Ante-mortem trepanation with signs of healing evident on the left side of the frontal of Skeleton VIII. 21. Sk. 3, a 35–45 year old female (Photo: E. Murphy).

that may have been due to a trepanation on the left side of the frontal (Fig. 2). The lesion was near circular, measuring 23.5 mm by 24.4 mm, and had very smooth margins. Although the regular circular shape of the lesion would suggest that the gouging method was practiced, the presence of a depressed area surrounding the perforation makes it more probable that the operation had been undertaken using the scraping technique. Studies on the healing of trepanations have indicated that little osseous regeneration occurs (Lisowski, 1967). It is probable, therefore, that the individual survived for a fairly long period of time following the operation, since the margins of the perforation were smooth.

The majority of trepanations identified in archaeological skeletal remains have been undertaken on the left side of the cranium. This may have occurred for two reasons. First, the majority of traumatic lesions may have been sustained as a result of interpersonal violence. If a right-handed adversary were positioned facing the victim, then most injuries caused by them would be to the left side of the victim's body. If the victim's head were the object of the attack, a trepanation may have been necessary to treat the injury. Second, the trepanation may have been undertaken by a right-handed surgeon who was positioned facing the patient. The left side of the patient's cranium would therefore be the easier location for the trepanation (Aufderheide and Rodríguez-Martín, 1998). It is probable that the trepanation evident in the Scythian period female had been undertaken for one of the three reasons outlined above (see Lisowski, 1967). Only the skull of the individual was preserved, however, and the only palaeopathological lesions present were related to the woman's dentition. It is possible that three dental abscesses apparent in the remains may have caused the individual to have suffered from headaches, prompting her to undergo a trepanation operation. This is, however, mere speculation and it is impossible to ascertain the motives which lay behind the operation on this woman.

Case Study 2: Post-Mortem Cranial Incision

Skeleton II. 4. Sk. 6, a 12–14 year-old adolescent, displayed an oval perforation which measured 18 mm medio-laterally by 8 mm antero-posteriorly. The perforation was present on the coronal suture immediately to the right of the bregma, and it had a smooth, bevelled margin which had a thickness of 8 mm (Fig. 3). The bevelled margin had a glossy appearance which may indicate that it had been made using a metal implement. Alternatively, the polished margins of the perforation may be suggestive of wear (Owsley et al., 1994). It was initially thought that the perforation represented a trepanation undertaken using the scraping technique while the individual was alive, but that the person had not survived the procedure. A number of features, however, tended to suggest that this was not the case and it is considered that the perforation was made post-mortem. In this case it is probably best to refer to the procedure as a decoupage post-mortem or a post-mortem cranial incision, as suggested by Dastugue and Gervais (1992).

Shallow scrape marks were distributed randomly over the cranial vault and were fairly coarse in morphology. The appearance of the scrape marks would suggest that the cranium had not been scalped, since in cases displaying evidence of scalping the incisions are generally made in a deliberate manner that follow the curvature of the cranium (Hamperl, 1967). This was not the case for the Aymyrlyg individual and, furthermore, the incisions bear no similarity to those cutmarks identified on the crania of three other individuals from Aymyrlyg which display diagnostic evidence of having been scalped (Murphy et al., forthcoming). The cutmarks apparent on the cranium of the adolescent were more reminiscent of defleshing, which is characterised by abundant cutmarks with a wide distribution over the face, the basicranium and the scalp region (Olsen and Shipman, 1994). In addition, only the skull of the individual was present in the tomb and it displayed a weathered appearance. Both of these findings may further indicate that the individual's head had been subject to some form of post-mortem alteration. These differences may mean that the three motivational factors outlined by Lisowski (1967) are not strictly appropriate for this case study.

Ethnographic studies in Africa have indicated that a common motive behind posthumous trepanation operations was to obtain roundels of human skull. The roundels were generally circular in shape, and were frequently perforated and polished so that they could be worn on necklaces. It was thought that the roundels had religico-magical properties, and they were regarded as amulets or charms (Lisowski, 1967). It is possible, therefore, that the Aymyrlyg individual had been trepanned post-mortem for ritual purposes, which involved the removal of a roundel of bone at the bregma. Since the perforation at the bregma only measured approximately 18 mm by 8 mm, however, it is thought that the roundel of bone would have been rather small for this purpose.

An alternative explanation for the post-mortem perforation of the crania may be found in the work of Gillman (1876), who reported on a series of artificially perforated crania

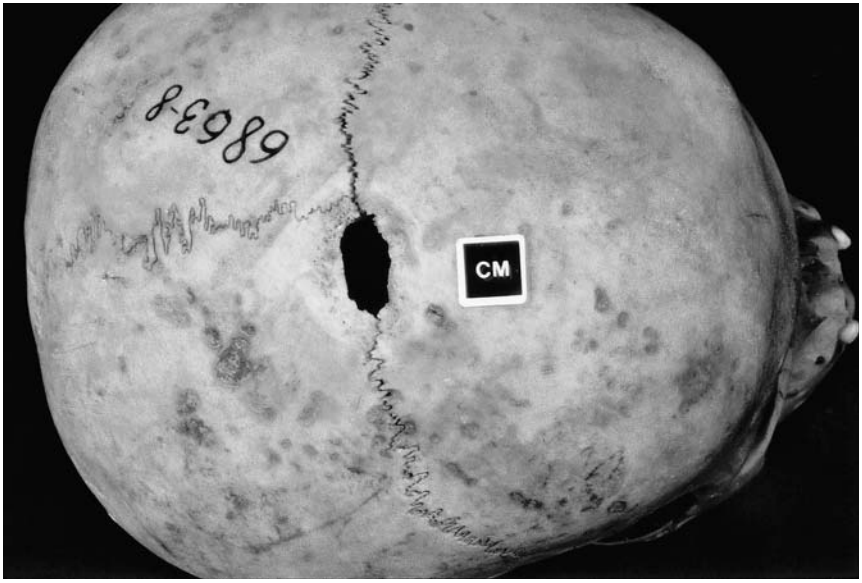


Figure 3. Post-mortem cranial incision on the coronal suture immediately to the right of the bregma of Skeleton II. 4. Sk. 6, a 12–14 year old adolescent (Photo: E. Murphy).

from Moundbuilder sites in Michigan, USA. The perforations on these crania were all considered to have been made post-mortem and they were invariably positioned on the superior aspect of the cranium. The openings were generally situated at or near the bregma, were circular, and measured approximately 10–25 mm in diameter. Gillman did not refer to any evidence for decapitation in these crania, and there was no evidence to suggest the deliberate detachment of the Aymyrlyg cranium from the remainder of the body. It is possible, however, that in all cases the skulls were detached from the bodies by cutting through the neck and that the signs would have been evident on the cervical vertebrae rather than the base of the cranium.

Gillman (1876) recounted that ethnographic studies of the Dyaks of Borneo had revealed that each village had a central house in which they kept the heads of their dead prisoners, suspended by a string that passed through a perforation in the superior aspect of the cranium. It is possible, therefore, that whoever had perforated the cranium of the individual from Aymyrlyg had intended to suspend the cranium, rather than obtain a roundel of bone.

The crania of the two individuals buried in Kurgan 2 at Pazyryk in the High Altai had both been trepanned in the post-mortem period. The perforated area measured approximately 40 mm by 55 mm in the cranium of the male. In this case it would appear that the perforation had facilitated the removal of the brain and the subsequent filling of the cranium with soil, pine needles and larch cones. The plate of bone that had been removed during the procedure was then replaced and the skin secured to the skull with a twist of black horsehair. The individuals recovered from Kurgan 5 at Pazyryk had also been trepanned post-mortemly (Rudenko, 1970). Mummies from the Oglakty cemetery in the Minusinsk Hollow, which approximately date to the Scythian period, also displayed evidence of post-mortem trepanation. Again it was considered that the perforations had been undertaken to facilitate the removal of the brain during the mummification process (Tallgren, 1936). Photographs of the perforated skulls indicate that the perforations were large, measuring approximately 90 mm by 45 mm.

The cranial perforations evident in the individuals from Pazyryk and Oglakty were all much larger than that apparent in the individual from Aymyrlyg. It is unlikely, therefore, that the perforation in the cranium from Aymyrlyg would have been large enough to facilitate the extraction of the brain during mummification. In addition, a number of other Aymyrlyg individuals displayed cutmarks indicative of defleshing and disarticulation for secondary burial processes, but none of these individuals displayed perforations in their crania (Murphy, 2000; Murphy and Mallory, 2000). This finding may indicate that the population group buried at Aymyrlyg did not remove the brain by means of an artificial perforation in the cranium as part of their secondary burial processes. The theory that the perforation had been used to enable the display of the cranium is considered, therefore, to be the most plausible explanation. Consequently, it is probable that the posthumous perforation had been made in the cranium of the Aymyrlyg individual for either ritual or warfare reasons, or as a combination of the two.

Case Study 3: Battle Axe Trauma

A final category of crania from Aymyrlyg displayed perforations that were caused by human modification. Similar perforations elsewhere in Scythian World populations have been identified as trepanations by some archaeological researchers. It is more probable, however, that the perforations represent evidence of pointed battle axe trauma as the following review of the evidence suggests.

Twelve Scythian period individuals displayed evidence of weapon trauma that was probably inflicted using pointed axes (chekany) (Fig. 4), resulting in a prevalence of 2.5% (12/473) for these injuries (Fig. 5). A summary of the injuries caused by pointed axes is presented in Table 1.

Of the twelve individuals displaying evidence of trauma inflicted by a pointed axe, 75% (9/12) were male, 17% (2/12) were subadults, and 8% (1/12) were female. Twenty injuries were identified, 40% (8/20) of which were situated on the parietals, 35% (7/20) on the frontal, 5% (1/20) on the temporal, 5% (1/20) on the zygomatic, 5% (1/20) on the occipital, and two injuries had affected more than one bone (10%; 2/20). The preponderance of injuries on the parietals and the frontal bones suggests that the individuals were likely to have been directly facing their opponent during combat.

The individual with the injury apparent at the lambda [Skeleton IX. 3 (i)] also displayed trauma to the frontal bone, and the right and left parietals. It is possible that the injury on the occipital represents the last blow struck by the attacker, possibly when the victim was defeated, already fatally injured, and lying in a prone position on the ground. The majority of injuries present on the parietals alone were situated on the left parietal (88%; 7/8). This finding is probably indicative of face-to-face combat in which the indi-

Figure 4. Pointed battle axe (chekan) recovered from the cemetery of Aymyrlyg (Photo: Photographic Archive of the Institute for the History of Material Culture, St. Petersburg).

Table 1. Scythian period individuals. Summary of pointed battle axe trauma in the adults and subadults (+ = healing present, o = healing not present, R = right, L = left).

Context	*Age*	*Sex*	*No. injuries*	*Location*	*Size (mm)*	*Healing*	*Identification*
B. 8. Sk. 1	35–45	M	2	L parietal	13x18	o	definite
				L parietal	15x17.5	o	definite
G. 7. Sk. 5	25–35	M	1	L parietal	4x4	+	probable
II. 4. Sk. 12	25–35	?M	3	L frontal	44x24.5	o	definite
				R frontal	64x25	o	definite
				R temporal	67x50	o	definite
II. 8 (iii)	25–35	?F	1	L parietal	24x24	+	possible
VI. 6	4–5	-	1	L parietal	13.5x13	o	definite
VI. 9. upper (ii)	7–10	-	1	R parietal/frontal	incomplete	o	possible
VII. 5. Sk. 4	25–35	M	1	L parietal	11.5x16.5	o	definite
IX. 3 (i)	17–25	M	4	Mid frontal	45x31	o	definite
				L parietal	8x8	o	definite
				R parietal/ temporal	92.5x20	o	definite
				Lambda	34x22.5	o	definite
XXI. 4. Sk. 4	17–25	M	1	R frontal	5x5	o	definite
XXIII. 4	25–35	M	1	R frontal	25x20	+	probable
XXIII. 13 (i)	25–35	?M	1	L zygomatic	10x10	+	possible
XXV. 16. Sk. 4	17–25	M	3	R parietal	25x12	o	definite
				Mid frontal	26x18	o	definite
				Mid frontal	12.5x11.5	o	definite

Figure 5. Two pointed battle axe injuries on the left parietal of Skeleton B. 8. Sk. 1, a 35–45 year old male. A further injury is visible on the left temporal although it is uncertain if this trauma had been caused by a blow from a pointed battle axe (Photo: E. Murphy).

Table 2. Scythian period individuals. Prevalence of pointed battle axe trauma in the adult and subadult cranial bones. A single injury which involved two bones is included in the count for both bones. If a bone displayed more than one injury it is only counted once for the purposes of determining the prevalence.

Bone	*No. injuries*	*No. observable*	*% injuries*
frontal	6	471	1.3
parietal	9	929	1.0
occipital	1	453	0.2
temporal	2	848	0.2
zygomatic	1	860	0.1

viduals who struck the blows were right-handed. A summary of the prevalence of the injuries in each observable cranial bone in the population group is provided in Table 2.

Eighty percent (16/20) of the pointed axe injuries were unhealed, attesting to the effectiveness of this type of axe as a lethal weapon. All four of the individuals – Skeleton G. 7. Sk. 5, Skeleton II. 8 (iii), Skeleton XXIII. 4 and Skeleton XXIII. 13 (i) – who displayed signs of healing associated with an axe injury only displayed a single lesion. The two subadults [Skeleton VI. 6 and Skeleton VI. 9. upper (ii)] with pointed axe injuries each displayed a single injury, and it is probable that the axe was able to perforate the immature cranial bones with ease, causing irreparable trauma to the brain. The four individuals [Skeleton B. 8. Sk. 1, Skeleton II. 4. Sk. 12, Skeleton IX. 3 (i) and Skeleton XXV. 16. Sk. 4] with evidence of multiple axe injuries displayed trauma on several cranial bones suggesting that they and/or their assailant were not stationary during the combat.

Four of the individuals with evidence of trauma inflicted by pointed axes also displayed conventional fractures. In Skeleton B. 8. Sk. 1, a 35–45 year-old male, a night-stick fracture was present on the left ulna and an ossified haematoma was apparent on the left femur. In Skeleton G. 7. Sk. 5, a 25–35 year-old male, the left side of the mandible was fractured. In Skeleton XXIII. 4, a 25–35 year-old male, fractures were apparent in the left 3rd and 4th metacarpals, and the right navicular. In Skeleton XXIII. 13 (i), a 25–35 year-old probable male, fractures were visible on the left side of the frontal bone, the left zygomatic, and the right nasal bone. The lesions with no clear association with weaponry apparent in Skeleton B. 8. Sk. 1, Skeleton G. 7. Sk. 5 and Skeleton XXIII. 13 (i) are all probably indicative of interpersonal violence. It is probable, therefore, that these three males were subject to repeated aggressive activities, and they may have been warriors.

It is interesting to note that one of the male individuals recovered from Kurgan 2 at Pazyryk in the High Altai displayed at least two pointed battle axe injuries on his cranium (Rudenko, 1970). In addition, the seven horses recovered from the same kurgan had each been killed with a single blow from a pointed axe that struck the superior aspects of their crania (Jettmar, 1951). The remains of other horses of the Pazyryk Culture killed by single blows from pointed battle axes were also recovered during the 1993 excavations at the Ukok Plateau in southern Siberia (Polosmak, 1994). In addition, the remains of skeletons with clear chekany injuries have been identified among the individuals buried in the Chowhougou cemeteries of northern China (Murphy, forthcoming). The tribes buried at these sites would have been contemporary neighbours of the Uyuk Culture in Tuva. Artistic depictions of warriors and battle scenes from the Scythian World are common, and a particularly clear depiction of a bearded warrior with a pointed battle axe occurs on a fourth-century BC bronze vessel recovered from Kurgan 3 of the Tchastye Kurgans, situated near the town of Voronezh in south Russia. The occurrence of pointed axe injuries among the dead of these separate cultures may attest to the widespread use of the pointed battle axe amongst the tribes of the Scythian World.

Conclusions

Extreme caution needs to be exercised when determining the aetiology of human-induced cranial perforations among the tribes of the Scythian World. There would appear to be at least four different motivational factors which can account for these perforations and it is important to differentiate between the holes produced for these different purposes.

- The first case study illustrates a genuine trepanation procedure, which would have been undertaken on a living patient for therapeutic, magico-therapeutic or magico-ritual motives.
- The second case study involved a decoupage post-mortem or a post-mortem cranial

incision, which may have been undertaken for the purposes of displaying the cranium, possibly for ritual or warfare purposes.

- The third category involves those crania that appear to have been perforated as part of the mummification process to enable the extraction of the brain. Examples of this form of perforation can be seen among the crania of the mummies buried at Pazyryk and Oglakty, but were not present among Aymyrlyg's Scythian period population.
- The final category of perforations are those which are not related to trepanation procedures at all, but represent a form of weapon trauma. These crania display small, generally circular, perforations which appear to have been made with pointed battle axes or chekany, a weapon that was in widespread use throughout the Scythian World. There appears, however, to be some confusion among a number of researchers as to the motivational factors that lay behind these perforations, and they have tended to be misinterpreted as trepanations.

It is hoped that this research has highlighted the dangers associated with the study of human skeletal remains in isolation from their archaeological context, or their broader cultural attributes, including the nature of the society's material culture, its funerary rituals and its warfare practices.

Acknowledgements

I would like to thank Professors Ilyia Gokhman and Yuri Chistov of the Department of Physical Anthropology at the Peter the Great Museum of Anthropology and Ethnography in St. Petersburg for permitting the study of the skeletal remains from Aymyrlyg.

I am also grateAdultful to the staff of the Photographic Archive of the Institute for the History of Material Culture, St. Petersburg, for providing me with Figure 4. I would also like to thank Professor Jim Mallory of the School of Archaeology and Palaeoecology, Queen's University Belfast, for supervising my doctoral research, and Dr. Colm Donnelly of the aforementioned school for his comments on the text.

References

Ackernecht EH (1967): Primitive Surgery. In: Brothwell D, Sandison AT, eds., *Diseases in Antiquity*. Springfield, Charles C Thomas, pp. 635–650.

Aufderheide AC, Rodríguez-Martín C (1998): *The Cambridge Encyclopedia of Human Paleopathology*. Cambridge, Cambridge University Press.

Bokovenko NA (1995): History of Studies and the Main Problems in the Archaeology of Southern Siberia During the Scythian Period. In: Davis-Kimball J, Bashilov VA, Yablonsky LT, eds., *Nomads of the Eurasian Steppes in the Early Iron Age*. Berkeley, Zinat Press, pp. 255–261.

Culebras A (1993): Trephination of the skull in pre-Columbian cultures. *J Hist Neurosci 2*: 11–12.

Dastugue J, Gervais V (1992): *Paléopathologie du Squelette Humaine*. Paris, Boubée (The Palaeopathology of the Skeleton).

Gillman H (1876): Certain Characteristics Pertaining to Ancient Man in Michigan. In: *Annual Report of the Board of Regents of the Smithsonian Institution for 1875*. Washington DC, Smithsonian, pp. 234–245.

Hamperl H (1967): The Osteological Consequences of Scalping. In: Brothwell D, Sandison AT, eds., *Diseases in Antiquity*. Springfield, Charles C Thomas, pp. 630–634.

Jettmar K (1951): *The Altai Before the Turks*. Stockholm, The Museum of Far Eastern Antiquities Bulletin 23.

Lisowski FP (1967): Prehistoric and Early Historic Trepanation. In: Brothwell D, Sandison AT, eds., *Diseases in Antiquity*. Springfield, Charles C Thomas, pp. 651–672.

Mandelshtam AM (1983): Issledovaniye na mogilnom polye Aymyrlyg: Nekotoriye itovi i perspektii. In: *Drevniye Kulturi Euraziiskih Stepei*. Leningrad, Institute for the History of Material Culture, pp. 25–33 (Research at the Aymyrlyg burial ground: some results and perspectives).

Mandelshtam AM (1992): Ranniye kochevniki Skifskova perioda na territorii Tuvi. In: Moshkova MG, ed., *Stepnaya Polosa Aziatskoi Chasti SSSR v Skifo-Sarmatskoye Vremya*. Archeologiya SSSR, Moskva, Nauka, pp. 178–196 (Early nomads of the Scythian period in the territory of Tuva).

Merbs CF (1989): Trauma. In: Iscan MY, Kennedy KAR, eds., *Reconstruction of Life from the Skeleton*. New York, Alan Liss Inc., pp. 161–189.

Murphy EM (1998): *An osteological and palaeopathological study of the Scythian and Hunno-Sarmatian period populations from the cemetery complex of Aymyrlyg, Tuva, South Siberia*. Unpublished PhD thesis, School of Archaeology and Palaeoecology, Queen's University Belfast.

Murphy EM (2000): Mummification and Body Processing – Evidence from the Iron Age in Southern Siberia. In: Davis-Kimball J, Murphy E, Koryakova L, Yablonsky L, eds., *Kurgans, Ritual Sites, and Settlements: The Eurasian Bronze and Iron Age*. Papers from the European Association of Archaeologists 4th and 5th Annual Meetings, BAR International Series 890, Oxford, Archaeopress, pp. 279–292.

Murphy EM, Mallory JP (2000): Herodotus and the Cannibals. *Antiquity 74*: 388– 394.

Murphy EM (forthcoming): Weapon trauma on human skeletal remains from the Chowhougou cemeteries. Unpublished report.

Murphy EM, Gokhman II, Chistov YK, Barkova LL (forthcoming): Old World Scalping from Iron Age South Siberia. *Am J Arch*.

Olsen SL, Shipman P (1994): Cutmarks and Perimortem Treatment of Skeletal Remains on the Northern Plains. In: Owsley DW, Jantz RL, eds., *Skeletal Biology of the Great Plains. Migration, Warfare, Health and Subsistence*. Washington, Smithsonian Institution Press, pp. 377–387.

Owsley D, Mann RW, Baugh TG (1994): Culturally Modified Human Bones from the Edwards I Site. In: Owsley DW, Jantz RL, eds., *Skeletal Biology of the Great Plains. Migration, Warfare, Health and Subsistence*. Washington, Smithsonian Institution Press, pp. 363–375.

Polosmak N (1994): A Mummy Unearthed from the Pastures of Heaven. *Nat Geo* 186: 80–103.

Rokhlin DG (1965): *Bolezni Drevnih Loodei* (Kosti Loodei Razlichnih Epoh- Normalniye I Patologicheski Izmenenniye). Moscow, Nauka (Diseases of Ancient People (Bones of the people of various epochs normal and pathologically changed).

Rudenko SI (1970): *Frozen Tombs of Siberia: the Pazyryk Burials of Iron Age Horsemen*. London, JM Dent & Sons Ltd.

Tallgren AM (1936): The South Siberian Cemetery of Oglakty from the Han Period. *Eurasia Sept Ant 11*: 69–90.

Vainshtein, SI (1980): *Nomads of South Siberia: The Pastoral Economies of Tuva*. Cambridge, Cambridge University Press.

Chapter 17

Trepanation in Prehistoric South America: Geographic and Temporal Trends over 2,000 Years

JOHN W. VERANO
Department of Anthropology, Tulane University, New Orleans, Louisiana, USA

Abstract

This article surveys trepanation practices in prehistoric South America, with a specific focus on trepanation techniques, success rates, and motivations for the procedure. The study is based on the examination of more than 600 trepanned skulls housed in various museums in Peru and the United States. The skulls were collected from archaeological sites throughout the Central Andes and coastal Peru, and date from ca 400 BC to ca 1,500 AD. Trepanation techniques, possible motivations for the procedure, and survival rates are found to vary significantly across time and space. The large size of this sample allows us to examine questions such as the evolution of trepanation techniques, the association between trepanation and skull fracture, and preferences in the location of trepanations.

Keywords: Trepanation, Skull Fracture, Surgery, Peru, South America

Introduction

In 1867 Paul Broca presented to the Société d'Anthropologie of Paris a portion of a skull he believed showed evidence of a trepanation performed on a living patient in prehistoric times (Broca, 1867). In subsequent decades, many more examples would be found by anthropologists exploring burial caves and tombs in the Central Andes, confirming Broca's assertion that a form of cranial surgery was practiced in prehistoric South America. Trepanned skulls would also be recognized from Neolithic sites in western Europe, and subsequently from other parts of the Old World (Piggot, 1940; Lisowski, 1967). However, Andean South America retains the distinction of having produced more prehistoric trepanned skulls than the rest of the world combined, estimated at as many as 1,000 specimens (Stewart, 1958).

Although it is unclear why trepanation was so common in prehistoric South America, advances have been made in documenting its geographic and temporal distribution, as well as the possible motivations for the practice. Most studies have been limited, however, to collections from a single geographic area and time period (Tello, 1913; MacCurdy, 1923; Stewart, 1958) or skulls of uncertain provenience and antiquity (Weiss, 1958; Lastres and Cabieses, 1960; Rifkinson-Mann, 1988), making it difficult to identify temporal trends and regional variation in techniques, survival rates, and possible motivation for the procedure. The present study, began with colleague J. Michael Williams in 1989, was designed to overcome the limitations of previous investigations by documenting as many collections of South American trepanned skulls as possible (Verano and Williams, 1992).

To date we have photographed and recorded detailed information on more than 600 prehistoric trepanned skulls housed in various museums in Peru and the United States (Verano, 1997). The collections we studied came from archaeological sites in coastal and highland Peru and highland Bolivia, and span approximately 2,000 years – from ca. 400 BC to the early part of the sixteenth century AD. In this paper we will focus on the Peruvian sample, which is significantly larger and therefore more useful for examining temporal and geographic variation in trepanation practices.

Materials and Methods

For each trepanned skull, we recorded data on geographic provenience, cultural association, age and sex,[1] trepanation technique, location, size, and degree of healing, and evidence of skull fracture or other visible pathology. All skulls were photographed, and drawings were made of trepanations and fractures on standardized recording forms. Where possible, non-trepanned skulls from the same populations also were examined for healed and unhealed skull fractures, to provide a reference base for evaluating the frequency of head injury in these populations. The information was entered into a computer database, which permitted rapid searching by time period, cultural phase, geographic area, age, sex, or other criteria.

Results

Geographic and Temporal Distribution

The known geographic and temporal distribution of trepanation in Pre-Columbian Peru is indicated in Figure 1 and Table 1. The earliest trepanations come from a cemetery at the site of Paracas on the south coast of Peru and date to approximately 400 BC–200 AD (Tello and Mejía Xesspe, 1979). Following this early period of experimentation, trepanation seems to fall out of favor on the south coast. Trepanned skulls from other south coast sites may post-date this early period (Allison and Pezzia, 1976), but they lack secure cultural context and dating.

During the Early Intermediate Period and Middle Horizon, ca 200–1,000 AD, trepanned skulls appear throughout a broad area of the Peruvian and Bolivian highlands, as well as in the high jungle in the Chachapoyas region of northern Peru during the Late Intermediate Period, ca 1,000–1,470 AD (Jackobsen et al., 1987). A few examples are also known from the central Coast of Peru during the period of Inca domination in the fourteenth and fifteenth centuries AD (Uhle, 1903).

Unfortunately, the dating of most trepanned skulls in museum collections is uncertain,

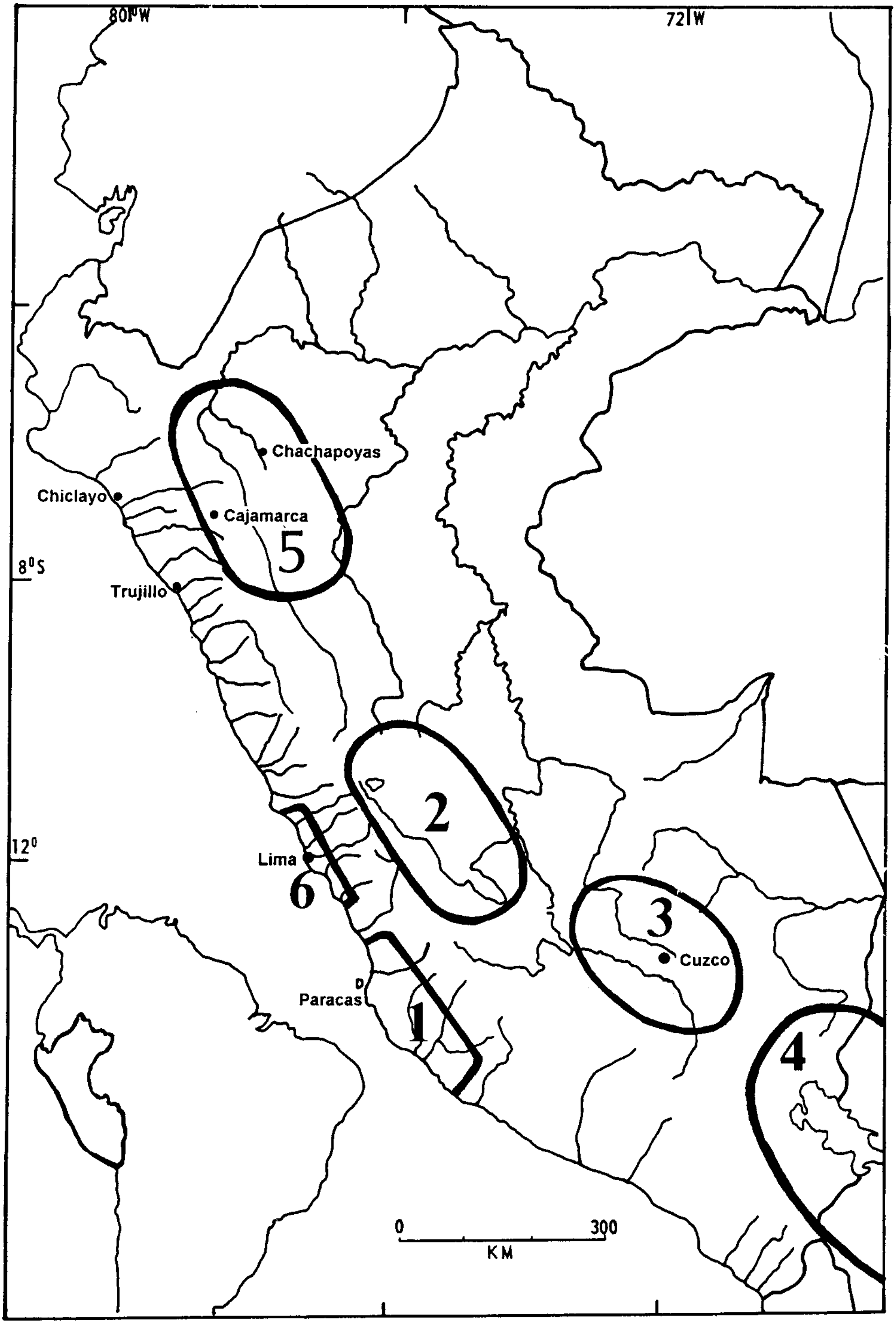
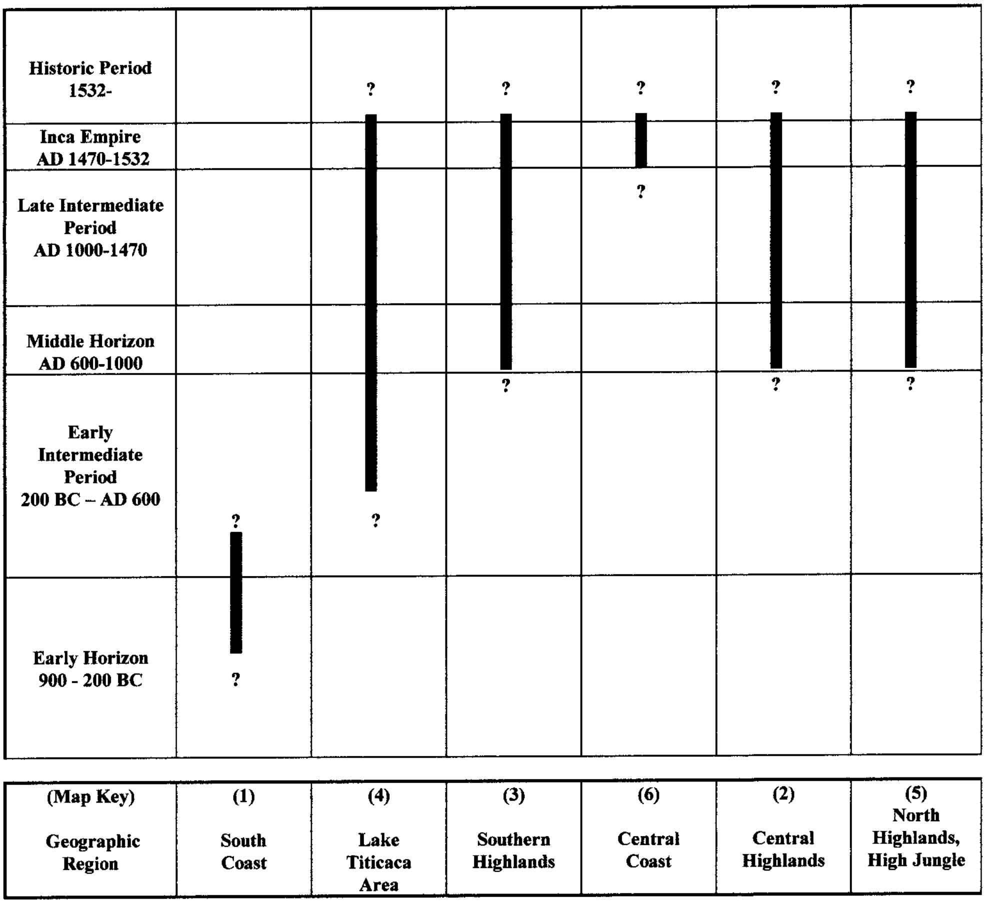


Figure 1. Map showing regions where trepanation was practiced in prehistoric South America. See Table 1 for explanation of numbers and chronology.

Table 1. Approximate dates for trepanned skull samples from various regions of Peru and Bolivia (see Fig. 1 for locations).



as the majority were surface collected from disturbed tombs in the late-nineteenth and early-twentieth centuries, and in most cases little attention was given to identifying cultural context (Tello, 1913; Hrdlika, 1914). A small number of scientifically excavated specimens are known, however, and these allow us to assign approximate dates to collections with limited contextual data. Nevertheless, there remains some uncertainty about the earliest and latest dates for trepanning in most regions, as is indicated by the question marks in Table 1.

Demographic Composition of the Sample

Table 2 gives a breakdown of our sample by age, sex, and geographic provenience. Adult males are a clear majority, although women and children were also were trepanned. Trepanations were found in several children under twelve years of age; the youngest was

Table 2. Geographic Distribution and Demographic Composition of the Sample. Adults of uncertain sex are excluded from the table.

Region	*Sample Size*	*Adult Males (%)*	*Adult Females (%)*	*Subadults (%)*
South Coast	60	65.0	30.0	5.0
Central Highlands	457	56.7	31.5	8.3
Southern Highlands	86	61.6	31.4	7.0
Northern Highlands	2	–	100.0	–
Central Coast	4	100.0	–	–
Lake Titicaca Area	12	50.0	50.0	–
TOTAL	621	58.1	31.7	7.6

a child of two to three years. The higher incidence of trepanation among adult males parallels the higher frequency of skull injuries in this group, suggesting a relationship between skull trauma and trepanation.

Trepanation Technique

Four trepanation techniques were used in ancient Peru: scraping, linear cutting, circular grooving, and boring and cutting (Fig. 2) (Lastres and Cabieses, 1960; Lisowski, 1967). Scraping was the earliest method – appearing on the south coast of Peru ca 400 BC. Bifacial obsidian knives were apparently the tool used in these early surgeries, as copper or bronze tools were unknown at this time. In contrast, the linear cutting technique is most characteristic of the central highlands, although trepanations by the scraping and boring and cutting technique are also found here, as well as in the southern highlands and high jungle of northern Peru. Some central highland trepanations show a combination of more than one technique, indicating that some experimentation occurred. Circular grooving appears late in the prehistoric record, and appears to have evolved in the southern highlands during the Late Horizon (Inca Empire). Copper and bronze knives and chisels have been recovered from central and southern highland sites, and these may have been the tools used to trepan skulls, although this has yet to be confirmed by detailed study of the cut marks themselves. Nevertheless, a Peruvian surgeon demonstrated that such tools were capable of cutting bone by performing a successful craniotomy on a living patient in 1944 using archaeological specimens (Anonymous, 1945).

In general, a trend can be seen towards the reduction in the size of trepanation openings through time, although there is substantial variability within time periods and geographic areas (Table 3). Very large trepanations are typical of the early skulls from the south coast (Fig. 3), while smaller and more consistent-sized trepanations are found in the southern highlands at Inca sites (Fig. 4).

Healing

A significant percentage of Peruvian trepanned skulls show evidence of healing, indicating survival following the procedure. Healing can be classified into three general catego-

Figure 2. Trepanation techniques in ancient South America: a. scraping. b. linear cutting. All skulls from the Museo Arqueológico de la Universidad San Antonio Abad, Cuzco, Peru.

a

b

c

d

Figure 2. Trepanation techniques in ancient South America: c. circular grooving. d. boring and cutting. All skulls from the Museo Arqueológico de la Universidad San Antonio Abad, Cuzco, Peru.

Figure 3. Large trepanation with evidence of short-term healing. Paracas, south coast of Peru. Museo Nacional de Antropología, Arqueología, y Historia, Lima, Peru.

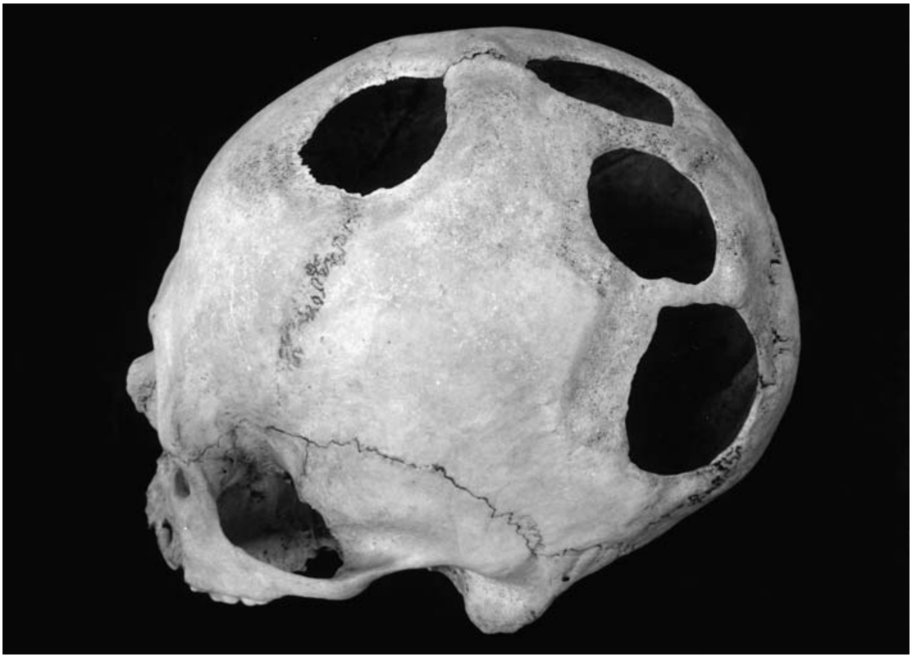


Figure 4. Inca cranium with four well-healed trepanations by the circular grooving technique. Museo Arqueológico de la Universidad San Antonio Abad, Cuzco, Peru.

Table 3. Trepanation size (area in cm^2).

Geographic Region	*Mean Area (cm^2)*	*Standard Deviation*	*Minimum*	*Maximum*
South Coast	28.3	29.1	1.0	82.0
Central Highlands	12.6	13.4	0.9	69.6
Southern Highlands	12.8	10.9	0.8	52.7

Table 4. Trepanation healing in south coast, central highlands, and southern highlands samples.

Area	*No Healing*	*Short-term Survival*	*Long-term Survival*
South Coast	39.7	24.1	36.2
Central Highlands	42.1	14.3	43.6
Southern Highlands	12.5	9.4	78.1

ries, based on the degree of bony reaction to the trepanation: 1. *None*- where there is no evidence of bony reaction, suggesting that death occurred during or within a matter of days following the operation (Fig. 2b, d); 2. *Short-term Survival*- where osteoclastic activity, bone necrosis, or hypervascularity is visible around the margins of the trepanation opening, indicating survival for at least several weeks (Figs 3, 5), and 3. *Long-term Survival*, where there is evidence of extensive remodeling of the margins of the trepanation defect (Figs 2a, 4). Table 4 presents data on trepanation healing for south coast, central highlands, and southern highlands samples. It can be seen that success rates improve from the earliest south coast trepanations to the later central highlands and southern highlands trepanations, reaching an impressive long-term survival rate of 78% by Inca times.

Trepanations by scraping and circular grooving generally show the highest success rates (with the exception of the early Paracas examples), whereas trepanations by straight cutting and drilling-and-cutting show the lowest. This probably reflects the fact that accidental penetration of the dura mater was more frequent with the latter two methods. The most impressive cases of multiple trepanations with long-term healing are known from the Late Horizon, where as many as seven healed trepanations have been found on a single skull (Brothwell, 1959).

Head Injury

Depressed skull fractures are common in some skeletal collections from prehistoric Peru, and we have noted particularly high frequencies in the central highlands. The majority of these injuries were probably produced by blows from clubs and sling stones, weapons widely used in the Andes in prehistoric times, although some may have resulted from falls or other accidents. The American physical anthropologist Aleš Hrdlika made extensive collections of skulls from Peruvian central highland sites in the early part of the twentieth century (Hrdlika, 1914), and these are particularly valuable in assessing the

Table 5. Frequency of healed depressed fractures in crania from Peruvian central highland sites where trepanation was practiced. Hrdlika Collection, National Museum of Natural History, Smithsonian Institution.

Site	*N*	*Adult Males with fractures (%)*	*Adult Females with fractures (%)*	*Subadults with fractures (%)*
San Damian	141	58.9	27.0	21.0
Cinco Cerros	35	47.4	46.7	100.0
Matucana	23	55.6	36.4	66.7
Huarochiri	13	50.0	33.3	0.0
Total	212	55.7	31.6	26.9

frequency of head injury in these trepanation-practicing groups. Data on healed depressed skull fractures for four central highlands sites collected by Hrdlika is presented in Table 5. It can be seen that head injuries were very common, not only in adult males, but in females and subadults (adolescents and children) as well. The high frequency in individuals of all ages and both sexes suggests conflicts involving whole villages, rather than organized warfare by men alone. This is consistent with a tradition of ritual battles still practiced in some isolated highland groups in Peru and Ecuador today, where slingstone fights involve participants from a broad segment of the population (Topic and Topic, 1997).

Trepanation and Skull Fracture

One of the objectives of our study was to examine the relationship between skull fracture and trepanation, an observation that had been made in previous studies of Peruvian trepanations (Tello, 1913; Daland, 1935; Stewart, 1958). Indeed we observed many cases where a trepanation was clearly associated with skull injury (Fig. 6). The highest frequency was found in the central highlands sample, where 26.2% of 457 trepanations were associated with visible skull fracture. In contrast, only 6.8% of Paracas trepanations and 11.8% of Southern Highlands trepanations had associated skull fracture. Interestingly, we found a number of examples in central highlands skulls of a trepanation begun at the site of a depressed fracture but not completed (Fig. 6), presumably because the patient died during the procedure or the trepanation was aborted for some reason and the patient died shortly afterward. Incomplete procedures such as these suggest that in other cases evidence of the fracture may have been removed by the trepanation itself. This is particularly likely in cases in which large portions of the cranial vault were removed, such as in the early crania from Paracas (see Table 3). Therefore, our estimate of the number of trepanations associated with skull fracture should be considered a minimum one; the true incidence is no doubt higher.

The objective of trepanation following head injury presumably was to elevate depressed fractures, remove bone fragments and smooth broken edges, and possibly to drain epidural hematomas. Although there is no soft tissue evidence to confirm this,

Figure 5. Trepanation with short-term healing, evidenced by areas of osteoclastic reaction around a central focus of necrotic bone (arrows). Museo Nacional de Antropología, Arqueología, y Historia, Lima, Peru.

practitioners probably learned through experience to avoid penetration of the dura matter, due to the high risk of infection and physical damage to the brain.

Location

At the preliminary stages of this study, predictions were made about the most likely and unlikely sites for trepanation procedures. We predicted that areas of the skull overlain by substantial muscle tissue, such as the nuchal area and the temporal fossa would probably be avoided, and our data tend to confirm this. We also searched for side preferences. An earlier study of central highland Peruvian trepanned skulls by Stewart (1958) found a higher frequency of trepanations on the left side of the skull. Stewart concluded that this reflected the treatment of skull fractures received from a right-handed assailant. It is reasonable to assume that trepanations performed to relieve depressed skull fractures would be placed at or near the site of injury. Results of our own examination, based on a substantially larger and more geographically and temporally varied sample than Stewart's, produce surprisingly similar results, with the greatest number of trepanations located on the left side of the skull (Table 6). It should be noted, however, that many openings are not associated with visible skull fracture, although as indicated previously, such evidence might have been removed by the surgery itself. Unfortunately, given the fact that we are limited to skeletal evidence alone, the specific motivation for most

Table 6. Location of trepanations relative to the mid-sagittal plane.

Sample	*Number of Crania*	*Number of Trepanations*	*Left Side*	*Right Side*	*Mid-Sagittal*
South Coast	60	69	46.4%	33.3%	20.3%
Central Highlands	457	551	49.9%	34.8%	15.2%
Southern Highlands	86	126	51.6%	28.6%	19.8%
Total	603	746	49.9%	33.6%	16.5%

Figure 6. Incomplete trepanation at the site of a depressed skull fracture in a skull from Cinco Cerros, central highland Peru. National Museum of Natural History, Smithsonian Institution.

trepanations is unknown, and other possible motives, such as attempts to treat headache, epilepsy, or paralysis, or some other health condition, must remain as possible alternatives.

We initially hypothesized that “elective” trepanations might show a distinct location pattern from those associated with acute trauma, reflecting such factors such as ease of surgical access, lower risk to the patient, or cultural beliefs about appropriate sites for the procedure. Unfortunately, preliminary analyses of trepanation locations have not been able to demonstrate a clear difference between those trepanations associated with trauma and those that are not. The issue is complicated by the fact, well-known to clinicians, that not all head injuries involve skull fracture. Distinguishing between trepanations performed to treat acute trauma and those that were done for other purposes is therefore difficult in the absence of visible skull fracture.

Conclusions

Trepanation was an indigenous surgical procedure practiced in Andean South America over a period of approximately 2,000 years. It clearly served as a practical treatment for depressed skull fracture, although it also might have evolved through time as a treatment for headaches or other neurological disorders. Skeletal collections from Peru document the frequent association between trepanation and skull fracture, although it is difficult to identify the motivation for many trepanation procedures, particularly cases of multiple operations on a single patient.

Ancient Peruvian trepanners experimented with various techniques to make openings in skulls. Although it is unknown how surgical knowledge was acquired and passed on, success rates increased through time, eventually resulting in an impressive surgical record among Inca practitioners of the southern highlands. Additional research remains to be done, however, to better document the practice of trepanation across space and time. Our database project, by locating collections scattered in various museums around the world and recording them in a systematic fashion, should contribute to resolving some of the long-standing questions about trepanation in ancient South America.

Acknowledgements

Financial support for aspects of research reported in this article came from Fulbright Lectureships in Peru (1989, 1996) granted by the Council for the International Exchange of Scholars, and travel funding from the Research Opportunities Fund of the National Museum of Natural History, Smithsonian Institution. I am grateful to the following museums for permission to study and photograph their collections: In Peru, the Museo Nacional de Antropología, Arqueología y Historia, Lima, and the Museo Arqueológico de la Universidad San Antonio Abad, Cuzco; in the United States, the National Museum of Natural History, Smithsonian Institution, the American Museum of Natural History, New York, the Peabody Museum of Archaeology and Ethnology, Harvard University, and the Field Museum of Natural History, Chicago. All photographs in this article were taken by the author.

Note

1. Age and sex were estimated using standard osteological and dental criteria outlined in Bass (1987) and Ubelaker (1989). Children were aged by dental calcification and eruption; adults were assigned to broad age categories (young/middle/old) on the basis of cranial suture closure and tooth wear.

References

Allison MJ, Pezzia A (1976): Treatment of Head Wounds in Pre-Columbian and Colonial Peru. *Med Coll VA Q 12*:74–79.

Anonymous (1945): Peruvian operated on with Inca instruments. *El Palacio 52*: 38–39.

Bass WM (1987): *Human Osteology: A Laboratory and Field Manual of the Human Skel-*

eton (third edition). Columbia, Missouri, Missouri Archaeological Society Special Publications.
Broca P (1867): Cas Singulier de Trépanation chez les Incas. *Bull Soc Anthropol (Paris) 2* (Série 2): 403–408.
Brothwell DR (1959): Notable Examples of Early Trephining. In: Oakley KP, Brooke WMA, Akester AR, Brothwell DR, Contributions on Trepanning or Trephination in Ancient and Modern Times. *MAN* (London) *59* (Article 133):95–96.
Daland J (1935): Depressed Fracture and Trephining of the Skull by the Incas of Peru. *Ann Med Hist 7*:550–558.
Hrdlicka A (1914): Anthropological Exploration in Peru. *Smithsonian Misc Coll 63*:47–53.
Jakobsen J, Jorgensen JB, Jorgensen LK, Schjellerup I (1987): “Cazadores de Cabezas” en Sitios Pre-Inca de Chachapoyas, Amazonas. *Revista Mus Nac (Peru) 48*: 135–185.
Lastres JB, Cabieses F (1960): *La Trepanacion del Craneo en el Antiguo Peru*. Universidad Nacional Mayor de San Marcos, Lima.
Lisowski FP (1967): Prehistoric and Early Historic Trepanation. In: Brothwell DR, Sandison AT, eds., *Diseases in Antiquity*. Springfield, Illinois, Charles C. Thomas, pp. 651-672.
MacCurdy GG (1923): Human Skeletal Remains From the Highlands of Peru. *Am J Phys Anthropol 6*:217–329.
Piggot S (1940): A Trepanned Skull of the Beaker Period From Dorset and the Practice of Trepanning in Prehistoric Europe. *Proc Prehist Soc 6*: 112-132.
Rifkinson-Mann S (1988): Cranial Surgery in Ancient Peru. *Neurosurgery 23*: 411-416.
Stewart TD (1958): Stone Age Skull Surgery: A General Review, With Emphasis on the New World. *Ann Rep Smithsonian Instit 1957*: 469–491.
Tello JC (1913): Prehistoric Trephining Among the Yauyos of Peru. *Proceedings of the XVIII. Session, International Congress of Americanists*. London: Harrison and Sons.
Tello JC, Mejia Xesspe T (1979): *Paracas, Segunda Parte: Cavernas y Necrópolis*. Universidad Nacional Mayor de San Marcos, Lima.
Topic JR, Topic TL (1997): La Guerra Mochica. *Revista Arqueol “SIAN” 4*: 10–12, Universidad Nacional de Trujillo, Perú.
Ubelaker DH (1989): *Human Skeletal Remains, Excavation, Analysis, Interpretation* (Second Edition). Washington, D.C., Taraxacum.
Uhle M (1903): *Pachacamac. Report of the William Pepper, M.D. LL.D. Peruvian Expedition of 1896*. Department of Archaeology, University of Pennsylvania, Philadelphia.
Verano JW (1997): La Trepanación como tratamiento terapeútico en el antiguo Peru. In: Ramos Rodríguez RM, Peña Reyes ME, eds, *Estudios de Antropología Biológica Volumen VIII*. Universidad Nacional Autónoma de México/Instituto de Investigaciones Antropológicas, Mexico D.F., pp. 65–81.
Verano JW, Williams JM (1992): Head Injury and Surgical Intervention in Pre-Columbian Peru. *Am J Phys Anthropol*, Supplement 14, pp.167–8 (Abstract).
Weiss P (1958) *Osteologia Cultural: Practicas Cefálicas. 1a. Parte*. Universidad Nacional Mayor de San Marcos, Lima.

Chapter 18

Pre-Columbian Skull Trepanation in North America

JAMES L. STONE[1] AND JAVIER URCID[2]
[1]Division of Neurosurgery, Cook County Hospital, Hektoen Institute for Medical Research, and Loyola University, Chicago, Illinois, USA; [2]Department of Anthropology, Brandeis University, Waltham, Massachusetts, USA

Abstract

Evidence for pre-Columbian trepanation in North America is sparse, although small concentrations of the practice have been discovered in Oaxaca, Mexico and British Columbia, Canada. Reports on 20 trepanned skulls recovered in Mexico, most of which date from the Classic Period (250–900 AD), have been reviewed. Twelve were found in the ancient city of Monte Alban, Oaxaca, and five in nearby areas. Similarly we have reviewed reports on 18 trepanned skulls, most believed to be pre-Columbian, recovered in the United States and Canada. Ten were from Canada (8 British Columbia, usually the Vancouver-Fraser River region) and 8 from the United States (2 New Mexico). Considering the total group; average age was approximated at 35 years, sexes were about equally divided, location on the skull was usually parietal, perforations averaged just over two centimeters, and evidence of trauma was present in seven skulls. Multiple openings were more common in Oaxacan skulls. The predominant trepanation method was gradual scraping, however in seven Oaxacan skulls a distinctive drilling technique was used. Bone remodeling suggested some degree of survival in 80% of Mexican and 90% of Canadian/USA skulls. Perhaps Mesoamerican lapidary technology and dental drilling contributed to cranial drilling in Mexico. Four additional trepanned skulls have been recently reported from the Valley of Oaxaca which appears to have been an area of indigenous trepanation activity in this region of the New World. The reasons for trepanation, other than trauma, remain largely conjectural.

Keywords: Primitive surgery, Northwest Pacific Coast Indians, Kwakiutl Indians, Mesoamerica, Zapotec culture, Oaxaca, drilling technique

Introduction

Skull trepanation in early times was independently practiced in many areas of the world, with the highest New World concentrations in Peru and adjacent Bolivia (Hrdlicka, 1939; Lisowski, 1967; Margetts, 1967; O'Connor and Walker, 1951). Among the South American Indians, trepanation was most common in ancient times, less common in the pre-Columbian (ca 1492 AD) era and still more uncommon at the time of Spanish contact (ca 1520s) and in the post-Columbian era (Lisowski, 1967). As the evidence for cranial surgery by the early Indian peoples of present day Mexico, the United States (USA), and Canada is relatively scarce, we believed it would be of interest to analyze the available anthropological data on North America as a whole. This includes the culturally distinct regions of Mesoamerica within the borders of Mexico (Hammond, 2000; Marcus and Flannery, 2000).

Methods

This study reviews reports of 38 trepanned crania from North America thought to be the result of intentionally produced ante-mortem trepanation. Twenty of the skulls were recovered in Mexico (Lumholtz and Hrdlicka, 1897; Marquez Morfin and Gonzalez Licon, 1992; Romero, 1952, 1970, 1974; Stewart, 1958; Urcid, 1998 a,b; Velasco-Suarez et al., 1992; Wilkinson, 1975 a, b; Wilkinson and Winter, 1975; Winter, 1984), ten from Canada (Cybulski, 1980; Griffin, 1976; Hrdlicka, 1939; Kidd, 1946; Leechman, 1944; Popham, 1954; Smith and Hrdlicka, 1924; Stewart, 1958; Stone and Miles, 1990), and eight from the USA (Cosgrove, 1929; Holbrook, 1877; Hrdlicka 1939; Moodie, 1930; Neiburger, 1978; Shapiro, 1927; Stewart, 1958; Stone and Miles, 1990; Wakefield and Dellinger, 1936).

Within Mexico, 17 of the 20 cases were found in the southern highland Valley of Oaxaca. Of the 11 Canadian skulls, eight were from British Columbia, usually the Vancouver-Fraser River region. Specimens reported in the USA were not concentrated in any particular area, although two were found in New Mexico.

We have tabulated the geographic location of the discovery, estimated age and sex of the skull, evidence of trauma, location and size of the opening in the skull, and the presumed technique of trepanation. Postoperative survival evidenced by the presence or absence of bony remodeling at the edge of the trepanation was deduced from the reports. The different variables were examined and compared.

Results

Tables 1, 2 and 3 summarize the reported data on trepanned skulls from Mexico, Canada, and the United States respectively. Most of the Mexican material dates from the Classic Period (250–900AD). Although just over one half of Canadian and USA specimens are considered pre-Columbian, three are post-Columbian, and six have not been dated. In the 20 Mexican skulls, a total of 51 perforations were found. Thirty-nine of these were completed (76%) in that both the outer and inner table of bone had been removed, and the remainder incomplete. Regarding the 18 Canadian/USA skulls, 21 trepanations were present and completed in 19 (90%).

One Oaxacan skull had evidence of eight trepanation openings. Average age of the skull at the time of death was approximated to be 40 years for Mexican and about 35 years for Canadian/USA skulls. In the Mexican series, females predominated over males 11 to 9, wheras in the Canadian/USA series males outnumbered females 8 to 5, with 5 undetermined. For North America as a whole, 17 were male, and 16 female. The presence of trauma evidenced by bony depression or less commonly a fracture diastasis was noted in 6 Mexican and 1 USA skulls. The location of the trepanation was usually pari-

Figure 1. Skull from British Columbia, Canada (Table 2, No. 4). A circular midline occipital trepanation with evidence of cicatrization indicating survival. The outer table is denuded over an area larger than the size of the inner table. A smaller, second trepanation is seen over the right lambdoid suture. The diploe are open, and there is no evidence of healing. (From Kidd, 1946.)

etal, and less often vertex, frontal or occipital. In the 51 Mexican perforations, 28 were left parietal, 14 right parietal, vertex-sagittal suture region in six, and frontal in three. Average size of the skull perforations were 1.8 cm, 3.35 cm, and 2.5 cm for the Mexican, Canadian,and USA specimens, respectively. Overall average size of the opening was 2.25 cm. Six skulls from Monte Alban, Oaxaca, Mexico and one from Lambityeco, Oaxaca, Mexico had perforations performed with a drilling technique (see below). Drilling was used to make 22 perforations or 43% of the Mexican openings, of which 15 were completed. Forty-five percent of the Mexican perforations and nearly all of the Canadian openings were done with a scraping technique (Figs 1–3).

Cutting, or cutting and scraping was used in the majority of USA examples, 8% of Mexican, and on one Canadian skull (Fig. 4). Considering all North American trepanations together, a scraping technique was used in 46% of examples, drilling in 30%, cutting and scraping in 10%, cutting in 7%, and uncertain in 7%. Evidence of any survival (bone remodeling) was present in 16 of 20 (80%) Mexican skulls and 16 of 18 (about 90%) Canadian/USA skulls. Considering all 51 Mexican perforations, survival was present in 24 of the 42 skulls, or 57% with available data. For the 21 Canadian/USA perforations, survival was evident in 85% (17/20) of trepanations with available data.

All seven cases of drilling from the Valley of Oaxaca have been dated to the Late

Figure 2. Skulls from British Columbia, Canada (Table 2, No. 8, left; No. 9, right). Left skull shows a left frontal, smooth trepanation that tapers slightly inward. Right skull shows a large, right parietal opening that tapers strongly inward. One edge of the opening was freshly broken upon discovery. Healing was believed present in both skulls. (From Smith and Hrdlicka, 1924.)

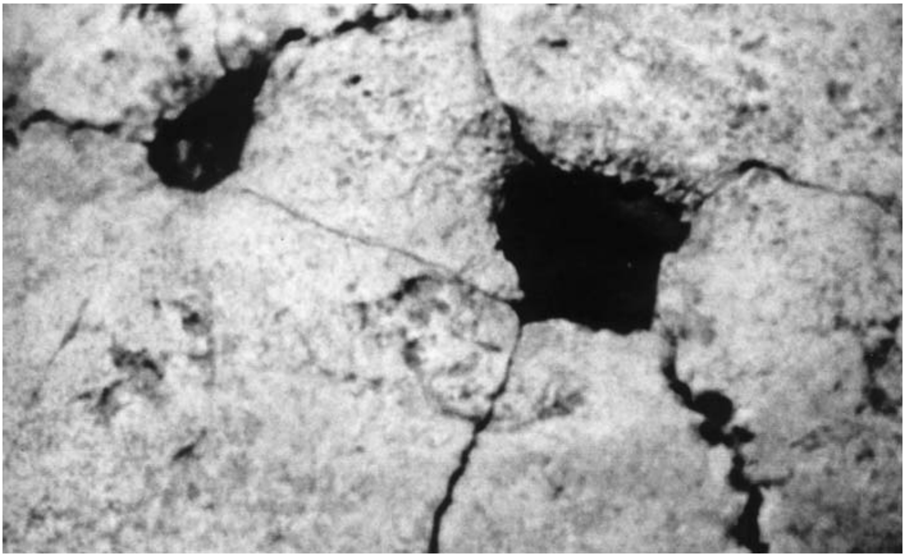


Figure 3. Skull from Monte Alban, Oaxaca, Mexico (Table 1, No. 14). Two trepanations, left opening is on the coronal suture, and right on the anterior sagittal suture. Scraping technique with evidence of survival in both. (Museum at Monte Alban, Oaxaca, Mexico, Courtesy of Javier Urcid.)

Classic Period (500–900 AD). Only one drilled skull had a single drill hole, the others had multiple drill holes, up to five in one skull (Fig. 5). Of the seven uncompleted drill holes, Skull number 3c illustrates what appears to be an incomplete perforation utilizing a hollow drill (Fig. 6). Size had been estimated in 18 of the 22 drilled perforations, and the average size was 1.14 cm. If we exclude drill holes of 0.25 cm or less (6 perforations), then the average size is 1.6 cm. Again, considering the 22 drilled Mexican perforations,

Figure 4. Skull from New Mexico, USA (Table 3, No. 4). There is a right frontal, sharply cut opening with no evidence of healing. Pathological elevations and depressions are seen on the calvarium (Moodie, 1930).

16 have been examined for evidence of survival, and only one drilled perforation, Skull number 8a (Fig. 7), shows convincing bony changes compatible with healing (6% survival). Conversely the Oaxaca drilling technique may be said to have had a mortality rate of 94%.

Discussion

Aleš Hrdlicka (1869–1943, Fig. 8), a noted pioneer of American anthropology, reported the discovery in Chihuahua, Mexico, of two trepanned skulls on the first expedition of his career (Lumholtz and Hrdlicka, 1897; Stewart, 1940). Whether these skulls of north-central Mexican Tarahumare origin (Table 1, Nos 19, 20) were pre-Columbian remains in doubt because the cranial walls of the first skull "still contain some animal matter, ... still somewhat fatty to touch, and retain some odor." (Lumholtz and Hrdlicka, 1897, p. 390). However they were considered unquestionable examples of ante-mortem trepanation, as both showed evidence of bone healing. Interestingly, the opening in the

Figure 5. Skull from Monte Alban, Oaxaca, Mexico (Table 1, No. 13). Left posterior parietal bone with 5 circular, drilled perforations. The circularity of the openings and their vertical walls point to the use of a drill. Two holes are a bit larger than the others, suggesting different drills. Healing was not believed present. (Museum at Monte Alban, Oaxaca, Mexico, Courtesy of Javier Urcid.)

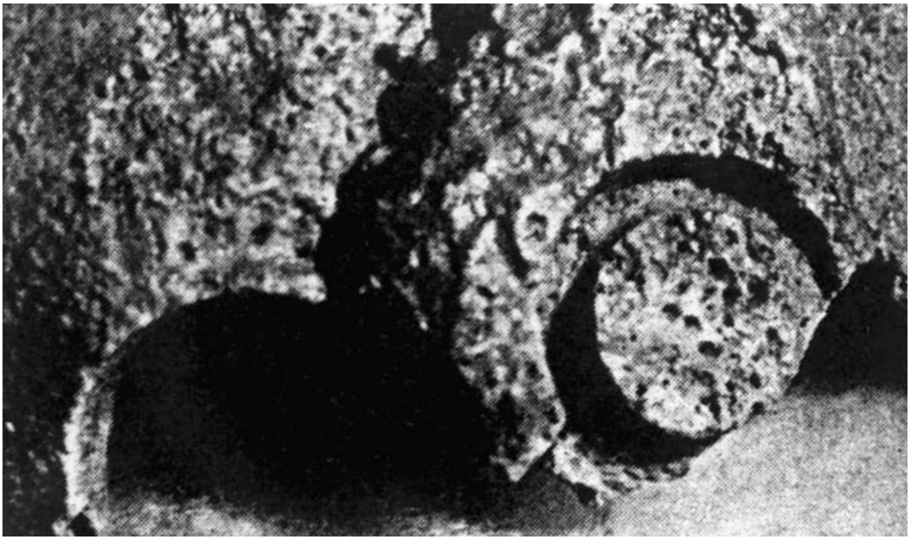


Figure 6. Skull from Monte Alban, Oaxaca, Mexico (Table 1, No. 3). Fragment of skull bone showing complete drilled trepanation at bregma (left) and incomplete drilled trepanation (right) utilizing a hollow drill. Healing was not believed present. (Regional Museum, Oaxaca City, Mexico, and Wilkinson, 1975b.)

first skull was "trephine-like" with steep walls and could have been made with a "flint wimble" (Lumholtz and Hrdlicka, 1897, p. 392).

Hrdlicka, who later visited Peru and Bolivia and was very familiar with trepanned skulls, and verified a handful of additional examples of trepanation from the USA and Canada (Hrdlicka, 1939; Stewart, 1958). One 2,000 year-old skull unearthed on Kodiac Island, Alaska (Anonymous, 1935; Hrdlicka, 1941) was cited by Hrdlicka as evidence of early Asian migration to the New World and the bringing of trepanation knowledge (Hrdlicka, 1939). Recent re-examination of this skull and several others from Hrdlicka's Kodiac material suggest the specimens to be examples of healed depressed skull fractures (Urcid, 1994). Certainly the pre-Columbian origin and legitimacy of some but not all of the Canada/USA trepanation examples have been questioned (Stewart, 1958; Cybulski, 1980).

Similar to trepanned skulls from many parts of the world, our review of Canadian and USA trepanned skulls suggests that gradual scraping possibly with a flint or obsidian tool to create oblong or circular beveled openings, in which the outer table opening was larger than the inner table opening, was the technique most commonly used (Lisowski, 1967) (Figs 1 and 2). Less tapered openings might have involved more of a cutting technique, expected to be easier to perform in areas of thinner cranium (Fig. 4). It is likely that a combination of both scraping and cutting techniques might have been used depending on the sharpness and abrasiveness of the available tool.

We have been unable to find references to ante-mortem skull trepanation in North American Indian folklore or ethnographical reviews of these diverse clutures. However, the clustering of eight British Columbia, Canadian examples, usually in the Vancouver-Fraser River region is not to be overlooked. The Kwakiutl Indians of this region were master woodworkers who constructed boats, symbolic family totem poles, elaborate masks, and other objects of art (Boas, 1966).

The Kwakiutl medicine men of the British Columbia area cauterized or pierced the scalp (nape of neck, crown, or temporal region) as a treatment for headaches (Boas, 1966). This same highly developed Northwest Pacific coast tribe clearly believed that an individual's soul was located in the head, bewitched enemies by placing charms or fetish objects within the skulls of the dead, and was known to use dried bone as a scraping or cutting knife in finger amputations (Boas, 1966). A long-time missionary among the coastal Indians of British Columbia recounted "being approached by a chief, carrying a brace and bit, who begged him to bore a hole in his skull to allow escape of an evil spirit causing him to have headaches" (Kidd, 1946, p. 514).

In reference to the trepanned skulls from the USA, two from New Mexico might have been Pueblo Indian in origin (Moodie, 1930; Shapiro, 1927), and those found in Arkansas, Illinois and Michigan might have come from the mound-building tribes (Holbrook, 1877; Hrdlicka, 1939; Wakefield and Dellinger, 1936).

The 20 trepanned skulls recovered in Mexico presented in Table 1 do not include all examples of reported trepanation in Mexico (Velasco-Suarez et al., 1992). To facilitate the study and understanding of this phenomenon, our emphasis has been to highlight Oaxaca as a likely Mesoamerican center of trepanation activity in ancient times. Although we do not discount that scattered examples of trepanation probably existed in Mexico as elsewhere, our approach is supported by contemporary archeologists and anthropologists working in the region, including the junior author of this chapter.

Certainly, more work must be done regarding further examination of Mexican crania in various museums, and placement of the findings within an appropriate ethnohistorical context. Nevertheless, certain trepanned skulls recovered in Mexico but outside of Oaxaca require further comment. Cases 19 and 20 reported by Hrdlicka (Lumholtz and Hrdlicka, 1897) were previously discussed. Case number 19 recovered at Palenque, Chiapas in the Maya lowlands appears to be a good example of healed scraping and cutting trepanations

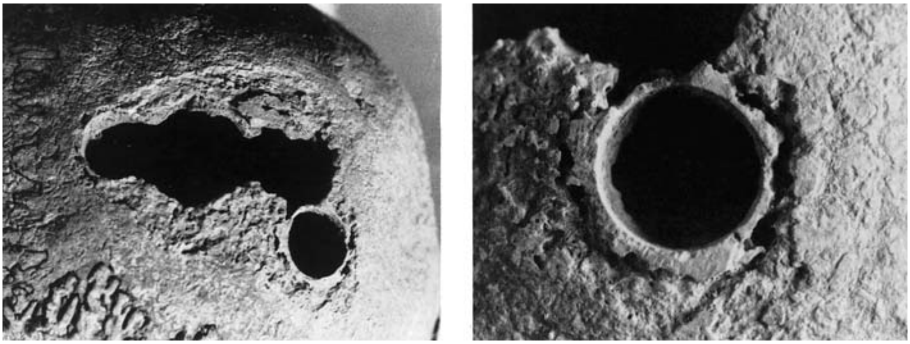


Figure 7. Skull from Monte Alban, Oaxaca, Mexico (Table 1, No. 8). Right parietal drilled trepanations. Four drilled openings with survival indicated by the dense collar of bone surrounding the inferior opening, as well as the roughened areas about the larger opening, possibly indicating infection . Scraping and cutting could also explain the irregular areas. (Regional Museum, Oaxaca City, Mexico, and Wilkinson, 1975a.)

(Velasco-Suarez et al., 1992, p.315, Fig. 3). Illustrated examples from Chichen Itza, in the Mayan Yucatan, are more properly called “suprainion lesions” or “pseudotrephinations”. This type of skull lesion just above the inion, also found in Peru and the Pueblo area of Southwest USA, appears related to early childhood bone irritation and necrosis caused by the head modification apparatus used to produce vertical-occipital flattening (Stewart, 1971). Alleged examples of trepanation from Preclassic Tlatilco in the Valley of Mexico have been questioned as traumatic defects, postmortem drilling, or gnawing by rodents (Wilkinson, 1975 a; J. Verano, April 2000, personal communication).

The recovery of 17 trepanned skulls from Monte Alban, Oaxaca and adjoining valleys in the southern Mexican highlands is a fascinating chapter in archeology and anthropology, from which further insight is expected with future excavations. Monte Alban, the ancient capital of the region, is situated in the center of the Valley of Oaxaca on a 400 m cleared hilltop, just west of the modern city of Oaxaca.

A large expanse of flat, fertile land with easily accessible water and a semiarid climate, the Oaxaca Valley at an elevation of 1,500 m is surrounded by 3,000 m-high rugged mountain ranges. Among the most grandiose of all American temple centers, a huge civic-ceremonial complex was constructed at Monte Alban encompassing a great plaza with religious structures, pyramids and platforms. This site was occupied for nearly 1,500 years (500 BC to ca 1,000 AD), and became one of the most advanced centers of ancient New World civilization. The agriculturally based Zapotec people who inhabited Monte Alban and the Valley of Oxaca developed a distinct language and culture typified by hieroglyphic writing on carved slabs, astronomical observations leading to a calendar, and arithmetical notations. The oldest hieroglyphic inscriptions in the New World are found on carved stone slabs from the Oaxaca Valley and Monte Alban dating from about 400 BC. The dating of archeological sites in the Valley of Oaxaca has been determined largely from basic ceramic chronology developed over a fifty-year period by Alfonso Caso and his students. At Monte Alban, as in other ancient Mesoamerican cultures such as the Mayan, people played a ritual ball game on a hard court, worshipped many gods, and believed in blood offerings, self mutilation and human sacrifice.

During the Classic Period (especially 200–700 AD) Monte Alban was enlarged into an urban metropolis with a population approximated at 25,000, which included residential suburbs surrounding the hilltop nucleus of public buildings, temples, carved monuments and rich tombs. Other Zapotec towns and villages were scattered on the slopes and floor of the Oaxaca Valley whose population approached 55,000.

However, by 800 to 900 AD, the lowland Maya centers to the east and south disintegrated politically, and about one century later Monte Alban likewise collapsed and was largely abandoned. Subsequent changes in Zapotec culture resulted from political competition with Mixtec elites, macro-regional interaction with other regions of Mesoamerica, desirability of living elsewhere in the valley, and perhaps disease or famine (Marcus and Flannery, 2000; Feinman et al., 1999; Blanton et al., 1999; Blanton et al., 1993; Coe, 1984).

In the 1930s and 1940s the Monte Alban excavations under the direction of Alfonso Caso yielded 5 skulls with evidence of trepanation (Romero, 1970; Wilkinson, 1975b). Three of the five skulls had openings made by scraping and cutting, presumably with an obsidian knife, producing an ellipsoidal shaped trepanation with beveled edges. The other two skulls had openings with uniform circularity and vertical walls suggestive of drilling. In one of these, a fragment of the skull disclosed a completed circular opening (Table 1, No. 3b) adjacent to an unfinished trepanation clearly undertaken with a hollow (tubular) drill (Table 1, No. 3c) (Fig. 6). The holes have different diameters and must have been made with different drills.

In the 1970s, additional trepanned skulls were unearthed at Monte Alban, some with evidence of scraping or cutting (Fig. 3) and others apparently drilled (Wilkinson, 1975 b) (Figs 5 and 7). Excavations in the same residential area produced four trepanned skulls by a similar scraping technique over the parietal and sagittal areas (Table 1, Nos 9,10,11, and 12). These adjacent burials suggest the possibility of surgery for ritualistic or therapeutic purposes. Funerary findings at the burial sites of these trepanation cases suggested a low socioeconomic status.

Cases numbers 10 and 11 were young adults found together, perhaps husband and wife, with similar vertically flattened, artificially deformed skulls. Many skulls from Monte Alban exhibit intentional reshaping of varying degrees, but the presence of many modified skulls with no trepanations and trepanned skulls with very slight flattening, rules out intentional reshaping as a motive for the surgery (Wilkinson, 1975b). Nevertheless the practice of intentional reshaping of the head was widespread in Mesoamerica and other parts of the American continent. The higher incidence of females in the Oaxaca material argues against trepanation for battle injuries, and perhaps more for curative purposes.

The earliest metal, copper, does not appear in Oaxaca until about 900–1,000 AD (G. Feinman, March 2000 personal communication), which is later than the period during which most of the trepanations in Oaxaca were believed to have occurred. Consequently a metal cutting tool, such as a tumi used by the Peruvians, is not believed to have been used in Oaxaca.

Recently, additional cases of ancient trepanation from Monte Alban have been collected in tabular form, disclosing a total of 12 skulls (Marquez Morfin and Gonzales

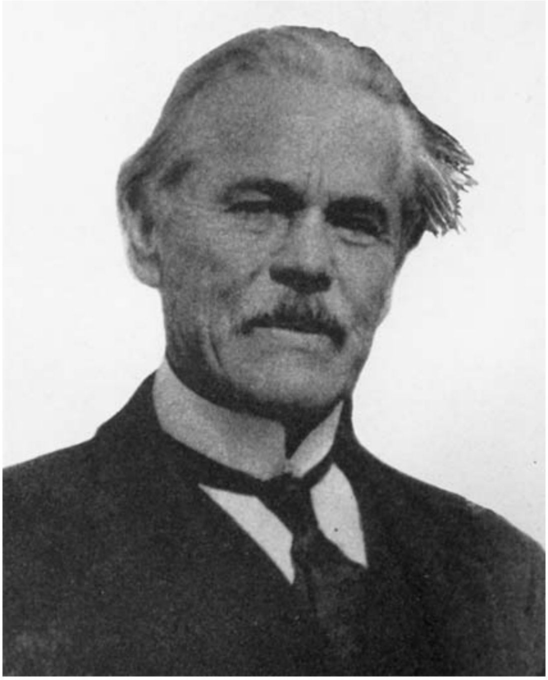


Figure 8. Aleš Hrdlicka (1869–1943). Pioneer North American Anthropologist.

Licon, 1992), and a total of 17 including Monte Alban and surrounding villages in the Valley of Oaxaca (Urcid, 1998 a,b). Clearly, the Valley of Oaxaca was the predominant New World center for skull surgery in Mesoamerica.

Perhaps the most interesting finding in seven of the 17 ancient trepanned skulls recovered from the Valley of Oaxaca is that a unique drilling technique had been used. Early trepanations of this character have not been described in skulls from South America or anywhere else in the world that we are aware. The Oaxacan drilling technique likely had it's origin in the early formative years of the region, roughly 1,000 BC. During this period drilling was performed in the making of ornaments and jewelry from stone, mica or marine shells (Coe, 1984). Drilled beads, pendants, and bracelets have been recovered as funerary objects from grave sites in Oaxaca, where such specialty goods were considered a sign of wealth (Blanton et al., 1999).

Small round disks or cores, which one would expect to obtain after the use of a hollow tubular drill, have been recovered at several sites in the central valleys of Oaxaca like Monte Alban, Mitla, and Ejutla (Urcid, 1998a). The cores from Ejutla date to Terminal Formative and Early Classic times (250 BC to 250 AD) (Feinman and Nicholas, 1993, 1995). Smooth, rounded marine shell drill plugs, approximately 0.75 to 1.5 cm in diameter, were assumed to have come from the use of a hollow drill of cane, perhaps utilizing water and sand in the drilling process (G. Feinman, March, 2000, personal communication).

A second example of drilling in ancient Oaxaca comes from the practice of dental inlays or the drilling of teeth. This was often done during life or to adorn the skull and mandible of the dead. Small precious stones were placed into holes which had been drilled through the tooth (Romero, 1970; Verut, 1973). Many examples of dental inlays and drilled ornamental jewelry have been recovered from the Middle Formative Period (900–600 BC), well before the late classic period from which the drilled Oaxaca trepanations emanate (Romero, 1970).

Furthermore, an actual bone drill was recovered from within an ancient onyx stone slab found in the Valley of Mexico (Holmes, 1897). The external diameter (1.3 cm) of the straight piece of bone closely matched that of the drilled hole, and appeared to be the femur of a large bird such as a crane. This hollow tubular drill was inadvertently discovered when the stone slab was damaged during transport and the drilled hole exposed. One flat end of the bone was "scratched and striated as if by attrition with fine sand." (Holmes, 1897, pp. 307–308). Careful analysis of material collected from the drilled holes revealed decomposed bone mixed with hard volcanic rock grains. One can envision a sharply cut hollow-bone drill rapidly spun between the hands, or by a bow drill, with volcanic sand employed as the abrasive cutting agent (Holmes, 1897, pp. 308–309). Perhaps skilled craftsmen were responsible for these drilled trepanations. It has been concluded that both dental drilling and cranial drilling in prehistoric times are uniquely Oaxacan (Wilkinson, 1975a).

Conclusion

The evidence for cranial trepanation in pre-Columbian North America has been presented and discussed. Concentrated areas of trepanation activity existed in the Oaxaca Valley of Mexico (17 cases) and British Columbia, Canada (8 cases). Although trepanations by scraping or cutting predominated, a unique drilling technique was identified in seven Oaxacan skulls. This technique appeared to employ the use of a hollow tubular drill of animal bone or cane, and was uncommonly associated with survival. In Oaxaca, cranial drilling probably evolved from lapidary work, jewelry making and dental drilling. Oaxaca, Mexico and less so British Columbia, Canada were seemingly independent centers for cranial surgery, with the highest New World concentration of trepanned skulls outside of South America.

References

Anonymous (1935): Alaska Indians had brain surgeons 2,000 years ago. *Sci News 28*: 377.

Blanton RE, Kowalewski SA, Feinman GM, Finsten LM (1993): *Ancient Mesoamerica. A Comparison of Change in Three Regions*. 2nd edition. Cambridge, UK, Cambridge University Press, pp. 50–105.

Blanton RE, Feinman GM, Kowalewski SA, Nicholas LM (1999): *Ancient Oaxaca*. The Monte Alban State. Cambridge, UK, Cambridge University Press.

Boas F (1966): *Kwakiutl Ethnography*. Codere H, ed., Chicago, University of Chicago Press, pp 148,149,384,386.

Coe MD (1984): *Mexico*. 3rd edition. London, Thames and Hudson, pp. 47, 81–85, 115–119, 137–142.

Cosgrove CB (1929): A note on a trephined Indian skull from Georgia. *Am J Phys Anthropol 13*: 353–357.

Cybulski JS (1980): Skeletal remains from Lillooet, British Columbia, with observations fro a possible diagnosis of skull trephination. *Syesis 13*: 53–59.

Feinman GM, Nicholas LM (1993): Shell-ornament production in Ejutla. *Anc Mesoam 4*: 103–119.

Feinman GM, Nicholas LM (1995): Household craft specialization and shell ornament manufacture in Ejutla, Mexico. *Expedition 37*, No. 2: 15–25.

Griffin JDM (1976): Trepanation among early Canadian Indians. *Can Psych Assoc J 21*: 123–125.

Hammond N (2000): The Maya lowlands: Pioneer framers to merchant princes. In: Adams REW, MacLeod MJ, eds., *The Cambridge History of the Native Peoples of the Americas*, Vol II, Part 1. Cambridge, United Kingdom, pp. 197–249.

Holbrook WC (1877): Examinations of Indian mounds on Rock River, at Sterling, Illinois. *Am Nat 11*:688–689.

Holmes WH (1897): *Archeological Studies Among the Ancient Cities of Mexico. Part II. Monuments of Chiapas, Oaxaca and the Valley of Mexico*. Chicago, Field Columbian Museum, Pub. 16, Anthropological Series, Vol 1, No.1: 304–309.

Hrdlicka A (1939): Trepanation among prehistoric people, especially in America. *Ciba Symposia 1*:170–177.

Hrdlicka A (1941): Diseases of and artifacts on skulls and bones from Kodiac Island. *Smithsonian Misc Coll, Vol. 101(4)*:1–25.

Kidd GE (1946): Trepanation the early Indians of British Columbia. *Can Med Assoc J 55*: 513–516.

Leechman D (1944): Trephined skulls from British Columbia. *Trans Roy Soc Can 2–4*:99–101.

Lisowski FP (1967): Prehistoric and early historic trepanation. In: Brothwell D, Sandison AT, eds., *Diseases in Antiquity*. Springfield, IL, Charles C. Thomas,pp. 651–672.

Lumholtz C, Hrdlicka A (1897): Trephining in Mexico. *Am Anthrop 10*: 389–396.

Marcus J, Flannery KV (2000): Cultural evolution in Oaxaca: The origins of the Zapotec and Mixtec civilizations. In: Adams REW, MacLeod MJ, eds., *The Cambridge History of the Native Peoples of the Americas*, Vol II, Part 1. Cambridge, United Kingdom, Cambridge Univ Press, pp. 358–406.

Margetts EL (1967): Trepanation of the skull by the medicine-men of primitive cultures, with particular reference to present-day native East-African practice. In: Brothwell D, Sandison AT, eds., *Diseases in Antiquity*. Springfield, IL, Charles C. Thomas, pp. 673–701.

Marquez Morfin L, Gonzalez Licon E (1992): La trepanacion craneana entre los antiguos zapotecos de Monte Alban. *Cuadernos del Sur (Oaxaca) 1*: 25–50.

Moodie RL (1930): Studies in paleopathology, XXIV. Prehistoric surgery in New Mexico. *Am J Surg 8*:905–908.

Neiburger EJ (1980): Trephination- Two probable cases in prehistoric Wisconsin Indians. *Wisc Archeol 59*: 253–265.

O'Connor DC, Walker AE (1951): Prologue: Prehistoric and primitive trepanation. In:

Walker AE, ed., *A History of Neurological Surgery*. Baltimore, Williams and Wilkins, pp. 1–9.

Popham RE (1954): Trepanation as a rational procedure in primitive surgery. *Univ Toronto Med J 31*:204–211.

Romero J (1952): Los patrones de la mutilacion dentaria rehispanica. *Anales Inst Nac Antrop e Hist* for 1949–50, vol.4, No. 32, footnote 19, pp.192–193.

Romero J (1970): Dental mutilation, cranial trephination and cranial deformation. In: Stewart TD, ed., *Handbook of Middle American Indians*, Vol 9. Austin, University of Texas Press, pp. 50–67.

Romero J (1974): La trepanacion prehispanica. In: Romero J, ed., *Anthropologia Fisica. Epoca Prehispanica. Panorama Historico y Cultural III*, Sep. Instituto National de Anthropologia e Historia, Mexico, pp. 179–194.

Shapiro HL (1927): Primitive surgery. First evidence of trephining in the Southwest (USA). *Natural History 27*:266–269.

Smith HI, Hrdlicka A (1924): Trephined aboriginal skulls from British Columbia and Washington. *Am J Phys Anthropol 7*:447–454.

Stewart TD (1940): The life and writings of Dr. Aleš Hrdlicka. *Am J Phys Anthropol 26*: 3–40.

Stewart TD (1958): Stone age skull surgery: A general review, with emphasis on the New World. *Smithson Inst Ann Rep 1957*:469–491.

Stewart TD (1971): Pseudotrephination. *Am J Phys Anthropol 35*:296–297.

Stone JL, Miles ML (1990): Skull trepanation among the early Indians of Canada and the United States. *Neurosurgery 26*: 1015–1020.

Urcid J (1994): Cannibalism and curated skulls: Bone ritualism at Kodiac Island, Alaska. In: Bray T and Killion T, eds., *Reckoning with the Dead: Larsen Bay and the Smithsonian Institution*. Washington D.C., Smithsonian Institute Press. pp. 101–121.

Urcid J (1998a): The technology of trephination in Mesomerica. Paper presented at the 61st Annual Meeting of the Society for American Archeology, Seattle, USA.

Urcid J (1998b): La technologia de la trepanacion en Oaxaca antugua. The Welte Institute for Oaxacan Studies. Tercera Conferencia Bianual De Estudios Oaxaquenos. Sesion: Arqueologia. Oaxaca, Mexico, 10 Julio, 1998.

Velasco-Suarez M, Bautista Martinez J, Garcia Oliveros R, Weinstein PR (1992): Archaeological origins of cranial surgery: Trephination in Mexico. *Neurosurgery 31*: 313–319.

Verut DD (1973): *Precolombian Dermatology and Cosmetology In Mexico*. New York, Schering Corporation.

Wakefield EG, Dellinger SC (1936): The probable adaptation of utilitarian implements for surgical procedures by the "mound builders" of Eastern Arkansas. *J Bone Joint Surg 18*:434–438.

Wilkinson RG (1975 a): Trephination by drilling in ancient Mexico. *Bull NY Acad Med 51*: 838–850.

Wilkinson RG (1975 b): Techniques of ancient skull surgery. *Nat Hist 84*, No 8:94–101.

Wilkinson RG, Winter MC (1975): New evidence for trephination from Monte Alban. *Actas Cong Inter Amer 1*: 127–130.

Winter MC (1984): La trepanacion en Oaxaca. In: Lopez Austin A, Viescas Trevino C, eds., *Historia General de la Medicina en Mexico*. Vol I, Mexico Antiguo, UNAM, Mexico, pp. 59–64.

Part 4: Trepanation in Western Medicine

"*If al (sic) means fail, the last remedy is to open the fore part of the skul (sic) with a Trepan*"

Riverius, 1655

Chapter 19

Galen and the Uses of Trepanation

JULIUS ROCCA
Research Fellow in Medical Humanities, Karolinska Institute, Stockholm, Sweden

Abstract

By the second century AD, *trepanation* (ἀνάτρησις) was an established procedure for dealing with skull fracture and its consequences. The foremost physician of Western Antiquity, Galen of Pergamum (129–ca 216 AD) employed trepanation in such cases. However, Galen also used the techniques of trepanation to good effect as part of a range of experiments which were undertaken to determine the function of the ventricles in his physiology of the brain. The purpose of this paper is to outline the role of trepanation in these experiments.

Keywords: Galen, trepanation, surgical instruments, history of anatomy, history of physiology

Introduction

Of all the forms of surgical intervention for whatever reason, that of making holes in the skull is possibly the oldest. Widespread in many cultures, as several of the papers in these proceedings attest, it is one of the earliest forms of intervention involving a bony structure whose evidence forms part of the archaeological record. As this paper will show, the use of trepanation is well attested in the written accounts of Greek and Roman medicine.[1] The purpose of this paper is to examine Galen's record on trepanation and how he manipulated the technique from the point of view of his studies on the physiology of the brain. Galen's employment of trepanation also reflects a physician's awareness of the dangers of such a procedure. Before Galen's account is examined, it is necessary to review how trepanation was employed by his antecedents, and the instruments that were used.

Trepanation and its Instruments

There is of course a limit on how far reliance can be placed on anecdotal material, but it is worth mentioning an account from Seneca. One of Gaius Julius Caesar's veterans apparently had endured a trepanation procedure of some sort, and emerged, if not physically unscathed, then with sufficient *ratio* to successfully argue his case before Caesar regarding distribution of land (*De beneficiis*, V.xxiv.3).

No details on the operative procedure are given, only a reference to his injury sustained being at the Battle of Munda, which resulted in the loss of an eye as well as "some bones removed from [my] skull" (*in capite lecta ossa*). Given the severity of such a wound, it is no more than reasonable to suppose that trepanation was employed in some way, and there is physical evidence to indicate that at least one instrument, the *crown trephine* was part of the Roman Army Surgeon's armamentarium (Davies, 1970, p. 91; Jackson, 1990, p. 18). In another story, Plutarch mentions a trepanned person, a Roman ambassador to Bithynia no less, who is chided for his lack of a head, that is, his wits (*Cato Major*, VIII.9).

These anecdotes reflect a knowledge of a procedure commonly performed in cases of injury to the head. The word *trepanation* (ἀνάτρησις) means a hole or perforation.[2] A *trephine* (χοινικίς) is, in essence, a toothed drilling instrument that, with modifications in its calibre, was also employed to drain body cavities The Hippocratic text *Internal Affections*, advises that fluid accumulating in the lung as a result of *dropsy* (ὕδερος), be drained by inserting a περητήριον, a "straight-pointed trephine" at the level of the third lowest rib (*Int.*, VII.23, 226, L; see Milne, 1907, p. 131).[3] Galen defines this instrument in his Hippocratic *Glossary* (XIX, 129,K), as a variant of the trephine. This *Glossary* also gives the term ὀρθοπρίων, for which there is no reference in any other medical author or text (XIX, 126,K). Both περητήριον and ὀρθοπρίων were likely to have been more sophisticated variants of the standard χοινικίς, and possibly, to judge by their rare citations, infrequently used.[4] Trephining the skull was usually performed in cases of *fracture* (ῥώγμη or κάταγμα) and its sequelae, although the skull was also trephined by some physicians in cases of epilepsy and paralysis. According to Caelius Aurelianus, the Methodist Themison employed the trephine (*terebra*) as a therapeutic adjunct in cases of epilepsy and paralysis (*Tardae passiones*, I.iv.118, 127, 143; II.i.59). Caelius disapproves of what he regards as unsound clinical practice, noting, in the case of trephining for paralysis, that it was "long since refuted in other Methodist writers" (*Tardae passiones*, II.i.59; tr. Drabkin, p. 602; cf. Temkin, 1971, p. 76). The term ῥωγμή is used by Galen to refer to an uncomplicated fracture, whereas κάταγμα implies a compound fracture, with several fracture lines.[5]

The earliest documented Western use of its employment for skull fractures is to be found in the Hippocratic Corpus. In *Places in Man* (*Loc.*), one of the earliest works, *trephining* (using the verb πρίειν) is recommended for what seems a depressed fracture, and the aim is to prevent the accumulation of purulent fluid (ἰχώρ) within the wound (*Loc.*, 32.1; 70; Craik, 1998). The procedure itself is not described (Craik, 1998, Commentary, pp. 187–8). *On Wounds to the Head* (*VC*, III, 188, 190, L) defines the brain topographically as lying more to the front of the head, under the *bregma*, where the bone is at its thinnest and weakest.[6] Towards the back of the head there is said to be less brain, and thus wounds there are less fatal than wounds at or about the bregma (*VC*, III, 192, L). Three cases are described in *Epidemics V* (V, 216, 16; 227, 27; 227–8, 28, L). Most had fatal outcomes, attributed in large part by failure to trephine earlier or more thoroughly (V, 216, 226–8, 402–4, L). In the third case, the presence of exposed suture lines in the wound is an indication of prompt trepanation. A fourth case is given in *Epidemics VII* (V, 35, 404, L).

The trepans in the Hippocratic Corpus are varying sizes of a *crown trepan* or *modiolus* (πρίων, πρίων χαρακτός, σμικρὸν τρύπανον), all of which lack a guard. *On Wounds to the Head* describes the conditions for their use (*VC*, XXI, 256–261, III, L; cf. Adams, 1849, p. 465 n.2; 442–3 and Plates I and II; Grmek, 1983, p. 287–8; Marganne, 1998, xi-xiii, pp. 74–83, 156, 160; Milne, 1907, pp. 131–2). *VC* cautions against the too enthusiastic use of the trephine, even in cases of what are depressed and comminuted fractures, since there is a significant risk of damage to the dura with the use of the instrument (XVII, 248–50, III, L; XXI, 258–60, III, L).

However, a fracture that is *not* comminuted is an indication for trephining (XIV, 240–42, III, L). In trepanning the skull, detailed instructions were given in regard to when, where, and how to operate (*VC*. III, 258, 260, L, Cf. *Morb. II*, VII, 28, L).

Trepanation provides some evidence that several of the Hippocratic authors were aware of at least the outer meningeal covering of the brain, and the often fatal consequences of damage to it both from direct trauma and surgical intervention. There is a mention of two meningeal layers in *Places in Man* (*Loc*. VI, 280, L), but although the description is accurate when interpreted with later knowledge, the passage must remain obscure. Phillips, interprets it as follows, "Of the two membranes, or *meninges*, the outer is thicker (the *dura mater*), while the inner (the *pia mater*) is thin and in contact with the brain." (1973, p. 47). There is no textual basis for such a claim. However, *On Fleshes* (*Carn.*) notes the presence of the "thick meninx" (μῆνιγξ παχεῖα), the *dura mater* (VIII, 588, L). The spinal cord is described as similar to the brain, and also possesses a membrane (VIII, 588, L).

Galen and the Teaching of Trepanation

Next to Hippocrates, Galen of Pergamum (129–ca 216 AD) is the most famous doctor in Antiquity (for general studies see Debru, 1997; Moraux, 1985; Nutton, 1970, 1972, 1973, 1984a,b, 1993a,b, 1995, 1998; Singer, 1997). Known for his extensive writings on medical and philosophical issues, it might come as a surprise to learn that Galen was also familiar with the use of surgical implements. But, returning home from his Egyptian sojourn in 157 AD, Galen was appointed physician to the gladiatorial school by the *chief priest* (ἀρχιερεύς), a position he held for four years (Nutton, 1993a).[7] It was no sinecure.

In *On examinations by which the best physicians are recognised* (*De optimo medico cognoscendo*), which has survived only in Arabic translation, Galen reveals how he was chosen for this position:

> A high priest followed this method (of choosing physicians) when I returned to our city from places which I had set out to visit. Although, at that time, I had not yet completed thirty years of my age he entrusted me with the treatment of all the wounded (men) among those who had fought duels in combats... Once I attended a public gathering where men had met to test the knowledge of physicians. I performed many anatomical demonstrations before the spectators: I made an incision in the abdomen of an ape and exposed its intestines: then I called upon the physicians who were present to replace them back (in position) and to make the necessary abdominal sutures – but none of them dared to do this. We ourselves then treated the ape displaying our skill, manual training, and dexterity. Furthermore, we deliberately severed many large veins, thus allowing the blood to run freely, and called upon the Elders of the physicians to provide treatment, but they had nothing to offer. We then provided treatment, making it clear to the intel-

> lectuals who were present that (physicians) who possess skills like mine should be in charge of the wounded. That man was delighted when he put me in charge of the wounded – and he was the first to entrust me with their care. With the exception of two, none of the wounded in my charge died, whereas sixteen individuals had died under my predecessor. Later, another high priest put me in charge of the wounded, and in doing so he was even more fortunate. None of the patients under my care died, even though each suffered grave and multiple wounds. (103.10–105.19; tr. Iskandar).

Since this text was written after Galen's first stay in Rome, in about 178, it is highly likely that his experiences there of public anatomical demonstrations have coloured the account of similar triumphs in Pergamum. Galen's account invites comparison to the medical contests which took place at Ephesus (see Nutton, 1995, pp. 47–8). This account perfectly displays the self-promotion which is characteristic of Galen. But this aside, four years of this type of work would have given Galen ample opportunity to master the practical skills he would need in order to produce his texts in anatomy and physiology.

Galen's accounts of trepanation of the skull are therefore not solely based on second-hand reports, but speak of direct, personal experience with a set of procedures in which he was highly skilled.[8]

By Galen's era, there is no doubt that trepanation was an established procedure for dealing with skull fracture and for ameliorating the consequences of a *depressed fracture* (ἐμπίεσμα), where there was danger of bone fragments pressing directly onto the outer meningeal covering of the brain. In such cases different instruments were employed, and a specific tool introduced to safeguard the dura. It is worth noting that the term ἐνπίεσμα appears as a relatively late development of a technical expression in anatomical pathology (its only instance in the Hippocratic Corpus is the verb ἐμπίεξεται, where the brain is said to exert pressure on the channels on the ears (*De glandulis*, 13, VIII, 568, L). In the pseudo-Galenic *Introductio* (XIVK, 782), a sophisticated classification of five types of skull fracture is presented, and a sixth admitted by some, based on the Hippocratic five-fold classification in *VC*. This classification is increased to eight in the pseudo-Galenic *Definitiones Medicae* (XIXK, 431), a text written in the first century BC (cf. Kollesch, 1973). However, ἐμπίεσμα is not part of the terminology employed in this system. Nor does it appear in Rufus or Aretaeus. Celsus (*Med.* VIII.4,13ff.), whilst delineating treatment for a depressed skull fracture, has no specific name for it, although Soranus (*De signis fracturarum*, I.1, XVI.1, and XV.1), uses it to define a depressed skull fracture, a depressed fracture to the sternum, and a fracture of the spine with displacement. The fullest definition before Galen is found in Heliodorus, a surgeon probably active in Alexandria in the first century AD and whose fragments are preserved in Oribasius (*Collectiones medicae*, XLIV.14, 164, Daremberg-Bussemaker). Heliodorus outlines his concern for the integrity of the dura whilst trephining in cases of ἐμπίεσμα: skull fracture with depression of bone fragments (cf. Marganne, 1986 and 1988; Sigerist, 1920, pp. 1–9). Galen's use of ἐμπίεσμα is singular, in the context of trepanning the skull and, like Heliodorus, he employs it in order to stress the need to protect the dura from the effects of the depressed bone fragment(s).

Two types of instruments were employed for the purposes of removing bone and relieving pressure (*Terebrarum autem duo genera sunt.*, Celsus, *Med.* VIII.3).[9] The first, as noted above, was the crown *trephine* for bone excision and relief of pressure in small wounds, and which lacked a guard. Durling defines this as “a kind of trepan” (1993, p. 339). It is most likely the πρίων χαρακός of *VC* (Adams, 1849, p. 465 n.3; Brothwell, 1974, pp. 209–211; Como, 1925, p. 160, Fig. 6, 1–5; Jackson, 1990, p. 18, Fig. 5.8; Künzl, 1996, Pl. IV, Figs 1–3; Majno, 1975, pp. 166–9). Galen’s comments, that this instrument is employed by those who are “either cowardly... or careful,” (εἴτε δειλοτέρους... εἴτ’ ἀσφαλεοτέρους, *Meth. Med,* X, 447–8,K), should not be taken strictly in a polemic sense, but as a reference to the high risks run by using such an instrument, the hazards of which were well known.

The second type of instrument, the *drill trepan* (τρύπανον), possessed a toothed bit and was used for larger wounds. In employing it, the goal was to perforate the affected bone at circumferential points to facilitate its subsequent removal (Celsus, *Med*., VIII.3; Galen *De comp. med. sec*. XII, 821,K; Oribasius, XLVI, 11.7; cf. Milne, 1907, pp. 126–9).[10] A variant of this instrument, employed to minimise possible damage to the dura, was the *abaptiston* or *terebrum non profundans* (ἀβάπτιστον, ἀβάπτιστον τρύπανον; see Galen’s description in *Meth. Med*. X, 446–7,K). This instrument, as Greenhill notes, is “a sort of trepan, with a ring or knob a little above the extremity, in order to prevent its penetrating the cranium too suddenly, and so injuring the brain. Hence the name, διὰ τὸ μὴ βαπτίζεσθαι, says Galen, because it could not be suddenly *plunged* or *immersed* into the brain” (1864, p. 556. See also Milne, 1907, pp. 129–30, Plate XLII, Figs 3, 4, 5).

It was not without its risks and could not have been an easy procedure to perform. As Horne remarks, “The tediousness which must attend the making of so many perforations, the disturbance given to the patient’s head, the hazards of wounding the membranes of the brain, of most of these troubles and dangers they were sensible... The cautions laid down by Hippocrates and others concerning the part of the bone whereon to fix the instrument, and the great attention which they admonish the operator to pay to its execution, all proceed from the same fear.” (1894, p. 17).[11]

The employment of either instrument meant invariably that a larger portion of bone would be excised than if the modiolus alone were employed. Therefore, to protect the dura it was recommended that the “protector of the meninx” (μηνιγγοφύλαξ, *meningophylax* or *membranae custos*) be employed (Celsus, *Med*., VIII.3). Galen refers to this tool in a way that strongly indicates that it was something with which he thoroughly familiar (*In Hipp. epid. comm*., 25, Wenkebach). The use of the *meningophylax* was not restricted to operations on the skull. For example, Galen describes the meningophylax as being used to protect the underlying pleura during excision of a rib (*AA* II, 686,K). Galen also notes that a *spathomele* can be employed for this protective function (cf. Milne, 1907, pp. 59–60).

Galen employs trepanation in two ways. In the first, as already remarked, trepanation is limited to the relief of pressure and its consequences, that is, to trauma involving the skull, and in such cases as the draining of phlegmatous lesions on the head (*In Hipp. de off. med. comment*., XVIIIB, 808,K). In the second, trepanation is used as a tool in Galen’s physiology. Galen’s clinical use of trepanation will be considered first.

Galen and the Clinical Uses of Trepanation

To carry out a trepanation adequately and safely, Galen recommends that its techniques be perfected on animals. The ideal one for these purposes is a primate's skull. Although Galen's text on animal vivisection, *De anatomia vivorum*, is not extant, there is sufficient evidence from other works which enables one to determine which animals Galen employed (*Ord. Lib. Propr*., XIX, 55,K). Much of his dissections and vivisections utilised primates, specifically, according to Galen, five types of "ape".[12] Apes were considered a "facetious imitation" (μίμημα γελοῖον) of human beings (*De usu partium* (= *UP*) II.273). The ape is γελοῖος with respect to the hand (*UP* I.58–59), and to the muscles of the leg (*UP* I.194). The list includes πίθηκος (the Barbary ape of North Africa, *Simia sylvanus* or *Macacus inuus*); λύγξ (an unknown tailed ape; Hill, 1974, p. 195); σάτυρος (not the gibbon but perhaps *Macaca mulatta*, the Rhesus monkey); κυνοκέφαλος (dog-headed baboon, *Papio hamadryas*; Hill, 1970, pp. 7–9); and κῆβος (sometimes employed as a synonym for σάτυρος, but possibly the North-East African *Cercopithecus pyrrhonotus*; *UP*. II.114; Aristotle, *HA* 502a17). The one most commonly used by Galen (and well known to Aristotle, *HA*, 502a 16–b26) was the Barbary ape.[13]

The five types of apes in turn formed for Galen part of a group of six classes of animals which Galen held were "not far removed from the nature of man" (ὡς οὐ πόρρω τανθρώπου φύσεως ὄντα, *AA*, II, 423,K). This classification, according to Galen, was known to the older anatomists (*Anatomical procedures*, XI.2; 72). Garofalo however, concludes that the six-class classification was devised by Galen: "The Ancients merely spoke of, and alluded to, the six classes, but did not institute the group." (1993, 86).

The six classes comprised 1. apes and ape-like animals; 2. bears; 3. pigs; 4. saw-toothed animals; 5. "horned two-hoofed ruminants" (τὸ κερασθόρον καὶ δίχηλον καὶ μηρυκάζον, *AA*, II, 430,K); and, finally, 6. hornless, smooth-hoofed animals (*AA* II, 431–1,K). Such a classificatory system clearly gave Galen an enormous leeway not only in what he could dissect. It further enabled him to claim that the anatomical findings made from these animals could be validly applied to that of humans. Galen states that he dissected not just those animals belonging to the six classes, "but also animals of the kind which crawl, those which move forwards by bringing the abdomen to their aid, water animals, and those which fly. And if I complete this work that I have started, as is my intention here, I want to dissect those animals also and to describe what there is to see in them." (*Anatomical procedures*, XI.12; 108). This project, Aristotelian in its scope, was not fulfilled. It would have cemented Galen's reputation as the foremost anatomist of Antiquity.

For dissections of the brain, however, Galen made extensive use of the ox (*Bos taurus*), an ungulate, a member of his fifth class. One reason for this choice is given by Galen at the beginning of the discussion of the brain in Book IX of *Anatomicis Administrationibus* (II, 708,K), when he specifically mentions that the brains he is dissecting are ox brains, which, in the large cities at least, were usually available. These could be freshly procured from the market with most of the cranial bones removed. That certain animals such as cattle, goats and pigs were kept in sufficient numbers for purposes of sacrifice and consumption is an important factor in their ready procurement for other uses, such as dissection and vivisection (Keller, 1909, pp. 336–7; 402–3 and Fig. 140; Ryberg, 1955, Chapter viii; Toynbee, 1973, pp. 55–60, 148–62, 166). When Galen mentions that a dissector should be prepared to dissect other animals if there is a shortage of apes, it is also an implicit acknowledgment that apes were sometimes unavailable (*AA* II, 227,K; cf. Garofalo, 1993, p. 85). Pliny (*HN* 6.xxxv, 184), gives evidence for a *cynocephalus* and a *sphingion* form of ape, as well as a reference to varieties of ape in general (see also 8.lxxx, 215–216). But there is nothing to indicate a breeding of domesticated monkeys (as claimed by Jennison, 1937, p. 128, for this passage). The question of the larger size of the ox brain relative to that of other animals Galen regularly dissected, combined with its ease of availability, made it the subject of choice.

Galen employed the brain and skull of the ape to demonstrate a number of quite discrete structures and to impart a specific set of practical instructions. The importance of the ape is stated when Galen begins his discourse on:

> ... the method of dissecting the parts of the brain while it remains in its place in the animal body. The dissection is best made in apes, and among the apes in such a one as has a face rounded to the greatest extent possible amongst apes. For the apes with rounded faces are most like human beings (Anatomical procedures, IX.10; 10).

This description fits the Barbary ape, and (probably) the Rhesus monkey (cf. *UP* II.114–115, where the ape which most resembles man is round-faced).

The ape brain and skull is a learning template for the dissector, enabling him to gain experience before embarking on more detailed anatomical investigations of the human brain (*Anatomical Procedures*, IX.10; 13). That Galen stresses the need to find as close an approximation as possible to man is significant: He wants to remind his audience that the information obtained from such an ape is directly applicable to that of man. This information is crucial for understanding of human osteology. That Galen is at least partly familiar with the anatomy of the human skull is noted in *Anatomical Procedures*, where Galen, in discussing skull foramina, points out that:

> All these foramina you will see with your own eyes in a cadaver in which all that overlies the bones is decayed and the bones alone remain, in their connections with one another, without separating from each other. These can be seen in such human cadavers as you happen to look at... and also in the bodies of apes when we have buried them for four months and more in earth that is not dry. (XIV.1, 182).

The words "in such cadavers as you happen to look at" should not be taken as conclusive evidence that Galen had recourse to a human skull for daily study when composing his anatomical works. An important part of Galen's anatomical study in Alexandria involved the human skeleton, the only place where such complete specimens were available for such a purpose. The situation in Rome was different. It is reasonable to suppose that Galen, at the time of setting down his observations of the brain, made use of his Alexandrian studies on the osteology of the human skull. In any case, Galen's anatomical studies of the brain were performed on the understanding that the human cranial cavity would be their locus, and that such an undertaking was capable of yielding meaningful results in human brain anatomy.

The skull of an ape in the above citation is presented as an important source of osteological information. The careful preparation of an ape body by interment for four months also emphasises the value of such material. The skull of the ape is therefore elaborated as a teaching tool. The preparation of the ape skull must be meticulous. Properly dried and prepared ape skull bones are indispensable as an aid to studying the nerve and vascular foramina, and the sutures. If this preparation is less than perfect, then, as Galen notes, errors of interpretation may arise:

> For what we wish to see in the remnant of the cadaver is not that the objects emerging from the foramina have come to be like leather thongs and stay fixed in their places; what we really want is that all of them should have fallen completely away, since these structures, should they remain as they were, hold together and bind to one another the bones which they meet. In this state the orifice of each of the foramina and its intrinsic curvature is made indistinct. An example of this is that just this type of inspection has led some [anatomists] to the firm conviction that some skulls have no sutures at all, and that others have not got the full complement of sutures.[14] I advise all of them to try what you have often seen me do. For I have always at hand a large number of specially prepared bones of apes, and you also will reach an understanding of the matter by preparing these bones and procuring them for yourselves, especially when you get skull bones and vertebrae (*Anatomical Procedures*, XIV.1; 182–3).

In *Anatomical Procedures* (IX.10; 11), Galen discusses the cranial bones in the ape, stressing their names, position, and sutures. The purpose of this is to emphasise the importance of the sutures as a landmark in trepanation, and Galen highlights this in the following way. After the entire skull of the ape has been exposed in a living specimen, the dissector is instructed to:

> Go on until you come to the sagittal suture and to the two limbs of the suture which resembles the letter Λ of the Greek script. For in this place the enveloping cranial membrane and the dura mater enter into close partnership. Their combination and partnership are clearly recognisable at the meeting place of any two bones, and between them a suture is interposed. In these places only should you leave the skull unstripped and unbared. Next cut away the whole of the bone between the two sutures. That is the bone called parietal, one on each side. Four lines limit it and mark it out, two of these travelling in the longitudinal diameter of the head, and two in the transverse diameter. As for the two lines running in the longitudinal direction, these are the so-called median suture [sagittal] and the scale-like [squamous] suture. The transverse ones are the lambdoid suture and the coronal. If you cut away these bones, as you are accustomed to do when you pierce through the skull, either with the perforator or with the instrument called the lens, then you see, when you take stock of and apply your intelligence to what is visible, how in the whole of that region round about, the dura mater is pressed down upon the brain, and you see how in the region of the suture running straight in the longitudinal direction it [the dura mater] attaches itself to the skull. And if, in addition, the animal is already very aged, then you see also that the part of the dura mater which I said may be pressed down upon the brain has also fallen away markedly from that part of it which is fused with the median suture. Similarly when you cut away the whole of that part of the skull behind the suture which resembles the letter *L* of the Greek script, and after you have preserved in this region the attachment of the dura mater to the skull, you see that all the

Table 1. Unguarded drills.

A *trephine* (χοινικίς) is a toothed drilling instrument without a guard. It is the trephine associated with "the ancients" (οἱ παλαιοί). Known variants include:

i. The more generally employed crown trephine or *modiolus* (πρίων, πρίων χαρακτός, σμικρὸν τρύπανον).

ii. περητήριον (τρυγλητηρίῳ: Kühn), a "straight-pointed trephine", used to drain fluid from a lung. περητηρίῳ is defined by Galen as a variant of the trephine.

iii ὀρθοπρίων, a term given by Galen, is unique. There is no reference in any other medical author. Both περητήριον and ὀρθοπρίων are likely to have been more sophisticated variants of the χοινικίς.

iv. The drill trepan (τρύπανον), employed for larger wounds, was used to perforate the affected bone at circumferential points to facilitate its subsequent removal.

v. The χοινικίς is contrasted with the τρύπανον by the use of the term κεφαλοτρύπανον, an instrument specifically used on the head.

> remaining subdivisions of the dura mater have fallen away from the part at [attached to] the suture. (IX.10; 11).

Galen's citation of the meninges allows an appreciation of their importance to applied anatomy. The relationship between the cranial bones and the outer meningeal layer, known as ἡ παχεῖα μῆνιγξ, or *the dura mater*) of the brain, is linked to the arrangement of the cranial sutures. These serve as landmarks in trepanation in order that the drill avoid contact with the dura. It was known by the author of *On Wounds to the Head* that if the integrity of this membrane was compromised, the results were, more often than not, fatal. It is crucial therefore that such operations were rehearsed many times until proficiency is gained. The "instrument called the "lens" is the *meningophylax* (μηνιγγοφύλαξ; see Table 2). To perform this procedure on a living animal enables the student to learn the importance of blood loss and thereby minimise trauma. The best way to gain such proficiency is first of all to utilise the skull bones and the dural relationships of an animal whose skull most resembles man. Thus the "apes with rounded faces" are chosen. Apes are as close to man as Galen can approach, and therefore provide the means for the most accurate approximation of a practical but potentially fatal technique.

To emphasise further the pedagogic value of such a practice, Galen also instructs those who are dissecting to "... construct for yourself in imagination this osteoclastic instrument which is commonly used and which everyone knows." (*Anatomical Procedures*, IX.10; 12). This is a reference to one of several such instruments which have been cited above. But such a thought experiment is possible only with the aid of the vivisectional and dissection material provided. In this way, says Galen, one may with the mind's eye employ a bone chisel to "... open up a place for inspection, through which you can make

Table 2. Guarded drills and associated instruments.

i. The ἀβάπτιστον or ἀβάπτιστον τρύπανον (*abaptiston* or *terebrum non profundans*) was employed to minimise damage to the dura mater. These drills were guarded in the sense that they possessed either a transverse pin which could be adjusted to a predetermined depth or were made with drill heads of varying diameter.
ii. To further protect the dura when bone fragments were levered out, the *meningophylax* (μηνιγγοφύλαξ), "protector of the meninx" (*membranae custos*) was employed. In essence, it was a flat piece of metal which was passed through the perforation or space exposed by bone fragments and manipulated over the dura.
iii. Associated instruments for elevating and removing bone fragments and sequestra include the chisel, (ἐκκοπεύς), bone lever (μοχλίσκος, ἀναβολεύς), and bone forceps (ὀστάγρα).

an entry and so inform yourself accurately on the gap between the dura mater and the brain." (ibid, IX.10; 13).

The whole point of such an experiment is to refine further the technique of trepanation. Where there is no tradition of (nor perhaps a need for) anatomical illustration, the brains and skulls of apes serve as a set of reference materials for pedagogic purposes.[15]

Trepanation and the Demands of Galen's Physiology

The second use to which Galen puts trepanation is as an important adjunct to his studies on the physiology of the brain. This physiology was centred within the brain's ventricles and psychic pneuma, which, Galen postulated, was contained within the ventricles and served as the effector agent for sensation and motion (Rocca, 1997, 1998a,b, and forthcoming, 2003). In order to understand the effects of pneuma, Galen experimented directly on the ventricles themselves. It is clear that trepanation, either performed by himself or witnessed in the hands of others, would have afforded Galen opportunities to observe those symptoms he ascribed as ensuing from consequent ventricular disturbance. These symptoms are clearly stated in *De locis affectis*:

> If one presses down too hard while treating the fractured bones of the skull by trepanation, the [patients] immediately loses all sensation and becomes motionless. (VIII, 128,K).

Here, it may be noted, only the general, unqualified effects of loss of sensation and motion are given, and they are not localised by Galen to any particular ventricle. Similarly, the description at the end of *De instrumento odoratus* (64.1–3, Kollesch), tells of a *stuporous-like* (καρώδης) state which occurs in cases of skull fracture when excessive pressure is applied to the ventricles of the brain during trepanation. However, it is not clear whether the pressure here is due to the drill itself or to the subsequent use of the meningophylax. If one turns to *Anatomical procedures* however, Galen provides a more detailed account.

There, once the brain of a living animal has been exposed, Galen recounts the nature of the experiments performed on it. Quoting this passage in its entirety provides a remarkable insight into Galen's experimental methodology:

> Should the dissection be thus performed, then after you have laid open the brain, and divested it of the dura mater, you can first of all press down upon the brain on each of its four ventricles, and observe what derangements have afflicted the animal. I will describe to you what is always to be seen when you make this dissection, and also before it, where the skull has been perforated, as soon as one presses upon the brain with the instrument which the ancients call the "protector of the dura mater".[16] Should the brain be compressed on both the two anterior ventricles, then the degree of stupor which overcomes the animal is slight.[17] Should it be compressed on the middle ventricle, then the stupor of the animal is heavier. And when one presses down upon that ventricle which is found in the part of the brain lying at the nape of the neck (the fourth or posterior ventricle), then the animal falls into a very heavy and pronounced stupor. This is what happens also when you cut into the cerebral ventricles, except that if you cut into these ventricles, the animal does not revert to its natural condition as it does when you press upon them. Nevertheless it does sometimes do this if the incision should become united.[18] This return to the normal condition follows more easily and more quickly, should the incision be made upon the two anterior ventricles. But if the incision encounters the middle ventricle, then the return to the normal comes to pass less easily and speedily. And if the incision should have been imposed upon the fourth, that is, the posterior ventricle, then the animal seldom returns to its natural condition; although nevertheless if the incision should be made into this fourth ventricle, provided that you do not make the cut very extensive, that you proceed quickly, and that in the compression of the wound in some way or other you employ a certain amount of haste,[19] the animal will revert to its normal state, since the pressure upon the wound is then temporary only – and indeed especially in those regions where no portion of the brain overlies this ventricle, but where the meninx only is found. You then see how the animal blinks with its eyes, especially when you bring some object near to the eyes, even when you have exposed to view the posterior ventricle. Should you go towards the animal while it is in this condition, and should you press upon some one part of the two anterior ventricles, no matter which part it may be, in the place where as I stated the root of the two optic nerves lies, thereupon the animal ceases to blink with its two eyes, even when you bring some object near to the pupils, and the whole appearance of the eye on the side on which lies the ventricle of the brain upon which you are pressing becomes like the eyes of blind men. (IX.10; 12).

The above passage is arguably the most impressive account of physiological experimentation extant in Antiquity. Whether Galen deals with the effects of pressure or incision, these results are, without doubt, remarkable. Galen presents his readers with a formidable combination of factors that few could manipulate successfully. Galen's intention is to stress that when pressure is applied to the ventricles, the two key losses are those which encompass the principal activities of the hegemonic agency of the body, namely, sensation and motion. Galen reinforces the site of this agency by noting in *De locis affectis*, that, as a result of such pressure, the *mind* (διάνοια) becomes permanently damaged (ἡ τῆς διανοίας οὖν βλάβη γίνεται διὰ παντός, VIII, 128,K). What constitutes unnecessary pressure is moot, and it is unlikely whether this was ever quantified. Given the stress in parts of Greek physiology on the importance of qualitative change, then the scope for using or expanding a quantitative methodological approach was limited (cf. Bylebyl, 1977; Grmek, 1990; idem, 1996; Shryock, 1961; Temkin, 1961). This is not to say that a quantitative method could not be employed to assist in solving a physiological problem involving qualitative change. As will now be examined, Galen presents a set of symptoms, the effects of which result in changes to the patient's physiological and psychological status. How these changes are read and interpreted depends on the skill of the observer.[20]

A more detailed account of Galen's noting the effects of a head injury and his interpretation of it in ventricular terms is given in his physiological masterwork, *De usu partium*. Here, Galen presents the remarkable story of a young person who survived a serious head injury:

> At Smyrna in Ionia I once witnessed an unexpected sight, a youth who had suffered a wound in one of the anterior ventricles and yet survived, apparently by divine will; however if both (ventricles) had been simultaneously wounded, he could not have survived for even a moment. Similarly, if some trouble other than a wound affects one of the ventricles while the other remains sound, the animal will be in less danger of its life than if both are affected simultaneously (I.481–2).

Galen gives no details as to the nature of the *wound* (τραῦμα) and what steps were taken to treat it, although it is more than probable that the injury involved a fracture to the skull and that trepanation would have formed part of the *treatment* (θεραπεία). It is also likely that for the young man to have survived was indeed "an unexpected sight" (το παράδοξον θέαμα). For Galen to mention that the wound was sustained "in one of the anterior ventricles" implies that the dura itself had been perforated. Any injury to the dura is a matter for grave concern, as Galen, in *On Medical Experience*, one of his earliest works, remarks in the context of an attack on Empiricist doctors and their attitude to clinical observation: "... I ask how often I have to see a lesion of the dura mater before I know exactly whether the patient will die, either always, or for the most part, or rarely, or half of the time." (Ch. VII, 95, Walzer; tr. Frede, 1985, p. 58).

In *De locis affectis*, the effect of a *meningeal wound* (μηνιγγότρωτον) is interpreted by Galen in terms of injury to the ventricle. The wound Galen describes is of such severity that it was only by good fortune (*qua* divine intervention) that the youth survived. Galen does not hesitate to correlate this account with his own experimental observations in vivisection, expressed in the change from human patient to *animal* subject (ζῷον). In his mention of the youth from Smyrna, Galen moves from discussing his clinical condition to a similar picture experimentally produced in an animal (*UP* I.481–2). The untoward effects of trepanation and the observations made from those who have sustained head injuries provide Galen with useful information which he correlates with his vivisectional experiments.

In *Anatomical Procedures* (IX.12, cited above), Galen states that pressure may be used as a specific experimental technique to determine the functional status of each ventricle (see also Clarke and O'Malley, 1968, pp. 492–97; Neuburger 1897, pp. 67–70). Pressure applied to both anterior ventricles results in a condition known as *stupor* (κάρος), which Galen describes as "slight". Galen employs stupor as an index of ventricular damage (albeit not in a quantitative sense). In *De locis affectis*, Galen defines stupor as follows:

> When the entire anterior part of the brain is affected, the foremost ventricle is necessarily affected by sympathy and the activities of the mind are harmed in similar

> fashion. And (the patient) lies in this way without sensation and motion, but respiration is unharmed. This condition is called stupor. (VIII, 231,K).[21]

Clearly, any adverse effect can elicit *sympathy* (συμπάθεια), and such a general term is used to interpret an insult from a chosen theoretical viewpoint. Galen's case, as recorded in *De locis affectis*, shows that a pathological condition of the anterior part of the brain affects the anterior ventricles, and that this clinical state is a close approximation of the experimental result of pressure applied to the anterior ventricles in *Anatomical Procedures* IX.12. Galen also speaks more generally of "diseases of the anterior part of the brain." (VIII, 232,K). In apoplexy, Galen notes that the body of the brain is chiefly affected, whereas stupor and epilepsy are primarily an affection of the ventricles. Stupor is more associated with the anterior part of the brain.

Anatomical Procedures also records that pressure on the middle ventricle results in a stupor that is "heavier" in degree (IX.12). This account should be augmented by the following from *De locis affectis* ,where Galen describes the effects of trepanation in the context of both the middle ventricle and his pneumatic physiology:

> When the middle cerebral ventricle is compressed by trepanning the bone, the person will go into a stupor without convulsions or difficulty in breathing... Just as stupor can be caused by lack of attention during trephining, if one lowers the blade guarding the meninges deeper than is permissible, and in the same manner when a fractured bone presses hard on the cerebral ventricle, especially the middle one, stupor follows. And such an affliction is attended by violent pain, when the tension of the psychic pneuma in the ventricles has fallen. (VIII, 232–3,K).

In the case given above, *compression* (θλίψις) of the middle ventricle results in stupor, but the patient continues to breathe and does not convulse. That is, the patient is unconscious. The description admits of such an interpretation for stupor involves loss of sensation and of voluntary motion, two indicators construed as part of an unconscious state. Convulsion and difficulty in breathing are for Galen indices of posterior ventricular damage.

This citation is also important as Galen introduces psychic pneuma to account for these changes in clinical status. As a result of trepanation, the *tension* (τόνος) of the pneuma in the ventricle is decreased, and this accounts for the pain the unfortunate individual suffers, notwithstanding that caused by the procedure itself. The concept of τόνος was, by the second century AD, a familiar item in the medical and philosophic lexicon and there does not appear to be any significant reworking by Galen from its earlier antecedents.[22] But in this case the exact mechanism of how tension might be maintained in the ventricular system is not explicitly stated. It would seem that an alteration to the balance of pneumatic tension by pressure alone seems sufficient to create a pathological condition. All Galen can provide is a rather speculative concept of a balance in pneumatic tension within the ventricles; that this is easily upset in cases of surgical intervention, and that such imbalances are instructive in that they may be used to interpret the experimental effects of pressure on the ventricles.

Finally, in *Anatomical Procedures*, Galen notes that pressure over the posterior ventricle produces "a very heavy and pronounced stupor." (IX.12). In *De locis affectis*, the symptoms of *apoplexy* (ἀποπληξία) are manifested by lack of sensation and motion, and slow breathing with effort (VIII, 231–2,K). Unlike stupor and epilepsy, which primarily affect the ventricles, the body of the brain (both anteriorly and posteriorly) is more affected in apoplexy. Later, Galen notes that in stupor (κάρος), damage to the voice may be a feature of the clinical picture. Convulsions or respiratory distress may also occur with the posterior ventricle affected (VIII, 270,K). These convulsions are not necessarily epileptic in nature; indeed, in *De locis affectis*, Galen also points out that the exact knowledge (of any kind) of a convulsion is not possible (VIII, 175,K). This does not exclude the possibility that if the *entire* ventricular system is affected, epileptic seizures will *not* occur. What is important for him is establishing the more general notion that the brain itself is affected. For Galen, one way to empirically determine these effects is by trepanation.

Conclusion

No matter what instrument was employed, trepanation involved several obvious attendant risks, and the skill of the operator was paramount in order to minimise blood loss and to avoid damage to the dura and the underlying brain. It is perhaps worth noting the effects of the trephine in the hands of another skilled operator before the era of antiseptic surgery. One of the foremost English surgeons of the eighteenth century, Percivall Pott (1768, pp. 145–157), described some eighteen cases of fractures to the skull. Of these, five were not trephined (and only one survived). Of those thirteen trephined, six died. Admittedly, these numbers are not statistically significant, but they are nevertheless indicative of a high risk procedure.

Pott, like Galen, was well aware of the hazards of trepanation, regardless of what instrument was used. The trepanation results that Galen records in his clinical and experimental studies reflect, apart from anything else, the workings of a remarkably skilled practitioner. His accounts speak of direct, personal, experience with a set of procedures with which he was highly familiar. Galen's breach of the skull opens a critical window on Galen the anatomist and physiologist.

Acknowledgements

I wish to record my thanks to Dr Robert Arnott, the organising committee, the University of Birmingham, and the members of the Colloquium for their courtesy and assistance. This paper forms part of my study on Galen's anatomy and physiology of the brain.

Notes

1. Whilst there is no mention of the practice of trepanation in the Edwin Smith Surgical Papyrus, evidence appears to show that the employment of this procedure was not unknown in Pharaonic times. The final Addenda to Breasted's edition to this Papyrus describes the *Discovery of a Single Example of Ancient Egyptian Trepanning*, although he concludes by stating that "trepanning was known... but was apparently very rarely practised, if we may judge by the rarity of surviving examples." (Breasted, 1931, p. 596). Cf. Nunn, 1996, pp. 168–9.

2. For example, Galen uses it to refer to stylomastoid foramen. *Anatomicis administrationibus* (= AA), IIK, 435. For Galen, most references are given according to the edition of Kühn, Vols. 1–20, 1821–1833 (= K). Unless otherwise indicated all translations from Kühn are my own. Citations from the *Corpus Medicorum Graecorum* (*CMG*) series are given by pagination and translation (where provided) of the editor concerned. References to Galen's *De usu partium* (UP) are from Helmreich's critical Greek edition with my translations. The extant Greek text of *Anatomicis Administrationibus* breaks off at book IX, Chapter 5. The remainder exists in Arabic only and comprises the latter six and one half books (IX,6–XV). This exists only in Arabic translation and for convenience will be cited hereafter as *Anatomical Procedures*. All references to it are to the edition and English translation of Duckworth, Lyons and Towers (= Duckworth).
3. Hippocrates is mostly cited according to the edition of Littré, 10 Vols., 1839–1861 (= L). References to other editions and translations are given by the cited author.
4. One may also note that the Pseudo-Galenic *Introductio sive medicus*, a text composed in the first century AD, states that the χοινικίς is already a tool associated with "the ancients" (XIVK, 783).
5. On the term ἐμπίεσμα for a depressed skull fracture, see the discussion in Section 3.
6. Withington (1928, p. 9), in the Loeb edition of Hippocrates, translates bregma as "dura mater", which is surely incorrect. It is the relative thinness and weakness of the bone over the bregma that is referred to, coupled to an observation that the flesh over the bregma is also at its thinnest (cf. Adams, 1849, p. 446). The author of *VC* is aware of the meningeal *coverings* (μήνιγγα) of the brain, referring to them in the final chapter which is devoted to the use of the trephine. It is dangerous to damage this membrane in any way (III, 258, L). Cf. Hanson, 1999, pp. 117–119.
7. The period in Pergamum was from Autumn 157 to Autumn 161 (cf. Swain, 1996, p. 358; but note Iskandar, 1988, p. 164, and n.2).
8. The following encapsulates what should be read as Galen's first-hand experience. Here, the need to protect the dura from the trephine is emphasised and the effects of the depressed skull fracture from lack of movement and sensation to apoplexy, are noted: ἐν ᾧ πάλιν ἐνδείκνυνται μηδ' ἀνατιτραμένῳ τινὶ παραγεγονότες. ὅταν γὰρ ἢ τοῖς δακτύλοις ἐπιθλίψῃ τις ἅμα ταῖς μήνιγξι τὸν ἐγκέφαλον ἢ διὰ τῶν καλουμένων μηνιγγοφυλάκων ἢ καὶ πρὸ, τῆς ἀνατρήσεως ὀστοῦν ἐμπιεσθὲν φλίβῃ τὰ μόρια ταῦτα, παραφροσύναι μὲν οὐ γίγνονται, καταφοραὶ δὲ βαθεῖαι καὶ ἀκινησίαι καὶ ἀναισθησίαι συμβαίνουσι, καρουμενων ἰσχυρῶς ἐνίοτε τῶν οὕτω πασχόντων. ὥσπερ ἐν ταῖς ἰσχυραῖς ἀποπληξίαις. (*In Hipp. epid. III comment*., 25.14–21, Wenkebach).
9. On Celsus' surgical knowledge, see Sabbah and Mudry (eds), 1994.
10. In the pseudo-Galenic *Introductio* (XIV, 783,K), the χοινικὶς is contrasted with the τρύπανον, by the use of the word κεφαλοτρύπανον, a term not found in any other ancient medical source. The only significance that should perhaps apply to this is that the κεφαλοτρύπανον may have represented something of an advance over the χοινικίς, and was regarded as an instrument specifically for the head, hence the prefix. A chisel, ἐκκοπεύς, bone lever (μοχλίσκος, ἀναβολεύς) or bone forceps (ὀστάγρα) would also have been used for elevating and removing bone fragments. Cf. Milne, 1907, pp. 133–5. See also Bliquez, 1994, pp. 27–8, and his description of three bone elevators (Nn. 91–3).
11. A fine description and illustration of the drill-bow which drove the trephine is provided by Caton, 1914.
12. It is important to remember that Galen did not differentiate between what are now classified as apes and monkeys. I therefore employ Galen's generic term for primates, πίθηκος, rendered as "ape". (Cf. Hill, 1953, pp. 3–4; idem, 1966, pp. 2–10, 211–212; 1970, pp. 7–9; 1974, pp. 194–6). See also Jennison, 1937, p. 21; McDermott, 1938, pp. 77–78, 95–100; Simon, 1906, II, xx-xxii. McDermott's account does not mention the Rhesus monkey by name in connection with Galen. In contrast, Singer holds that although Galen "preferred the Barbary ape... it is probable that he relied chiefly on the Rhesus monkey." (1956, p. 240, n.22). Singer assembles some evidence in support of this claim, but no anatomical description of Galen's can be exclusively applied to *Macaca mulatta* (cf. Hill, 1966, pp. 9–10). Savage-Smith states that Galen "did not use the Rhesus monkey but rather the then plentiful Barbary ape." (1971, p. 79; cf. Hartman

and Straus (eds), 1933, which discusses the types and distribution of the *Macaca* species.
13. Aristotle also mentions – but without a complete description – the κῆβος and the κυνοκέφαλος. Cf. Jennison, 1937, 20–21, 127–129; Hill, 1966, 9, 213; idem, 1974, 194–6.
14. This is possibly a reference to the account of skull sutures in VC (182f., III, L), and in Aristotle (HA 491b2f., 516a18f.). Celsus (Med., VIII.1.2–4) states that the number and position of sutures in the skull is not known for certain.
15. There is no evidence that Galen resorted to pictorial representations of the brain in his demonstrations to students or colleagues. He does, it is true, make use of a diagram in his description of the insertion and origin of the deltoid muscle (*AA* II, 273–4K) and the cervical part of the trapezius muscle (*AA* II, 445–6K). These are geometric idealisations which are meant to aid, not substitute for dissection. Similarly, the depiction of visual rays is given in strict geometric terms (*UP* II. 94–99). Aristotle seems to have used illustrations, judging by the references to his lost text on anatomy (*HA* 497a32, 509b23, 510a30, 525a8, 550a25, 566a15; *GA* 746a14, 758a24. However, such drawings would most likely to have been highly stylised. See also Peck, 1965, p. 73. On their later history see Choulant (1852); Herrlinger (1970).
16. What Galen emphasises at this point is the opportunity to observe similar effects from another procedure, that of trepanning. On the instruments employed, see Tables 1 & 2.
17. Galen in this case is describing the effects of pressure only on the ventricles.
18. Galen is probably deducing wound closure due to tamponade.
19. This serves to stress the importance of the fourth ventricle as it also stresses Galen's dexterity and experimental technique.
20. On Galen's skill as a diagnostician, see García-Ballester, 1994; Nutton, 1993b.
21. Alexander of Tralles (I, 510, 535, Puschmann, 1878), notes that κάρος is a symptom which affects the anterior part of the brain in cases of phrenitis, and is also seen as a symptom when the middle ventricle is affected in trepanning procedures. cf. Soury, 1899, pp. 322–3.
22. According to Galen, Stoic τόνος is used to explain bodily cohesion as well as character states (cf. *De placitis Hippocratis et Platonis*, 270.25ff., De Lacy; see also Inwood, 1985, pp. 31–32, 40, 162–164, 301n.119). Galen describes muscles as possessing a (pneumatic) tension necessary to carry out movement (*De motu musculorum*, IVK, 402–403). In *De tremore, palpitatione, convulsione et rigore*, Galen differentiates τόνος from *palpitation* (παλμός, VIIK, 589–596). The former is associated with voluntary motion; the latter with involuntary motion and disease states.

References

Adams F (1849): *The Genuine Works of Hippocrates*. The Sydenham Society, London.

Bliquez LJ (1994): *Roman Surgical Instruments and Other Minor Objects in the National Archaeological Museum of Naples*. Mainz, Philipp von Zabern Verlag.

Breasted JH (1930): *The Edwin Smith Surgical Papyrus*. Two Volumes. University of Chicago Press.

Brothwell DR (1974): Osteological Evidence of the use of a Surgical Modiolus in a Romano-British population: an Aspect of Primitive Technology. *J Arch Sci 1*: 209–211.

Bussemaker UC, Daremberg C (1851–76): *Œuvres d'Oribase*. I-VI. Paris.

Bylebyl JJ (1977): Nutrition, Quantification and Circulation. *BHM 51*: 369–385.

Caton R (1914): Notes on a Group of Medical and Surgical Instruments found near Kolophon. *JHS 34*: 114–118.

Choulant L (1852): *History and Bibliography of Anatomical Illustration*. Translated and Annotated by Frank M (1962). Hafner.

Clarke E, O'Malley CD (1968): *The Human Brain and Spinal Cord*. California.

Como J (1925): "Das Grab eines römischen Arztes in Bingen". *Germania IX*: 152–162.

Craik EM (1998): *Hippocrates. Places in Man*. Oxford.
Davies RW (1970): The Roman Military Medical Service. *Saalburg Jahrbuch 27*: 84–104.
Debru A (1997): Galien. In Brunschwig J, Lloyd GER, Pellegrin P, eds., *Le Savoir Grec*. Paris, Flammarion, pp. 677–688.
Drabkin IE (1950): *Caelius Aurelianus. De morbis acutis et chroniis*. Chicago.
Duckworth WLH, Lyons MC, Towers B (1962): *Galen. On Anatomical Procedures, The Later Books*. Cambridge.
Frede M (1985): *Galen. Three Treatises on the Nature of Science*. Indianapolis, Hackett Publishing Company.
García-Ballester L (1994): Galen as a Clinician: his Methods in Diagnosis. *ANRW II. 37.2*: 1636–1671.
Garofalo I (1993): The six classes of animals in Galen. In: López-Férez JA, ed., *Galeno. Obra, Pensamiento, E Influencia*. Madrid, Universidad Nacional De Education A Distancia, pp. 73–87.
Greenhill WA (1864): Adversaria Medico-Philologica. *British and Foreign Medico-chirurgical Review* Part I, n.s. 34: 555–560.
Grmek MD (1983): Ancienneté de la Chirurgie Hippocratique. In: Lasserre F, Mudry P, eds., *Formes De Pensée Dans La Collection Hippocratique*. Geneva, pp. 285–295.
Grmek MD (1990): *La Première Révolution biologique. Réflexions sur la physiologie et la médecine du XVIII*[e] *siècle*. Paris, Éditions Payot.
Grmek MD (1996): *Il calderone di Medea: La sperimentazione sul vivente nell'Antichità*. Rome, Editori Laterza.
Hanson M (1999): *Hippocrates. On Head Wounds*. Berlin, CMG I, 4, 1.
Hartman CG, Straus W-L, eds. (1933): *The Anatomy of the Rhesus Monkey*. London.
Helmreich G (1907/1909): *Galeni de usu partium libri xvii*. Teubner, Leipzig, I and II (reprinted 1968).
Herrlinger R (1970): *History of Medical Illustrations from Antiquity to 1600*. London. Pitman.
Hill, WCO (1953, 1960, 1966, 1970, 1974): *Primates. Comparative Anatomy and Taxonomy*. Edinburgh University Press.
Horne JF (1894): *Trephining in Ancient and Modern Aspect*. London, John Bale & Sons.
Ilberg J (1927): *Soranus. De signis fracturarum*. Leipzig, CMG IV.
Inwood B (1985): *Ethics and Human Action in Early Stoicism*. Clarendon Press.
Iskandar AZ (1988): *On Examinations by which the Best Physicians are Recognised*. Berlin, CMG Supplementum Orientale, IV.
Jackson R (1990): Roman doctors and their instruments: recent research into ancient practice. *J.Roman Archaeol 3*: 15–27.
Jennison G (1937): *Animals for Show and Pleasure in Ancient Rome*. Manchester University Press.
Keller O (1909): *Die Antike Tierwelt*, I. Leipzig, Wilhelm Engelmann Verlag.
Kollesch J (1964): *De instrumento odoratus*. Berlin, CMG Supplement. V.
Kollesch J (1973): *Untersuchungen zu den pseudogalenischen Definitiones Medicae*. Berlin, Zentralinstitut für Alte Geschichte und Archäologie, Schriften zur Geschichte und Kultur der Antike 7.
Kühn CG (1821–33): *Claudii Galeni Opera omnia*, Vols. 1–20. Lipsiae. Reprinted: Hildesheim, George Olms, (1964–65); Oxford Microform Publications, 1976.
Künzl E (1996): Forschungsbericht zu den antiken medizinischen Instrumenten. *ANRW* II.37.3, 2433–2639.

De Lacy P (1978, 1980, 1984): *De Placitis Hippocratis et Platonis*, Parts I-3. Berlin, CMG V, 4, 1, 2.

Littré E (1839–61): *Œuvres complètes d'Hippocrate*, 10 Vols. Paris, J. B. Bailliere.

Majno G (1975): *The Healing Hand. Man and Wound in the Ancient World*. Harvard University Press.

Marganne M-H (1986): La *Cirurgia Eliodori* et le P. Genève Inv. III. *Études de Lettres* 1986: 65–73.

Marganne M-H (1988): Le chirurgien Héliodore: tradition directe et indirecte. In: Sabbah G, ed., *Études de Médecine Romaine*, Mémoires VIII. St Étienne, Centre Jean-Palerne, pp. 107–111.

Marganne M-H (1998): *La chirurgie dans l'Egypte gréco-romaine d'après les papyrus littéraires grecs*. Leiden, Brill.

Marx F (1915): *Auli Cornelii Celsi quae supersunt*. Leipzig, CML 1.

McDermott W C (1938): *The Ape in Antiquity*. Johns Hopkins University Studies in Archaeology, 27.

Milne JS (1907): *Surgical Instruments in Greek and Roman Times*. Clarendon Press.

Moraux P (1985): *Galien De Pergame. Souvenirs d'un médecin*. Paris, Les Belles Lettres.

Neuburger M (1897): *The Historical Development of Experimental Brain and Spinal Cord Physiology before Flourens*, 1897. Translated and edited, with additional material by Clarke E (1981). Johns Hopkins.

Nunn JF (1996): *Ancient Egyptian Medicine*. British Museum Press.

Nutton V (1970):*The Medical profession in the Roman Empire from Augustus to Justinian*. Unpublished Ph.D. Dissertation, Cambridge.

Nutton V (1972): Galen and Medical Autobiography. *PCPhS* n.s. *18*: 50–62 (= 1988, I)

Nutton V (1973): The chronology of Galen's early career. *CQ* xxiii: 158–171 (=1988, II).

Nutton V (1984a): From Galen to Alexander, aspects of medicine and medical practice in late Antiquity. *DOP 38*: 1–14 (=1988, X).

Nutton V (1984b): Galen in the eyes of his contemporaries. *BHM 58*: 315–324 (= 1988, III).

Nutton V (1988): *From Democedes to Harvey: Studies in the History of Medicine*. London, Variorum Reprints.

Nutton V (1993a): Galen and Egypt. In Kollesch J, Nickel D eds., *Galen und das hellenistische Erbe*. Verhandlungen des IV. Internationalen Galen-Symposiums, Sudhoffs Archiv Beihefte 32. Stuttgart, Franz Steiner Verlag. pp. 11–31.

Nutton V (1993b): Galen at the bedside: the methods of a medical detective. In: Bynum WF, Porter R eds., *Medicine and the five senses*. Cambridge, pp. 7–16.

Nutton V (1995): Roman medicine, 250BC to AD 200. In: Conrad LI, Neve M, Nutton V, Porter R, Wear A, eds., *The Western Medical Tradition*. Cambridge, pp. 39–70.

Nutton V (1998): Galen. *Der Neue Pauly.* cols. 747–756.

Peck AL (1965): *Aristotle. History of Animals*. Harvard, Heinemann.

Phillips ED (1973):*Greek Medicine*. Thames and Hudson (= 1987: *Aspects of Greek Medicine*. Philadelphia, The Charles Press).

Pott P (1768): *Observations on the Nature and Consequences of those Injuries to which the Head is liable from External violence*. London, Hawkes, Clarke and Collins.

Puschmann T (1878): *Alexander von Tralles*, I. Vienna, Braumüller. (reprinted, Amsterdam, Hakkert, 1963).

Rocca J (1997): Galen and the Ventricular System. *J Hist Neurosci 6* (3), 227–239.

Rocca J (1998a): Galen and Greek Neuroscience (notes towards a preliminary survey). *Early Science and Medicine 3* (3), 216–240.
Rocca J (1998b): Galen and Greek Pneuma Theory. The Limitations of Physiological Explanation. In: Boudouris KJ, ed., *Philosophy and Medicine. II. Studies in Greek Philosophy, 29*. Athens, Ionia Publications. pp. 171–197.
Rocca J (forthcoming, 2003): *Galen on the Brain: anatomical knowledge and physiological speculation in the second century AD*. Leiden, Brill.
Ryberg IS (1955): *Rites of the State Religion in Roman Art*. Memoirs of the American Academy in Rome, XXII.
Sabbah G, Mudry, P eds. (1994): *La médecine de Celse. Aspects historiques, scientifiques et littéraires*, Mémoires VIII. St Étienne, Centre Jean-Palerne.
Savage-Smith E (1971): Galen's Account of the Cranial Nerves and the Autonomic Nervous System. Parts 1 and 2. *CM* 77–98; 173–194.
Shryock RH (1961): The History of Quantification in Medical Science. *Isis 52*: 215–237.
Sigerist H (1920): Die "Cirurgia Eliodori". *AGM 12*: 1–9.
Simon M (1906): *Sieben Bücher Anatomie des Galen*. I and II. Leipzig.
Singer C (1956): *Galen. On Anatomical Procedures*. Oxford, Wellcome Historical Medical Museum.
Singer PN (1997): *Galen. Selected Works*. Oxford, The World's Classics.
Soury J (1899): *Le système nerveux central. Structure et fonctions. Histoire Critique de théories et des doctrines*, I and II. Paris, Georges Couiré et C. Nard, Éditeurs.
Spencer WG (1938): *Celsus. De Medicina*. Three Volumes. Harvard, Heinemann.
Swain S (1996): *Hellenism and Empire*. Clarendon Press.
Temkin O (1961): A Galenic model for Quantitative Physiological Reasoning? *BHM 35*: 470–475 (= 1977, 162–166).
Temkin O (1971): *The Falling Sickness: A History of Epilepsy from the Greeks to the Beginnings of Modern Neurology*, Second Edition. Johns Hopkins.
Temkin O (1977): *The Double Face of Janus and Other Essays in the History of Medicine*, Johns Hopkins.
Toynbee JMC (1973): *Animals in Roman Life and Art*. London, Thames and Hudson.
Walzer R (1944): *Galen on Medical Experience. First Edition of the Arabic Version with English Translation and Notes*. Oxford.
Wenkebach E (1934): *Galeni In Hippocratis epidemiarum librum primum commentaria III*. Leipzig, CMG V, 10,1.
Withington ET (1928): *Hippocrates*, Volume III. Harvard, Heinemann.

Chapter 20

Lorenz Heister (1683–1758) and the "Bachmann Case": Social Setting and Medical Practice of Trepanation in Eighteenth-Century Germany

MARION MARIA RUISINGER
Institute for the History of Medicine, University Erlangen-Nürnberg, Germany

Abstract

Cranial trepanation belonged to the standard operations of eighteenth-century surgery. It challenged the surgeon's professional skill with its intricate surgical practice, as well as with its unusual social setting. For in no other operation was the patient incapable of conscious consent, and in no other operation was there a similar discrepancy between the invisible damage to be cured and the visible damage caused by the cure itself. The present paper illustrates the social setting and the surgical practice of trepanation by interweaving two points of view. On the one hand, a general account is given on the basis of surgical publications written by Lorenz Heister and his contemporaries. On the other hand, the unpublished sources of the Heister correspondence serve to reconstruct one particular case of repeated trepanation, which took place in 1753. The interdependence of society and physicians was a general feature of surgery at that time. By joining these two viewpoints it can be shown, however, that this interdependence was nowhere so obvious and distinct as in trepanation.

Keywords: Lorenz Heister (1683–1758), trepanation, history of surgery, eighteenth century, case study

In the eighteenth century, cranial trepanation belonged to the standard techniques a surgeon was supposed to have mastered. Pierre Dionis stated in his "Cours d'Opérations de Chirurgie" that no other operation on the head or the eyes was performed more frequently, not even the couching of the cataract (Dionis, 1734, p. 529). The "drilling of the skull" challenged the surgeon's skill in two respects: on the one hand, the intricate handling of the various instruments made high demands on his manual dexterity; on the other, the unique circumstances of head trauma required a considerable degree of social competence and sensibility on his part. Surgery was performed at that time on conscious patients with visible diseases. Trepanation may be regarded as the only exception to this rule. Only in the case of severe head trauma was the surgeon confronted with an unconscious patient and an invisible disease. In what follows the double challenge of trepanation – the difficulty of carrying it out and its unusual social setting – will be illustrated by the example of Lorenz Heister and the "Bachmann case".

Heister (Fig. 1) was born the son of an innkeeper in Frankfurt/Main in 1683. After his studies at the universities of Giessen and Wetzlar, he went to Amsterdam, where he continued his training in anatomy and surgery under the supervision of Friedrich Ruysch and Johann Jacob Rau. In 1710 Heister was offered the chair of anatomy and surgery at the university of Nuremberg, which then was located in Altdorf, a small town in the vicinity of the Imperial City. Ten years later he accepted the professorship of anatomy, surgery and physiology at Helmstedt university in the Duchy of Braunschweig-Wolfenbüttel. Heister enjoyed the reputation of a skilful surgeon, a popular university teacher, and a widely recommended physician. And he was "the one among the surgical authors who wrote the most books", as his contemporary Albrecht von Haller (1775, p. 5) put it.

The topic of trepanation shows up at many places in this copious oeuvre, namely in the handbook of surgery and the case studies, and it is mentioned in Heister's correspondence as well. In each of these text categories the author focused on the subject from a different point of view, according to the recipient or the scope of his text. Due to the different characteristics of the written sources, they will be presented consecutively, gleaning the information they can give us with respect to the "drilling of the skull" in general. In a second step, we shall take a closer look at a specific trepanation that took place in the spring of 1753. This history, the "Bachmann case", will lead to some of the crucial questions of trepanation in the eighteenth century.

The first text category comprises Heister's famous handbook of surgery with its various translations and revisions. The "Chirurgie" was first published in Nuremberg in the year 1719 (Heister, 1719). The book turned out to be a best-seller. Three reprints followed in close succession. In 1739, twenty years after its first publication, the long expected Latin edition saw the light of day, the "Institutiones Chirurgicae" (Heister, 1739). This largely revised version served as a pattern for the subsequent editions in German (Heister, 1743a), English (Heister, 1743b), Spanish (Heister, 1747–1750) and Italian (Heister, 1756). In 1752 the author proudly stated that his German handbook had become "virtually the bible of all physicians, surgeons and barbers".[1]

When Heister decided to publish his handbook in the vernacular and not, as initially planned, in Latin, he did so because the German barber surgeons were his main target group. The author claimed to cover the whole field of their daily work in his "Chirurgie". It goes without saying that this also included trepanation, its indication, technique, and instruments, which were depicted with copper engravings of high quality. Thus the handbook enables us to reconstruct the standard operation technique of the time.

Compared to other operations, the "drilling of the skull" seems to have undergone few changes during the four decades between the first and the last German editions of Heister's lifetime. A simple look at the number of pages dedicated to trepanation seems to tell as much: in 1719 the topic covered 9 of 753 pages, whereas in 1752 one counts 10 of 1078 pages, with no relevant changes in content. This does not mean, however, that surgery itself entered a period of stagnation during the first half of the century. Other operations attracted much publicity by their dynamic development in that time, especially lithotomy. Due to the dazzling personality of "Frère Jacques", who surprised the Paris surgeons with his unorthodox way to cut for the bladder stone, and the innovative techniques of the London surgeon William Cheselden, the respective chapter of Heister's handbook grew from 32 pages in 1719 to as much as 83 in 1752.

Figure 1. Lorenz Heister (1683–1758), depicted as scientific author amidst the symbols of anatomy, medicine, surgery and botany (Brucker and Haid, 1741–1747).

The second group of texts are the case histories, which were published in two volumes under the title “Medizinische, Chirurgische und Anatomische Wahrnehmungen”, i.e. “Medical, Surgical and Anatomical Observations” (Heister, 1753, 1770). They do not deal with the method in general, like the handbook of surgery, but with the individual patient, his specific treatment and his unique sociobiographical context. These case studies were popular reading not only with the medical profession, but also with interested laymen and laywomen.

The broad reception of the histories may be illustrated by a letter that was sent in 1758 from the Bavarian city of Straubing to Heister’s residence in Lower Saxony. It was undersigned by “Madame Adelheid la Comtesse de Closen”, a middle-aged widow who suffered from a tumour of her left breast.[2] Before the writer went into the details of her case, she explained why she had utter confidence in Heister’s ability as a physician and a surgeon: she had heard much about “his most praiseworthy intelligence and experience” and, moreover, she herself had read “widely in his published medical and surgical observations”. Hence her readiness to undertake the long trip from Straubing to Helmstedt necessary for her cure. In his answer, Heister seized the opportunity to compare the countess” case to a similar one published and illustrated in his observations, but he did not refer to her acquaintance with his book as anything noteworthy (EUL Trew: Heister 17, undated). Obviously the case histories belonged to the kind of literature a well-read and well-to-do woman with a personal interest in medical education was supposed to be aware of.

What do the collected observations tell us about the “drilling of the skull”? The two volumes outline about 1200 cases of medical, surgical or anatomical interest. Only five of them deal with the topic of trepanation.[3] This may be due to one or more of the following factors. To begin with, it may well be imagined that the lay reader, who identified himself automatically with the patient, shrank back from the idea of unconsciousness. In trepanation the dialog ceased and the patient was in the surgeon’s hands without any possibility of interfering. Was it out of regard for future patients’ feelings that the editor preferred to publish only a few selected cases of trepanation?

Furthermore, one might suggest that the operation was standardised to a very high degree and that, so to speak, one explained them all. This interpretation is supported by the above-mentioned lack of innovative development, which characterised this operation in the first half of the eighteenth century.

Perhaps the small number of trepanations mentioned simply reflects the rarity of the operation in Heister’s own practice. That leads to the question whether it was only seldom undertaken, or if this were just a peculiar feature of Heister’s practice. The latter seems to be the more probable: Lorenz Heister was a famous physician with a widespread clientele. His advice as a surgeon was mostly sought for difficult chronic diseases like bladder stones, cataracts, and hernias. The drilling of the skull, however, had as its main indication acute brain damage, and was therefore a case for the nearby local wound surgeon, not for the far-off academic specialist.

There may be still another reason why the “drilling of the skull” plays only a minor role in the surgical practice of Heister, and that is the unfavourable prognosis of the operation, as we learn from his handbook of surgery:

> The Surgeon can hardly ever be certain of the Success of this Operation, [...], the Disorder generally turning out worse than its Symptoms indicated; and therefore we need the less wonder that most Patients miscarry after the Use of the Trepan, not from the Operation, but the Violence of their Disorder, or the Injury received. (Heister 1748, p. 357)

While the success of trepanation was doubtful at best, the bad effects of an unsuccessful case were certain. The surgeon's good reputation was his most precious capital. It would obviously not be in the best interest of any surgeon to take responsibility for patients who had little chance of surviving due to their severe brain alterations. This interpretation corresponds with the account given by the French surgeon Joseph de LaCharrière about his colleagues' aversion to trepanning: "the most famous practitioners do not dare to undertake the operation, because they fear that they might not find anything [i.e. no intracranial haemorrhage] and pass for wicked and audacious." (LaCharrière, 1700, p. 230).

The surgical publications of Heister having been examined with respect to the representation of trepanation, we can proceed now to analyse his correspondence, which forms part of the Trew Collection in the Erlangen University Library. The letters reflect the versatile personality of their author: Heister the scholar, discussing with learned men all over Europe questions of scientific interest, and Heister the "hands-on physician", giving medical advice in specific cases. The trepanation theme shows up in both kinds of letters, and it does so in very different contexts.

In his scientific correspondence, trepanation is referred to by Hartwig Wilhelm Ludwig Taube and Johann Gottlob Sturm, both former students of Heister who continued their medical training in Paris during the 1730s. In a letter from April 1732, Taube communicated to his former professor two observations on trepanning. First, he had noticed that French surgeons, having performed the cross-shaped incision on the scalp, cut the resulting four flaps of skin away, thus making a circular wound, which was easy to dress and healed well. Second, he had watched the surgeon Sauveur François Morand cut the dura mater in a roughly cruciform manner in cases with subdural haemorrhage. This was a procedure Taube "wasn't pleased with". He concluded with the general observation that "patients and surgeons are more accepting of operations in this country, than in ours" (EUL Trew: Taube 13).

Sturm had spent some months in Paris during the winter term 1736/37. With respect to trepanation, he noted briefly in his letter to Heister: "Two times I saw trepanning, but the Hôtel Dieu cannot praise itself to have brought through a single patient in 50 years on whom this operation has been performed". By comparison, it can be mentioned that Sturm watched as many as 64 lithotomies during the same period (EUL Trew: Sturm 2). The pessimistic picture drawn by the young physician corresponds with the description given by Dionis and Jean Baptiste Verduc. Dionis wrote that "in the Hôtel Dieu nearly all of them [i.e. the trepanned] perish". He argued that the polluted air in the hospital was the reason for this unhappy course and pleaded for the establishment of a place in the outskirts of Paris exclusively for patients wounded on the head (Dionis, 1734, pp. 555f.). Verduc, for his part, stated that "many able practitioners have already remarked that the linen used in dressing the trepanned causes their death". He argued that the badly washed bandages were still polluted with arsenic particles from their former use on various wounds, thus causing a gangrene of the dura (Verduc, 1703, p. 177).

The scientific correspondence conveys a personal, but nevertheless professional, perspective of surgery at the time. The other part of the correspondence, however, reflects the individual case from a very intimate point of view. These “case-centred” letters give a genuine account of the communication which took place between the patient, the local physician, and Lorenz Heister, the supervising authority. Some of the letters exchanged refer to the case of a man who was subjected to trepanation in 1753. The very same case is published as number 477 in the second volume of the observations (Heister, 1770, pp. 840–844). It is this specific trepanation that I shall focus on, looking closely on the details of the case.

On a rainy day during the spring of 1753, Friedrich Bachmann, a young, well-to-do German merchant, was on his way back from Strasbourg. Musingly he looked out of the carriage window. How he longed to be home again! An endless winter had passed since his departure from Magdeburg. But there was still the Easter fair in Frankfurt/Main to visit, and the fair in Leipzig. His bright blue eyes darkened with sorrow. It would be June before he would be free to return to his beloved ones.

This recreation of the setting is certainly fictional, but the facts make it plausible. In fact, in the spring of 1753 a 36 year-old German merchant named Bachmann was involved in a traffic accident on the road from Strasbourg to Frankfurt/Main (EUL Trew: Keßler 2). His carriage turned over and his head knocked heavily against the ceiling. He had to lie down in the grass for some time before he was able to continue his travel. Every bump of the carriage caused him severe pain in the head. Over the next days he suffered from headache, dizziness, and pain in the neck. Then his complaints gradually subsided. In spite of his shaken health, he was perfectly able to transact his business at the fairs in Frankfurt and Leipzig.

All of a sudden, the situation got worse. On Ascension Day his headaches and vertigo came back with force. Two days later, on Saturday, 2nd June, 1753, he mounted the carriage to travel home to Magdeburg. On his arrival on Sunday evening he was already somnolent, recognised his friends only vaguely, and could not walk on his own.

Johann Daniel Keßler was called immediately. He was not only the patient’s physician, but also his intimate friend. Keßler opened a vein on Bachman’s foot, but without effect. The next morning another physician, Doctor Stockhausen, was asked for his advice with this difficult case. A manifold therapeutic activity followed: the patient was submitted to phlebotomy on his arm, to blisters on his neck, arms, and calves, and to several enemas. The following day another bleeding was tried, but still without any sign of improvement. The merchant remained somnolent and opened his eyes only every now and then, but seemed to recognise his friends. The examination of his head showed no external alteration whatsoever. Keßler and Stockhausen discussed the case thoroughly. They arrived at the conclusion that Bachman’s state might be attributed to the bruise on his head and possible bleeding in the brain or under the skull.

The two physicians faced a dilemma. The question was whether to use the trepan or not. The patient’s symptoms fitted the indications for trepanation, but there was no external trauma and the traffic accident had happened 8 weeks ago. Apart from the uncertainty of the medical facts there might also have been some personal reasoning which made the physicians shrink back from the operation: The merchant was a well-known personality in Magdeburg and his suffering was observed with much compassion by the citizens. It was not only Bachman’s life that was at stake, but each physician’s own reputation and future prosperity.

Keßler and Stockhausen resolved to entrust a third physician with the responsibility, a physician who surpassed them in professional authority, but was less personally involved than themselves: Lorenz Heister. On Thursday, 7th June, an express messenger was sent to the small university town of Helmstedt, about 40 miles from Magdeburg. He carried a letter by Doctor Keßler to the famous professor, which was “written with a trembling hand”. The author beseeched Heister “to exhibit his love for the family of this Gentleman and for myself” and to come to Magdeburg without delay.

This was not an uncommon request in the eighteenth century. Usually it was the patient who took the trouble of the journey. A visit to a distinguished surgeon was attraction enough to outweigh the discomfort. But when the patient was too feeble – or too aristocratic – to travel, the physician was asked to make the journey and stay at the patient’s house during the treatment.

Lorenz Heister arrived at Magdeburg the day after the letter had been sent. He visited the patient, conferred with his colleagues, and examined the prescribed medicines, which met with his approval. But he decided against trepanation, at least for the moment.[4]

Heister was well aware of the fact that his cautious attitude was not shared by other influential physicians of the time. His famous French colleague Dionis encouraged young surgeons to trepan immediately every one who, after being hit on the head, drops to the ground and loses his senses (Dionis, 1708, p. 349). Heister esteemed Dionis highly and even translated his “Cours d’Opérations de Chirurgie” into German (Dionis, 1734). But he passionately disagreed with him on this point and stated that “the Trepan [is] not to be used hastily”. On the contrary, he encouraged his readers “to try first the Use of other Remedies both external and internal [...], rather than immediately to subject the Patient to the Trepan, before you are convinced it is absolutely necessary” (Heister, 1748, p. 357). According to Heister, the operation is only clearly justified in fractures or depressions of the skull with clinical symptoms, such as “Restlessness, Delirium, Convulsions, Vertigo, Apoplexies, Stupidity, with a Loss of the Senses, Speech, and voluntary Motion” (Heister, 1748, p. 356). It never should be performed, however, on internal disorders of the head. This once very popular use of the trepan he regarded as definitely obsolete.

Let us have a look at this patient. One week had passed since Heister’s arrival in Magdeburg. External and internal remedies had been applied to a great extent, amongst them emetics and a phlebotomy of the jugular vein. These therapeutic measures were based on the principle of humouralism. According to this ancient concept of physiology, the human body consists of four fluids or “humours”: blood, phlegm, yellow bile and black bile. Health and disease were considered to derive from the balance or imbalance of these humours, respectively. The duty of the physician, therefore, was to correct the imbalance. He achieved this by prescribing appropriate foods and drugs, or by evacuating the superfluous humours by means of what might be called “humoural surgery”, i.e. leeches, cupping, bloodletting, blisters and setons.

In the Bachman case the whole spectrum of evacuating had been tried, all without lasting effect. The time was now ripe for trepanation. Heister examined the patient’s shaved head carefully. At the left parietal bone he found a slight unevenness and on

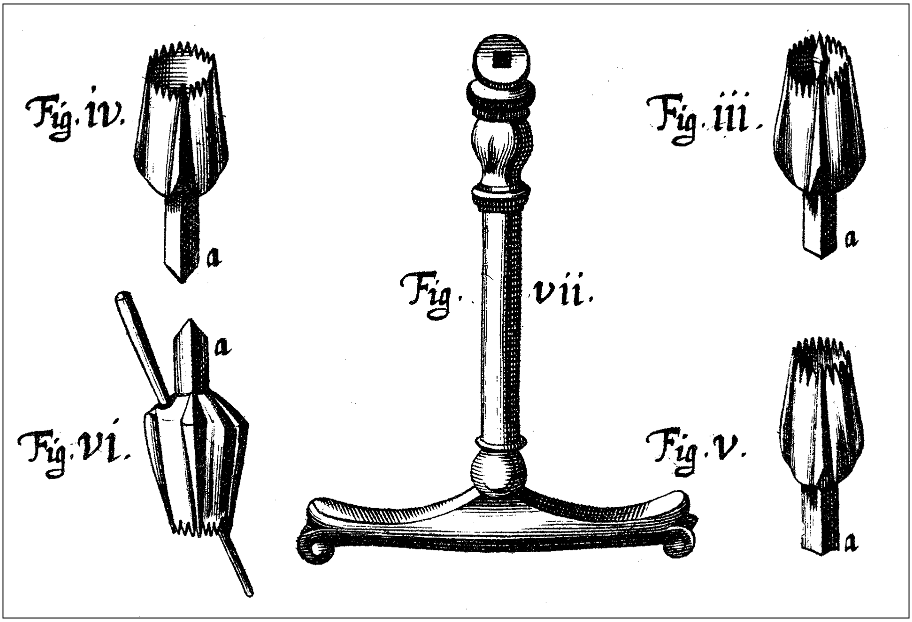


Figure 2. The hand trepan after Fabricius ab Aquapendente (Scultetus 1666, part 1, Tabula II).

pressing it the patient gave signs of pain. This was the place to be trepanned.

What technique was used in the middle of the eighteenth century for opening the human skull? Usually the operation was performed in two steps: After the incision of the integument, the surgeon waited about 12 hours to achieve optimal haemostasy before starting the trepanation itself. Meanwhile, he prepared the required instruments and dressings. The heart of the apparatus was, of course, the trepan itself. Heister specified in his surgery two different models: a plain instrument that was worked with one hand, and a more sophisticated one for two-handed use.

According to Heister it was the Italian Fabricius ab Aquapendente, who had constructed the first mentioned plain instrument. In his "Operationes chirurgicae" of 1619, Fabricius himself described how he had invented this instrument by combining the main features of the two ancient trepans described by Celsus, namely the handle of the "terebra" and the crown of the "modiolus". He furnished the latter with four wings ("modiolus alatus quatuor alis"), so that the danger of causing involuntary damage to the dura might be reduced (Fabricius, 1619, p. 9f.).

Heister depicted this trepan as "made in the Shape of a common Gimlet" (Heister, 1748, p. 359) and called it the "Trepanum Aquapendentis", or simply the "hand trepan". A detailed description of the shape and handling of this instrument is passed on to us by Johann Scultetus, who had studied under Fabricius in Padua (Fig. 2). The German surgeon writes in his "Wund-Artzneyisches Zeug-Hauß" that the instrument was furnished with a set of slightly different crowns. The so-called "male crown" was used in the beginning (Fig. 2, iii). It was equipped with a sharp central point a little longer than the crown itself. This point helped to centralise and stabilise the trepan during the first turns. Then the surgeon exchanged the “male crown” for a “female one” without a point (Fig. 2, iv, v). The latter was replaced now and then by another, identical one, whilst a helper cleaned the used crown and cooled it in water or attar of roses (Scultetus, 1666, part 1, pp. 7–9). By 1631 the hand trepan was used by most London surgeons (Paré, 1631, p. 25), and it enjoyed great popularity throughout the rest of the century. By Heister’s time, however, it had been generally replaced by the more sophisticated two-handed model, which he regarded as “much more commodious than the ancient one” (Heister, 1748, pp. 359f.).

The copper engraving (Fig. 3) from the Latin edition of Heister’s handbook of surgery depicts the intricate equipment needed for trepanation in his time. First, there was the trepan itself (Fig. 3, number 3) with its crown (A). This “male crown” could be transformed into a “female” one by simply taking out the point (Fig. 3, number 4; E) with the winch (Fig. 3, number 5). The trepanation set was enlarged by some accessories, which could be screwed into the handle instead of the crown. They turned the trepan into a multifunctional instrument: A so-called “lenticular scalpel” (Fig. 3, number 6) with a round and flat head for smoothing the sharp inner edge of the trepanned aperture; an instrument for gradually depressing the dura mater (Fig. 3, number 7), and a perforating instrument (Fig. 3, number 8). A brush made out of hog bristles completed the equipment. It served to clear away the sawdust in the operation (Fig. 3, number 9).

As already mentioned, the trepan was worked with both hands: The surgeon fixed the top of the handle with his left hand and turned the handle cautiously with his right one. In doing so, he placed his head on the top of the handle in order to stabilise the turning trepan and to reinforce the pressure on its crown. It is important to stress this point, as it is closely connected to one of the few changes in the method of trepanning made during the first half of the eighteenth century: the shift away from what may be called the “frontal method” to the “mental method” or “chin method”.

The famous illustration from Diderot’s “encyclopédie” (Fig. 4) depicts a surgeon who has lowered his chin on the top of the trepan, suggesting this to be the standard method of the time (Diderot, 1763). But to use the chin instead of the forehead was a comparatively new method. It was introduced into surgery by Jean-Louis Petit, and first described according to his model by the French surgeon René Jacques Croissant de Garengeot in 1725, in the new edition of his “Traité des Instrumens de Chirurgie”. Six years later, in the second edition of his “Traité des Opérations de Chirurgie”, Garengeot explained the advantages of the new “chin method” compared to the traditional “front method”: it offered the surgeon an undisturbed view of the turning crown and enabled him to keep the applied pressure under better control than before (Garengeot, 1731, p. 187). The author illustrated the innovative technique with two copper engravings, which probably served as a copy for the trepanation scene in Diderot’s encyclopaedia.

In this respect, Heister shows his awareness of current developments and his readiness to incorporate them in his own work: in the first edition of his “Chirurgie” he mentioned only the “forehead method” (Heister, 1719, p. 444); in the Latin translation published 20 years later he referred to both (Heister, 1739, p. 529); whereas in a concise version edited under the title “Kleine Chirurgie” in 1747 he recommended solely the “chin method”, because it gave the surgeon a better view of his work (Heister, 1747, p. 233).

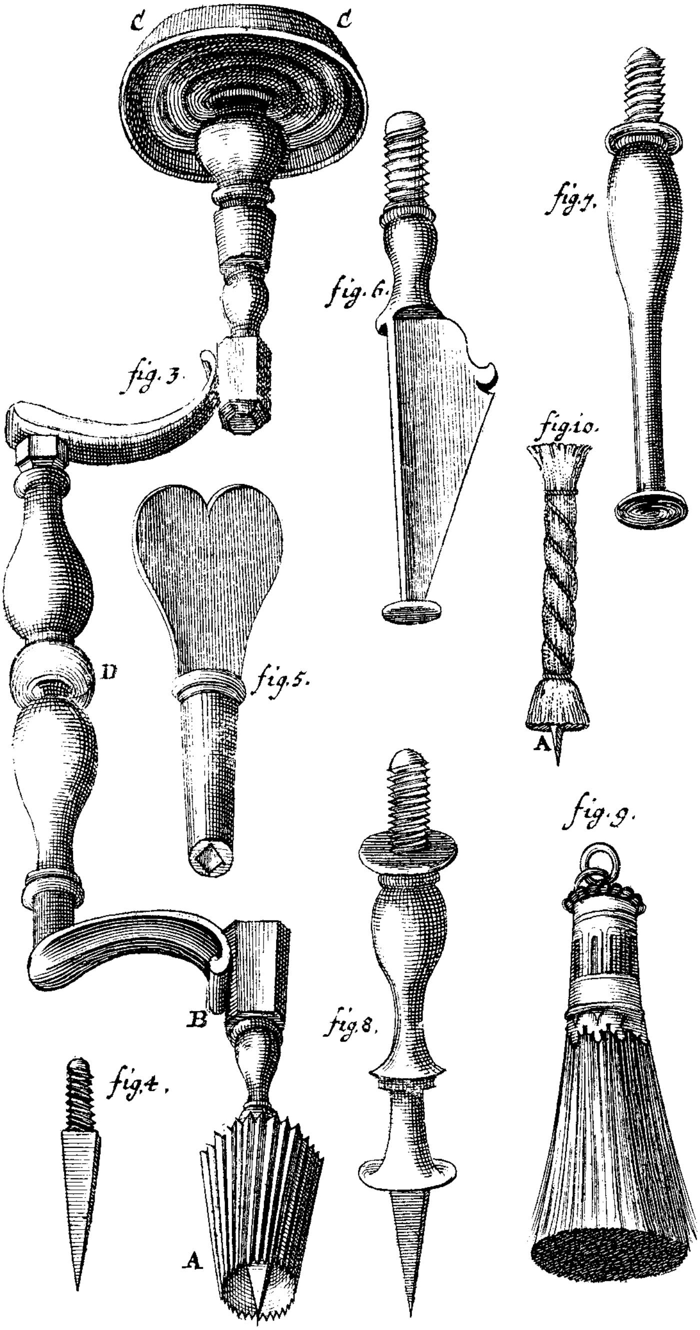


Figure 3. The equipment recommended by Lorenz Heister for trepanation (Heister, 1719, Tabula XVI, slightly rearranged).

Before the trepan could be used, however, some preparations had to be made. Because the theory of humours taught that the membranes of the brain were of a distinctly hot quality, it was believed that "nothing is more enemy to the Braine than cold." (Paré, 1631, p. 24). Consequently all doors and windows had to be shut and chafing dishes of coals had to be provided for, so that no cold draughts would reach the trepanned part of the patient's head (Garengeot, 1720, p. 146). Hence, one finds the presence of a servant warming bandages with a coal-pan in many illustrations showing trepanation, such as those in in DallaCroce's "Seven books of surgery" (DallaCroce, 1573, p. 52^{r}, 53^{v}, 54^{r}).

It was not only the cold air from which the patient must be protected. According to contemporary belief, another danger to health might emanate from strong emotions. This was not only true at the time of the operation itself, but also for the period of convalescence, when the patient was strictly advised to commit no irregularities "in the Non-naturals, either in drinking, and bad Diet, or by Frights, Anger, Venery, and other intense Passions" (Heister, 1748, p. 357f.). The surgeon's duty was to protect the patient during the trepanation from two possible sources of fright: the sound of the drill and the sight of the instruments.

To achieve an acoustic isolation, the surgeon had to "observe [...] that the eares of the Patient must bee well stopped with Lint or Bumbast" so that he "may not heare the noyse of the Trepan or other instruments which haply might affright him." (Paré, 1631, p. 24). Analogous advice was already given at the end of the fifteenth century (Brunschwig, 1497, p. 51^{r}; Gersdorff, 1517, p. 21^{v}) and was still en vogue 200 years later (Purmann, 1692, p. 85; Barbette, 1694, p. 67). Dionis generally agreed with this practice in his "Cours d'Opérations". He adds, however, that "he had watched some be trepanned with this ceremony being neglected, who had not suffered from more pain", thus heralding the procedure's gradual loss of significance (Dionis, 1734, p. 562). Heister himself did not even mention this method, which had been regarded as indispensable by his predecessors.

The second possible source of fright the patient had to be protected from was the sight of the instruments. Therefore the surgeon was supposed to prepare his tools in an adjacent room and to cover them with a piece of linen before placing them within the patient's view (Dionis, 1734, p. 561). This corresponds with numerous directives given in other operations that all aim at the same goal: to keep the patient unaware of the presence of the instruments and the moment of their application as long as possible (e.g. Scultetus, 1666, part 1, p. 5).

The operation on the merchant Bachmann was performed in two steps. Interestingly enough it was not Heister, the skilled surgeon, who handled the instruments, but a local military surgeon named Bruesse, with Heister, Keßler, Stockhausen and others standing by and following closely every single move he made. The incision of the integument took place on Thursday evening and the drilling of the skull was done the following morning. The result of the trepanation was unsatisfactory: only a little epidural blood could be evacuated, and the patient showed no signs of recovery. The next day further steps were discussed. The three physicians suspected extravasated liquid under the dura mater. Consequently they decided to open the dura itself.

This was an audacious decision. To open or not to open the dura mater was a crucial question at that time. Most laymen believed that the dura should not be traumatised no

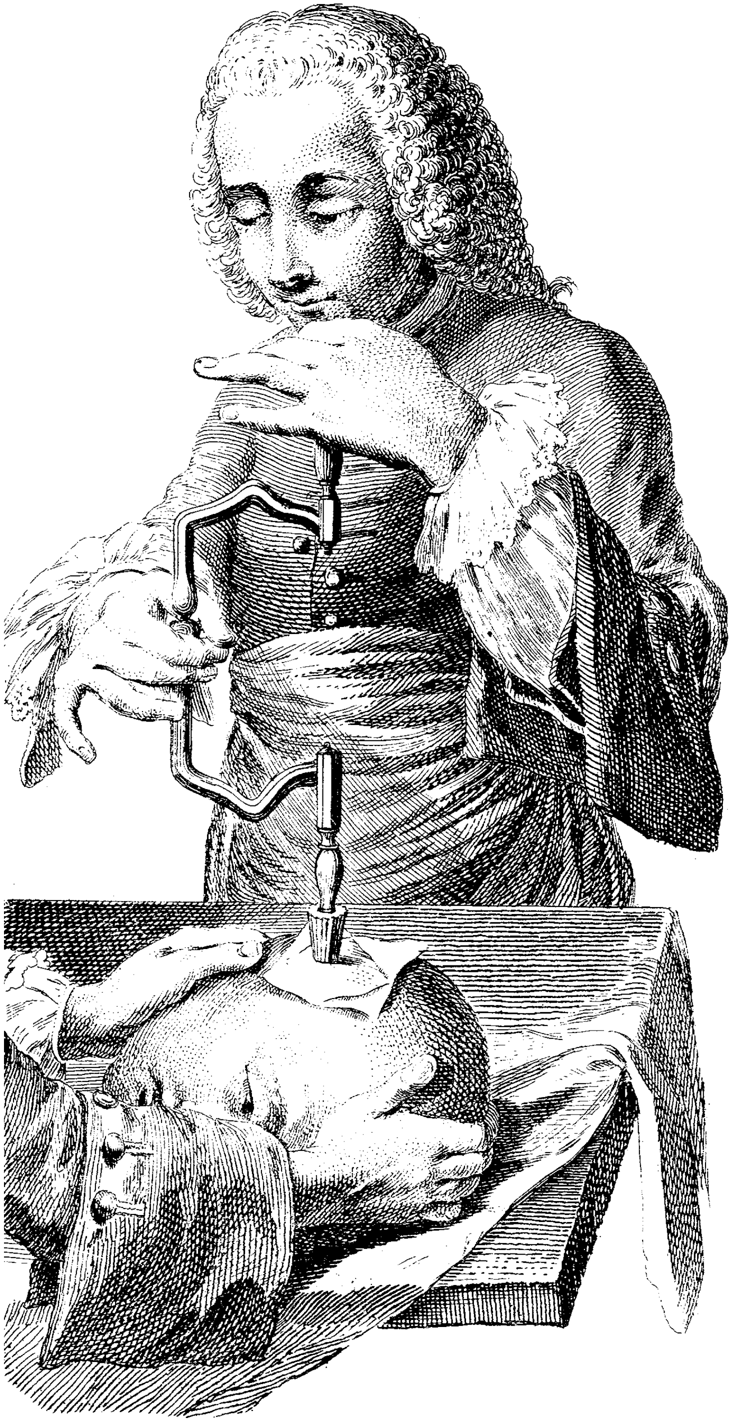


Figure 4. Trepanation scene from French “encyclopédie” (Diderot, 1763).

matter what “because it is lethal” (Gersdorff, 1517, p. 22[r]). Most medical authors agreed, however, that the perforation of the dura should be allowed in cases where there was nothing to lose (e.g. Barbette, 1694, p. 66; Schultze, 1695, p. 190; Heister, 1748, p. 362). The resulting gap between common opinion and the professional state of the art put the surgeon to a severe test when it came to the decision of whether to perforate the dura mater or not. He had to perform a tightrope act between benefiting the patient and serving his own best interest – or, as Antonius Nuck pointedly stated, he had to cut the dura and avoid vile gossip in doing so (Nuck, 1709, p. 23). How was this achieved?

Walther Schultze recommended “for sake of better carefulness in this action to inform the [patient’s] friends in this and all cases about the necessity of the operation as well as the hope and the danger involved, so that no future difficulties will hit us more than anticipated.” (Schultze, 1695, p. 190). LaCharrière and Verduc, for their part, suggested opening the dura secretly with a lancet hidden in a swab, so that the bystanders would not be aware of it (LaCharrière, 1700, p. 241; Verduc, 1703, p. 175). Heister also advised his readers to use a small lancet wrapped in linen, with only the point left free (Fig. 5). He claimed that in this way the surgeon was prevented from accidentally cutting deeper than desired. One may speculate, however, that the hiding of the blade had also a very welcome effect on the psychological disposition of the bystanders.

How was this controversial operation performed in the Bachmann case? The wound surgeon opened the dura the day after the trepanation, using a covered lancet like the one shown in Heister’s handbook of surgery. A very small quantity of blood emerged from the cut, but without any effect on the patient’s state of health. Now the uttermost had been performed: the skull had been trepanned and the dura perforated. Heister and his authority were no longer needed. He departed the same day, not without leaving advice for future procedures: he recommended watching the patient for some days, and in case there was no improvement, next trepanning the right side of the skull.

In fact, there was a remarkable improvement (EUL Trew: Keßler 3), but it lasted only two days. Then the patient became worse than before: his mouth tilted, spasms started in his left side, and his right arm became paralysed (EUL Trew: Keßler 4). Again an express messenger was sent to Helmstedt. The answer arrived the next day: Heister recommended additional trepanation, even if the patient showed some improvement (Heister, 1770, p. 841). The trepanation was performed the same day, despite the violent epileptic seizures the merchant was now suffering (EUL Trew: Keßler 5). The dura was found extended. When it was opened, a considerable amount of blood gushed forth. After the operation was finished the convulsions decreased a little, only to return in more severe form.

The next day the patient was in a desperate condition. Now the physicians abandoned their cautious attitude and acted without restraint, obviously under the impression there was nothing to lose. They performed another incision of the dura at the site of the first trepanation, deeper than the first time, and now a teaspoon-full of thick, yellow matter was evacuated. They desperately tried to obtain more of it, but without success. During the night the epileptic seizures became worse than ever. Hence, the physicians resolved to do a last, hazardous step: they cut deep into the gray matter of the brain (Heister, 1770, p. 841).

With this cut the limits of traditional surgery were surpassed and the new terrain of

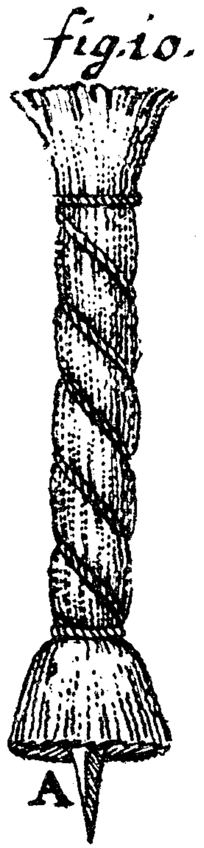


Figure 5. Hidden lancet for the underhand perforation of the dura (Heister, 1719, Tabula 10).

brain surgery was explored. This was not entirely new ground, as Bakay (1987) elaborated in his essay on "Francois Quesnay and the birth of brain surgery". In fact, Quesnay, physician of Madame Pompadour and secretary of the *Académie Royale de Chirurgie*, had, in 1743, published a highly controversial paper on brain surgery in the "mémoires" of the same academy. Heister was a member of the French Royal Academy of Surgeons, and he subscribed the society's journal. It may well be imagined that the daring operations of Quesnay had been discussed during the eight days of Heister's stay at the merchant's home, encouraging the physicians to delve into the brain themselves. They did so hoping to come across a hidden abscess, but all in vain. The cut in the gray matter brought nothing to light. Bachmann died the same day after violent epileptic seizures.

The next morning Keßler wrote a short letter to Heister. He told the professor about the sad ending to the case and informed him that they "would open the head today". Keßler promised to send the report of the autopsy to Helmstedt. "We remain stunned to the heart by the loss of a worthy friend", he concluded (EUL Trew: Keßler 6).

It is this autopsy report (EUL Trew: Keßler 7) that was published as case number 477 in the second volume of Heister's observations, after the generously inserted Latin terminology of the original letter was replaced with common German terms (Heister, 1770, p. 840–844). Heister added a reflection of his own: he wondered how the merchant managed to travel as far as he did and to attend to all his business affairs with such violent damage to his brain. The long free period between the accident and the symptoms was a phenomenon Heister had read of in medical literature, e.g. in the observations of Scultetus, but he had never before come upon such a case himself.

The maximum length this "free period" might cover had been a topic of lively discussion not only among surgeons, but also among jurists. Dionis stated with regard to French legislation that "the men of law have made a rule that after 40 days the danger has passed, and if an injured person happens to die after this period, this was no longer due to the wound" (Dionis, 1734, p. 542). He admitted that this solution might be helpful for the pragmatic needs of a judge. A prudent surgeon, however, should never bind himself to a positive prognosis before 100 days had passed. Dionis' estimation concurred with the above mentioned observations of Scultetus, who in 1666 gave an account of two cases of head trauma that turned fatal after free periods of 100 days and nine weeks (Scultetus, 1666, part 2, pp. 22–29).

In the post-mortem examination Doctor Keßler found that the trepanation was done to perfection, but that the case as such had been incurable. Heister agreed and stated in his closing letter that in this case it had not been within the power of men to help. Thus, the post-mortem examination served as a subsequent justification for the chosen therapeutic measures. It was a justification not only for the conscience of the physicians themselves, but above all for the public. This was important. The public was a severe judge and the physicians were forced to consider in every move they made the effect it might have on the bystanders and, indirectly, on their own reputations. They had to take into account the dogma of medicine as well as the principles of the society in which they were working when they decided the crucial questions of trepanation: when to trepan, which technique to use, whether to incise the dura, and to cut the brain or not. The interdependence of society and medical practice was a general feature of surgery at that time. One might state, however, that it is nowhere so obvious and distinct as in trepanation. For in no other operation was the patient incapable of conscious consent, and in no other operation was there such a discrepancy between the invisible damage to be cured and the visible damage caused by the cure itself.

Notes

1. Heister in a letter to an anonymous judicial officer, dated 22 Feb. 1752 (Niedersächsisches Staatsarchiv Wolfenbüttel, 37 Alt 735).
2. Erlangen University Library, Manuscript Department, Trew Briefsammlung: Closen 1 (26 Feb. 1758). – In the following this letter collection is referred to as "EUL Trew".
3. Heister (1753) pp. 81f., 90f., 108f.; Heister (1770), pp. 840-844.
4. EUL Trew: Keßler Beilage (undated autograph from Lorenz Heister).

References

Bakay L (1987): *Neurosurgeons of the Past*. Springfield, CC Thomas, pp. 45–57.
Barbette P (1694): *Chirurgische und Anatomische Schriften*. 3rd edition. Frankfurt, JM Bencard.
Brucker J, Haid JJ (1741–1747): *Bilder-Sal heutiges Tages lebender, und durch Gelahrtheit berühmter Schriftsteller*. Published in 10 parts. Augsburg, JJ Haid.
Brunschwig H (1497): *Dis ist das buch der Cirurgia. Hantwirckung der wund artzny*. Straßburg, J Grüninger. Reprint (1968): München, K Kölbl.
DallaCroce GA (1573): *Chirurgiae libri septem*. Venice, G Ziletti.
Diderot D, D'Alembert J-B (1763): *Encyclopédie*. Paris, Briasson, David, Le Breton, Durand, Vol. II Planches III, plate XVII. Reprint (1967): Stuttgart, F Frommann, Vol. 24.
Dionis P (1708): *Cours d'Opérations de Chirurgie*. Brüssel, Les Freres t'Serstevens, A Claudinot.
Dionis P (1734): *Chirurgie*, edited by L Heister. Augsburg, DR Mertz, JJ Mayer.
Fabricius ab Aquapendente (1619): *Operationes chirurgicae*. Venedig, Megliettus.
Garengeot JC de (1720): *Traité des Opérations de Chirurgie*. Paris, G Cavelier jun.
Garengeot JC de (1725): *Nouveau Traité des Instrumens de Chirurgie les plus utiles*. Vol. 2. La Haye, H Scheurleer.
Garengeot JC de (1731): *Traité des Operations de Chirurgie*. 2nd edition. Paris, Huart.
Gersdorff H von (1517): *Feldbuch der wundartzney*. Straßburg. Reprint (1976): Lindau, Antiqua.
Haller A (1775): *Bibliotheca Chirurgica*. vol. 2. Bern, Basel, E Haller, J Schweighauser. Reprint (1971): Hildesheim, New York, G Olms.
Heister L (1719): *Chirurgie*. Nürnberg, J Hoffmann's heirs.
Heister L (1739): *Institutiones Chirurgicae*. Amsterdam, Jansson-Waesberg.
Heister L (1743a): *Chirurgie*. 4th edition. Nürnberg, J Stein's widow.
Heister L (1743b): *A general system of surgery*. London, W Innys.
Heister L (1747–1750): *Instituciones chirurgicas*. 4 volumes. Madrid, C Rey, MF Rodriguez.
Heister L (1747): *Kleine Chirurgie*. Nürnberg, JA Stein und GN Raspe.
Heister L (1748): *A general system of surgery*. 3rd edition. London, W Innys.
Heister L (1752): *Chirurgie*. Nürnberg, JA Stein, GN Raspe.
Heister L (1753): *Medizinische, Chirurgische und Anatomische Wahrnehmungen*. vol. 1. Rostock, JC Koppe.
Heister L (1756): *Instituzioni chirurgiche*. Venice, F Pitteri.
Heister L (1770): *Medizinische, Chirurgische und Anatomische Wahrnehmungen*. vol. 2. Edited by WF Cappel, Rostock, JC Koppe.
LaCharrière J de (1700): *Tractatus Operationum Chirurgicarum oder Abhandlung chirurgischer Hand-Griffen*. Frankfurt, GH Oehrling.
Nuck A (1709): *Chirurgische Handgriffe und Experimenta*. Lübeck, Wißmar, JC Schmidt.
Paré A (1631): *An Explanation of the fashion and use of three and fifty instruments of Chirurgery*. London, M Sparke.
Purmann MG (1692): *Grosser und gantz neugewundener Lorbeer-Krantz, oder Wund-Artzney*. 2nd edition. Frankfurt, Leipzig, Rohrlach.
Quesnay F (1743): Remarques sur les playes due cerbeau. *Mém Acad Roy Chirurg 1*: 293–301.
Schultze W (1695): *Verletzter Kopff*. Leipzig, JL Gleditsch, MG Weidmann's heirs.
Scultetus J (1666): *Wund-Artzneyisches Zeug-Hauß*. 2 parts. Frankfurt, J Gerlin's widow. Reprint (1714): Stuttgart, W Kohlhammer (Forschungen zur Geschichte der Stadt Ulm 14).
Verduc JB (1703): *Traité des operations de chirurgie*. 3rd edition. Paris, L d'Houry.

Chapter 21

The Evolution of Cranial Saws and Related Instruments

JOHN KIRKUP
Royal College of Surgeons of England

Abstract

Most organic and metal instruments employed for trepanation have, if examined carefully, serrated profiles although few are applied in true saw-like action with to and fro movement radiating dangerously from the shoulder joint. Thus on ergonomic grounds it is argued linear flint gravers, used to trepan rectilinear apertures, were inherently unsafe and abandoned in favour of more closely controlled techniques with scrapers and drills. Twentieth-century ethnographic studies support the successful practices of these latter techniques, which included the employment of metal scrapers and guarded drills. The introduction of metal promoted production of the modiolus or cylindrical saw and, later, manufacture of small linear saws. Cylindrical saws, also known as crown saws, are believed to be specific to the art of trepanation and, when controlled by trepan brace and trephine handles, dominated surgical access to the skull from the sixteenth to twentieth centuries. In the twentieth century, the Gigli flexible saw reversed the ergonomic forces previously applied during skull penetration to direct menacing saw teeth away from the dura, enabling large replaceable flaps to be formed rapidly with minimal bone loss. Today, mechanised craniotomes also provide safe access. Tomorrow, new ventures will question whether large cranial apertures have a future.

Keywords: Trepanation, Organic instruments, Metal saws, Ergonomics, Ethnography

The general definition of a "saw" as a flat blade with a serrated edge of evenly distributed teeth, visible to the naked eye, requires interpretation when analysing the trepanning instruments of craniotomy. Detailed examination demonstrated that most if not all artefacts, believed to have been utilised for penetrating the skull vault, have serrated if irregular cutting edges, plainly evident in the case of flint, obsidian, basalt, shark's teeth and marine shells. In fact, even the keenest scalpel blade is serrated when magnified under the microscope, as studies by both Bourgery (1837) and Tubby (1928) showed; the latter concluded, "every knife-edge is a saw in miniature" (Tubby, 1928, p. 737, Fig. 7B). Scalpels however are not applied in saw-like action, with alternating to and fro movements, characteristic of amputation saws, or with alternating rotational movements, characteristic of cylindrical crown saws.

Despite often rough and ready appearances, at least three categories of saw-edged organic implements have been identified as probable ancient trepanation instruments: 1. scrapers, manipulated by alternate pulling and pushing movements to excavate circular, oval or linear apertures, the pulling element predominating; 2. gravers, manipulated by very short to and fro sawing actions to incise linear, square, rectangular or circular aper-

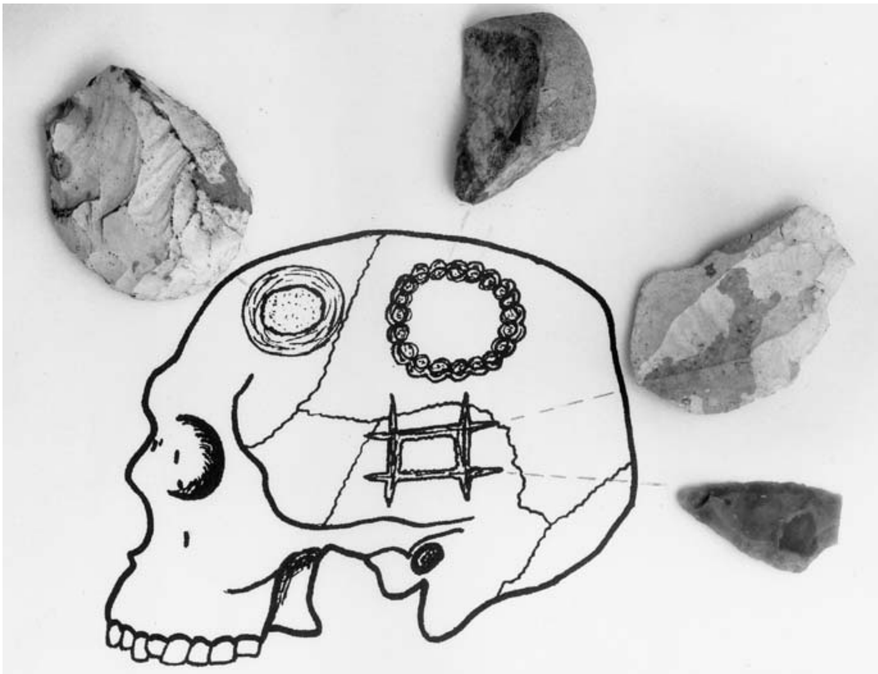


Figure 1. Montage to show known modes of skull access and flint instruments suitable for making the apertures. From ten o'clock, clockwise: finely worked scraper, three sided borer, two flat arrow headed gravers. (From Windmill Hill, ca 1,500 BC.)

tures, or possibly by continuous circular motion, termed by some grooving; and 3. gimlets, perforators or drills, manipulated by alternate rotational movements, clock and anti-clockwise, to mark out a circular defect of multiple perforations, then linked by gravers (Fig. 1).

Closer examination of the application, or ergonomics, of these implements and their metallic successors merits consideration if we are to understand former techniques, and contributes to the debate seeking to explain the types and distribution of holes in ancient skulls.

Ergonomic Considerations

The following manual actions are associated with the instruments of cranial trepanation: scraping, graving or incising and related grooving, drilling or perforation, chiselling and true sawing. More modern techniques involve mechanical oscillation and reciprocation sawing equipment, not considered for analysis here.

1. Scraping produces rounded apertures, the outer skull table diameter being larger than the inner, using mineral, shell or metal scrapers. This technique depends on gentle wrist flexion and extension combined with forearm rotation during which the shoul-

der and elbow are held close to the trunk, virtually immobile. The radius of movement is small and well controlled, visualisation of the developing aperture is good and, if slow, the technique is safe.

2. Graving or incising produces a linear track, V-shaped in section, thus wider in the outer table than inner, dependant on the thickness and shape of the artefact; in order to fashion a square or rectangular aperture four separate tracks must be fashioned. The technique involves firm fixation of the instrument by opposing fingers and thumb, immobility of wrist and forearm, with to and fro sawing movements, power being exerted at elbow and shoulder level. At the same time, downward pressure is essential to excavate the track whose deepest point becomes more difficult to visualise as graving continues. Even if the elbow is kept supported by the trunk, the radius of movement, centred on the shoulder joint, is very large and control is less secure than that of scraping. Grooving is associated with gravers applied in a circular fashion to produce a roundel of bone although the actual technique is uncertain. Lisowski suggested: "…a series of curved grooves are drawn and redrawn on the skull with a sharp instrument, until the bone between the grooves becomes loose…" (Lisowski, 1967, p. 663), as the probable procedure for obtaining roundels. Others have indicated that the graver was applied in a continuous circling movement, either clock or anti-clockwise. Bearing in mind differences in thickness of each skull, this approach is both technically difficult and hazardous, and a series of short curved grooves linked to form a circle would be easier and diminish dangers of precipitate entry at a thin area. This technique entails to and fro motion within consecutive small sectors of a circle, presumably mapped out initially. However, as in the case of graving in a straight line, the radius of motion is large being centred at the shoulder, the depth of the groove is visually obscure, and safe control remains suspect.
3. Drilling or boring with organic materials produces a small cone-shaped hole at right angles to the outer table; metal drills fashion a more cylindrical track. A single perforation might be developed subsequently by graving, sawing and chiselling but, in general, it is believed a series of drill holes, in close proximity, outlined a circle or other form, which was then completed by graving. Drilling with organic materials was performed in two ways, firstly by twisting a pointed artefact held by fingers and thumb in alternate directions, or secondly by mounting the artefact on a cylindrical stick that was rotated between the palms of the hands or by bow string, again in alternate directions. Concurrently, downward pressure was needed to ensure penetration of the bone; yet, if excessive, sudden perforation into the dura was possible, although the cone shape of organic drills would diminish this risk. This first method relied on a firm grip by opposing digits, gentle rotation of the forearm with the elbow and shoulder held against the trunk, whilst downward pressure was exerted by slight extension of the flexed elbow to bring the weight of the arm and upper trunk to bear down the track. The second method required firm pressure between the palms and fully extended digits, immobility of wrists and forearms, with minor excursions of alternate flexion and extension of the elbow joints held against the trunk at about a right angle. Although the radius of movement hinges on the upper forearms and elbow joints, the excursions of movement are small and well controlled. However, in this attitude, it is virtually impossible to exert downward pressure unless the proxi-

mal handle is held against the forehead, chin or chest, or possibly and assistant pushes down on the rotating handle. Metal drills are applied similarly, although in recent centuries these have been motivated by Archimedean screw and trepan or trephine handles which are more efficient and, with care, provide better control.

4. Chiselling implies the use of metal but, as Ralph Jackson has reminded us at this Colloquium, chisels were only employed after a circle of drill holes had been made or after open skull fracture. In the second century AD, Galen referred to a guarded chisel known as a lenticular for this purpose; it had a vertical cutting edge protected by a flat lens shape termination which could safely glide over the dura with the instrument held against the inner table in a vertical position; its thickened edge was tapped with a small hammer tangential to the skull (Galen quoted by Adams, 1846, p. 432). In the early-twentieth century, Doyen (1917, pp. 316–317) introduced a probe-guarded skull chisel to be applied horizontal or tangential to the outer table. Nevertheless, chisels rely on hammer blows focussed on large radius shoulder movement and are inherently dangerous if the blows are to be effective.
5. Sawing by means of metal blades, with serrations obvious to the unaided eye, is either linear or circular. Linear sawing requires to and fro motion with all movements taking place at the elbow and shoulder, combined with downward pressure derived from the weight of the arm and trunk; in general, maximal cutting results from forward movement of the saw, although much depends on the exact setting of the teeth. Circular sawing by metallic instruments to excise roundels of bone, generally called skull trepanation, was undertaken by Hippocrates in the fourth century BC, with “a serrated trepan” which is understood to be a cylindrical saw mounted on a fixed handle, since called a modiolus (Fig. 2). However he also speaks of: “…perforating the bone with a small trepan…” (Adams, 1849, p. 463), which suggests a drill and, indeed, the Greek origin of trepan or trypanon means a borer. The modiolus was manipulated similarly to a drill, either between the palms or with a bow string, and had the same draw backs in requiring downward pressure additional to rotation. Celsus remarked:

> The modiolus is a hollow cylindrical iron instrument with its lower edges serrated; in the middle of which is fixed a pin… so that, the pin being fixed, the modiolus when rotated cannot slip; it is then rotated… by means of a strap. The pressure must be such that it both bores and rotates: for if pressed lightly it makes little advance, if heavily it does not rotate. (Spencer, 1935, VIII, 3)

Control of detachable cylindrical or crown saws with the artisan’s brace (Fig. 3), from the sixteenth century onwards, provided increased power and speed of penetration either by continuous rotation in one direction or more cautiously by alternate rotations in both directions, motivated by elbow and shoulder movements alone; its wide diameter handle was tolerated by the forehead, chin or chest to exert necessary downward pressure. Dangerous penetration was reduced by making the saw cylinder cone shaped to impact in the skull gradually; cylindrical guards were also added to limit penetration (Fig. 3). In the seventeenth century, the T-shaped trephine handle for crown saws (Fig. 2) became popular in Britain and parts of the United States, until the end of the nineteenth century.

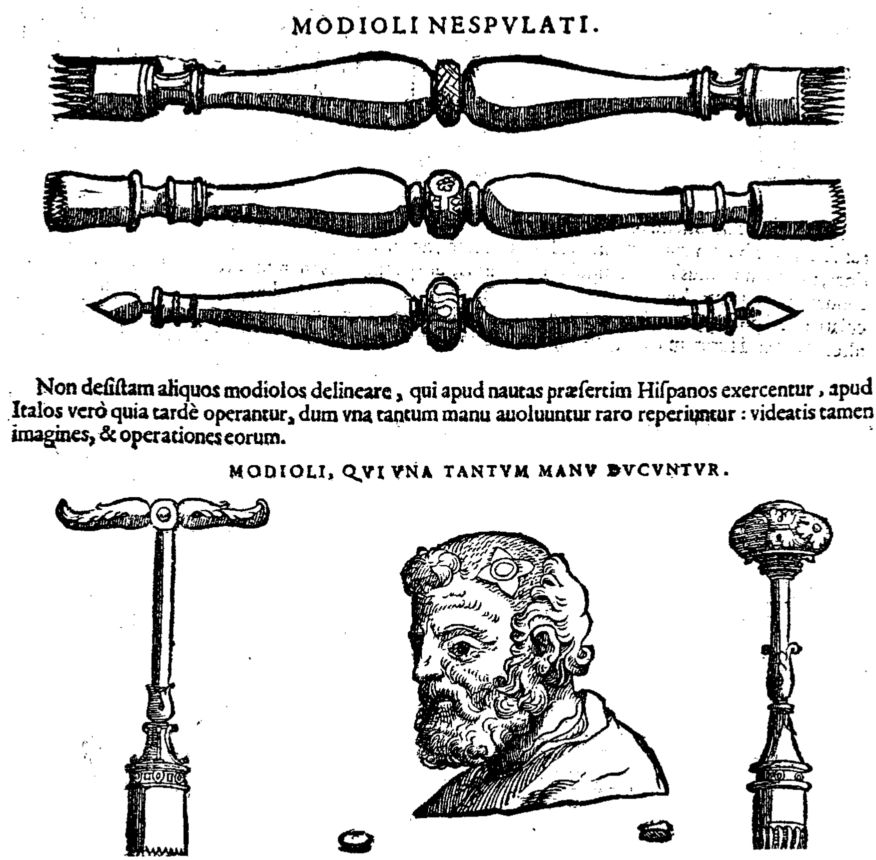


Figure 2. Modioli and early trephine handles for cylindrical saws (Croce, 1563).

Trephines operate by alternate pronation and supination of the forearm alone, combining downward pressure through fixed motionless wrist, elbow and shoulder joints. Circular trephine sawing was inherently safer than brace sawing, with its larger radius of movement centred on the shoulder, but trephining was also much harder work for surgeons, and especially exhausting for forearm muscles.

Ethnographic Records

Archaeological evidence of prehistoric tools suitable for trepanation is largely based on deductions of exclusion and probability. Many mineral artefacts, especially long spear and arrow heads, appear inappropriate, leaving a range of small artefacts suitable for creating ancient skull apertures. However, is more recently recorded evidence available to confirm these probabilities? With this in mind, a few selected observations made in the twentieth century are examined.

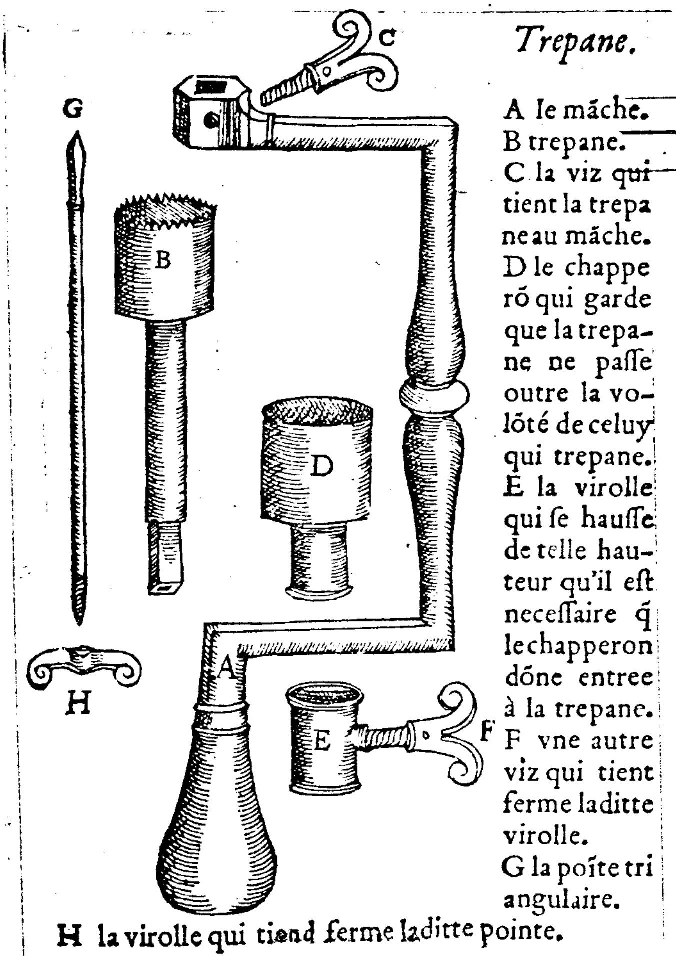


Figure 3. Cylindrical saw (B) and brace handle (A) with removable centre pin (G), depth guard (D) controlled by (E). (Paré, 1545.)

1. Aures Mountains, Algeria: Between 1913 and 1922, Hilton-Simpson (1922) gained the confidence of local Berber Shawiya practitioners in this remote and rugged region, recording their surgical activities and collecting a contemporary steel-based surgical armamentarium, still accessible for study.[1] Trepanning the skull was a common procedure after head injury, usually performed within seven days, normally taking an hour and a half but sometimes pursued in daily stages. Usually, a circle of scalp was excised by application of a cylindrical hot iron cautery, followed by craniotomy adjacent to fractures, if such were present, by drilling and sawing; scraping alone with fan-shaped raspatories was rare. A wide variety of drills and short flat saws were available, including drills with carved wooden sleeves, which were steadied by forehead pressure leaving both hands free to rotate the drill whose points were guarded

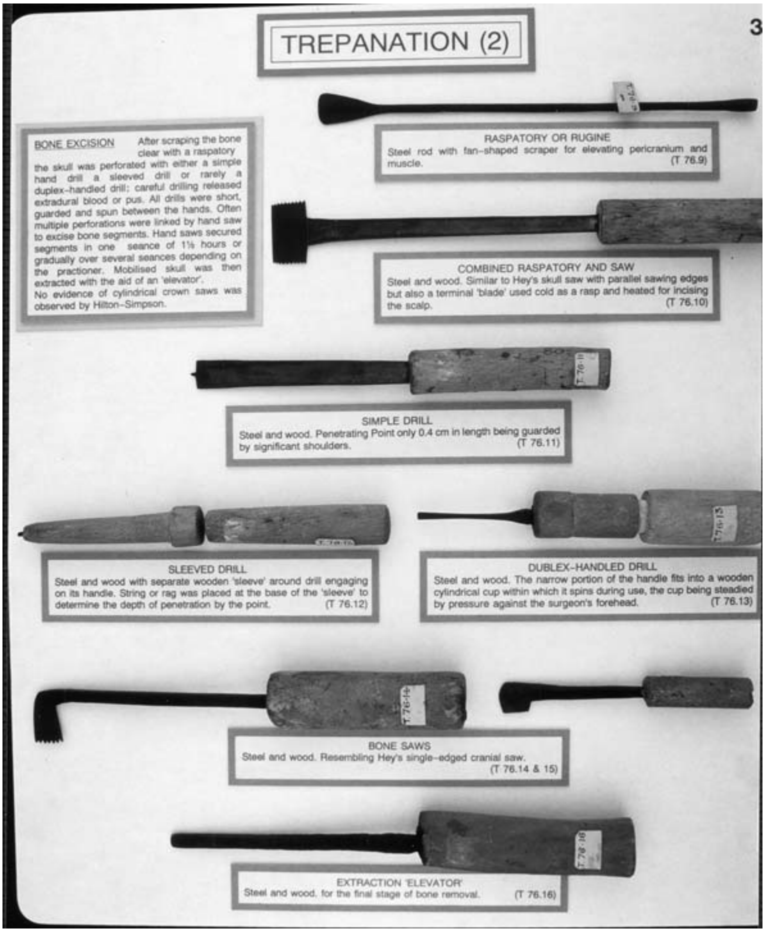


Figure 4. Exhibition board to illustrate saws and drills used by Berber surgeons of the Aures Mountains, ca 1922 (the text is not expected to be fully legible). From top to bottom: raspatory or rugine, combined raspatory and saw, simple guarded drill, sleeved guarded drill, duplex-handled drill controlled by forehead pressure whilst distal drill rotated, bone saws, extraction elevator. (With permission, Royal College of Surgeons of England.)

against deep penetration (Fig. 4). The saws were L- or T-shaped with very short serrated edges of six to nine teeth; one cylindrical saw with a prominent fixed centre pin was seen, but Hilton-Simpson understood this was an attempted but dangerous copy of a crown saw which had never been used. Normally a series of drill holes was made and linked by saw cuts but sometimes a single drill hole was used as starting point for a saw to complete the aperture; exceptionally, one surgeon took 15 to 20 days to complete removal of a piece about the size of a penny. Hilton-Simpson did not debate the origins of these singular forms of trepanation which, however, may be very ancient; in the writer's view, the Berber armamentarium closely reflects certain elements of instrumentation illustrated by Albucasis in the tenth century AD.

2. New Ireland and New Britain, Western Pacific: In New Ireland, trepanation has been reported for insanity, epilepsy, headache as well as fracture, using obsidian, shell or shark's teeth as scrapers (Margetts, 1967). In New Britain, Brodsky (1938) located actual instruments associated with trepanation during the late-nineteenth and early-twentieth centuries, but only performed for compound skull fracture due to sling stone injuries. After scraping soft tissues clear with a piece of igneous rock, loose bone fragments were removed with bamboo forceps or coconut shell; unfortunately no evidence of sawing or trepanation was observed.
3. Ogaden, Horn of Africa: The Somalis of this region, observed by Brotmacher (1955), trepanned immediately after fracture, including the inner table, with the objective of relieving intracranial haemorrhage. It is stated bone was removed by scraping but, unfortunately, no actual instrument is named.
4. Zagros Mountains, Iran: Roney (1954) reported the Bakhitiari of this region trepanned for concussion due to injury but only after the patient regained consciousness to enable them to sit up for surgery! After excision scalp with knife and scissors, bone was scraped "…with a knife that looks like a razor. But the full thickness of the bone is never scraped clear through." (Roney, 1954, p. 490). Ointment was then applied until the remaining bone extruded; by this technique, acute cerebral decompression was not possible. However if the skull were fractured, fragments were removed without trepanation.
5. Eastern Lake Victoria, Kenya: The Kisii are celebrated for extensive and often multiple trepanations for persistent headache after injury, undertaken by traditional methods (Meschig, 1983), and performed until very recently, as several contributors to this colloquium have noted. With the patient lying or sitting, bone was removed by scraping or a combination of scraping and sawing by means of steel blades, mostly curved, some with tips like raspatories, some knife edged, and others clearly serrated (Fig. 5). Frequently large and irregular sections of skull were removed, yet with a high recovery rate.

These authenticated twentieth-century methods have nineteenth-century roots that doubtless go further back in time. Oblivious to and uninfluenced by scientific neurosurgical procedures, they can be related more closely to presumed prehistoric methods of trepanation. For both ancient and recent trepanations, lack of anaesthesia and aseptic conditions were not significant barriers provided integrity of the dural membrane was respected, doubtless a lesson discovered only slowly. Significant variation in indications, procedures, and instruments in the twentieth century, even within one community, is seemingly also characteristic of ancient trepanation. However, the twentieth-century techniques studied did not include graving alone or linear sawing alone, by to and fro movement, whereas these formed part of ancient techniques to produce square or rectangular apertures. During the formation of such apertures, the dura is threatened four times by linear incisions which are unnecessarily long, due to required bony overlap to effect a removable square or rectangle.

As suggested earlier, these methods were hazardous on ergonomic grounds and, from evidence communicated at this colloquium, survivors subjected to them are uncommon in the archaeological record. Rytel (1962) who believed in an evolutionary methodolo-

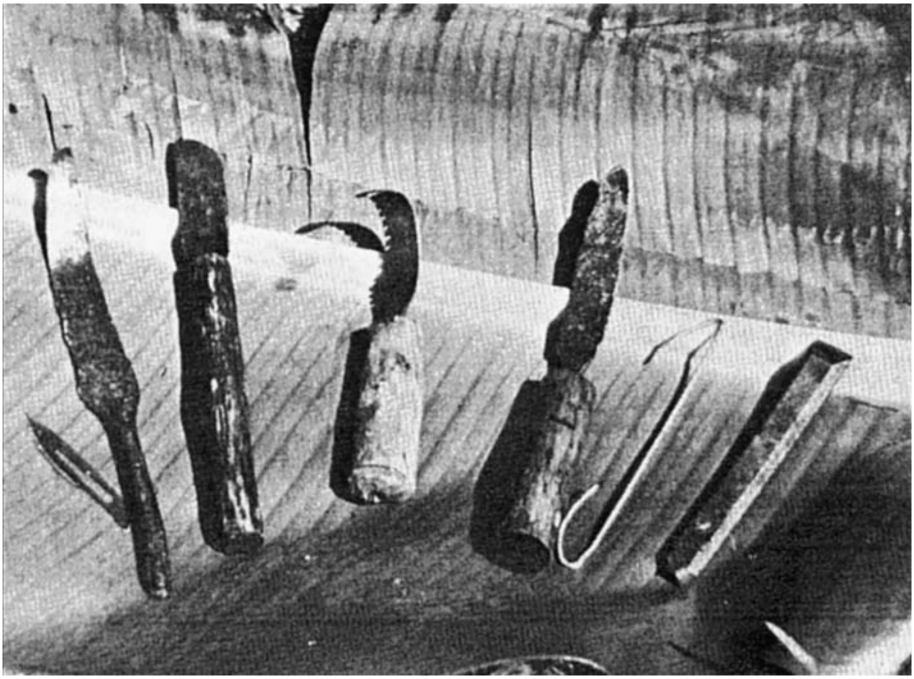


Figure 5. Armamentarium of trepan practioner of the Kisii tribe, Kenya, ca 1980. Curved serrated blades are shown as well as modern scalpel blade and engineer's chisel. (With permission, Trilitsch Verlag.)

gy of trepanation, hypothesized the earliest procedure was by rectilinear incisions to produce rectangular openings, followed by circular graving or grooving, then scraping methods and, finally, boring or drilling combined with graving or sawing. From ancient skull evidence and recent traditional procedures, it is suggested scraping and combined drilling-graving trepanations predominated (at least for the living skull) until the circular saw or modiolus was applied, as mentioned by Hippocrates. Linear metal saws may have been employed in some instances before this, but evidence is tenuous. Russu and Bolga (1961) discovered a saw in a Celtic burial, around the second century BC, in Romania with a terminal half moon shaped blade, thinner towards the serrated cutting edge whose wedge shape would not penetrate deeper than 5 to 7 mm and therefore was safe for trepanation. Another saw of wedged profile, about the same age from Hungary, was believed by Holländer (1915) also suitable for trepanation.

Metallic Cranial Saws

Cranial saws recorded in historic times are classified as flat, cylindrical, circular or flexible. Cylindrical saws are further subdivided into the ancient modiolus and more recent crown saws controlled by trepan brace or trephine handle.

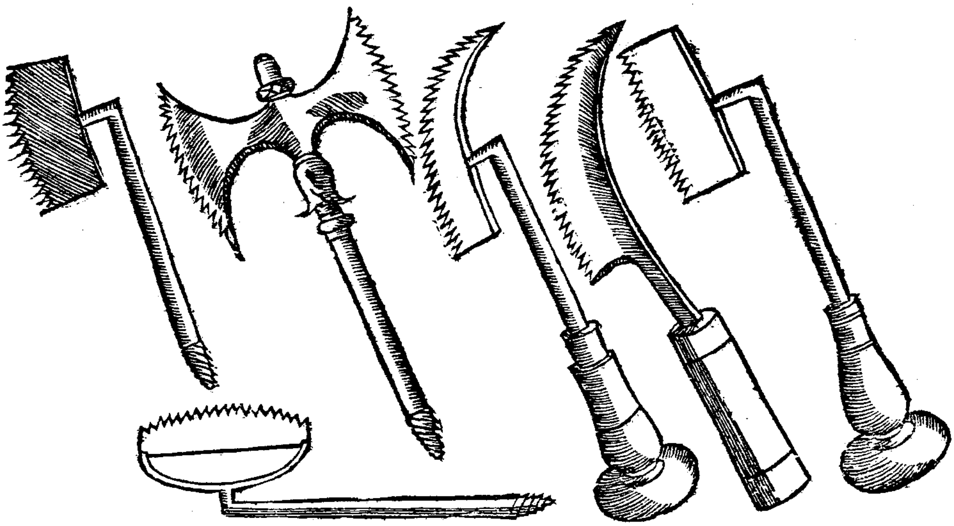


Figure 6. Flat hand saws for cranial surgery. To the left, three saws for common handle (not shown) (Croce, 1573.)

1. Flat or Head Saws: Celsus recommended removal of fracture fragments by sawing, in the first century AD, without specifying the type of saw (Adams, 1849), and Albucasis in the tenth century AD referred to the use of scrapers for craniotomy, yet figured instruments with obvious serrated margins (Spink and Lewis, 1973). However, no convincing flat head saws are noted before Carpi in 1518 (Lind, 1990a), followed by Paré and especially Croce (1573), who illustrated six different forms for excising fractured bone (Fig. 6). Compared to conventional surgical saws, the blades are shorter and the serrations fewer, to avoid damaging adjacent soft tissues unnecessarily.

   According to Thompson (1939), head saws fell into disuse in the seventeenth century, being revived by Cockel and Hey at the end of the eighteenth century. Of head saws with a convex blade, Hey wrote:

   > Such a saw I can now, with confidence recommend, after a trial of thirty years; during which time I have rarely used the trephine in fractures of the skull… It was first shown to me by the late Dr. Cockel, an ingenious practitioner of Pontefract… (Hey, 1814, p. 9)

   Thereafter, in Anglo-Saxon parlance, these saws were termed Hey's! Despite Hey's comment, head saws were not generally advocated for trepanation of intact skulls, which suggests their safety margins were suspect. Safety certainly motivated Doyen (1917), who devised a version with a moveable guard limited to cutting the outer table during elective craniotomy, but its popularity was brief.
2. Cylindrical Saws: In contrast to many surgical instruments, usually derived from other sources, it is possible cylindrical saws were invented specifically for trepanation, for

no evidence of earlier precursors have been found. Moreover, they are not a common form employed domestically or by craftsmen. Cylindrical saw are subdivided by ergonomic factors into three basic types: the bi-palmar rotated modiolus, the bimanual rotated trepan brace, and the unimanual rotated trephine.

a. The Modiolus: Hippocrates' serrated trepan, believed to be a form of modiolus, was manipulated by alternate rotations either between the palms or by bow string. No surviving modiolus has been traced for examination and we can only turn to the detailed woodcuts of Croce (Fig. 2). Even if the precise profile of the serrations is unclear, it is likely the teeth were simple and symmetrical, permitting bone cutting in both directions of rotation. Sawing was initiated with one extremity projecting a centre pin and, when a circular track was established, continued more safely by the other without a pin. As it was impossible to steady a two-ended modiolus by forehead or chin support, downward pressure was difficult, unless a single-ended modiolus was substituted; even so, these instruments appear to offer both poor control and uncertain penetration. They were not used by Paré and disappeared from texts in the sixteenth century.
b. The Trepan: Rare, short cylindrical saws made of bronze and worked by bow string, from Roman finds at Bingen, are illustrated by Kunzl (1983) without, it is believed, original wooden handles to provide downward pressure. This short form of cylindrical saw is not known again until the Renaissance when *De Fractura Craneii* of Carpi (1518) figured the two handed brace trepan; admittedly the saw is tiny, and indeed was described by Carpi as a drill bit with a pipe (Lind, 1990b). However Paré, Croce and others soon developed the theme, providing interchangeable starting bits, a range of cylindrical or crown saws with a choice of diameters and also removable centre-pins (Fig. 3). It is believed the brace of trepanation was borrowed from carpentry and must have a longer history. Crown saws were initially truly cylindrical but later became cone shaped to impede their progress through the inner table, on grounds of safety, although some cylindrical saws had adjustable cylindrical guards for the same purpose (Fig. 3). Many braces were made with a removable wooden handle to promote easier packaging and carriage, but when surgery became aseptic and hospital based at the end of the nineteenth century, all metal braces were introduced with permanently fixed handles.
c. The Trephine: Woodall (1639) claimed he had devised the trephine to control crown unimanually and stated the term derived from *tribus finibus* or *tres finis* meaning three points or the three ends of its T-shaped handle and crown saw. However, Croce (1573) illustrated such an instrument, both with T-shaped and globular handles, terming them handled modioli (Fig. 2); he did not use the term trephine. A similar instrument was illustrated by Fabricius Abaquapendente (1620) and by Crooke (1631) when he published illustrations of instruments taken from Paré, including the trepan, adding an illustration of a trephine with a crown saw stating: "there is another sort of Trepan or Trefine, now generally in use amongst our London Chirurgians, called the hand Trepan…" (Crooke, 1631, p. 25) (Fig. 7). Thus Woodall's claim of priority is suspect although he may have introduced the taper or cone-shaped crown saw. Nevertheless, from this period the hand trephine gradually displaced the brace trepan in Britain, the old British

Figure 7. Cylindrical saws and trephine handles. From left to right: Woodall trephine with cone shaped cylinder and centre pin removed (early-seventeenth century), cylindrical saw with movable centre pin (eighteenth century), trephine and stepped cylindrical saw (eighteenth century), cone-shaped cylinder with centre pin which is removed from within cylinder (seventeenth century). (With permission, Royal College of Surgeons of England.)

Commonwealth, and parts of America, until the all-metal brace took its place at the end of the nineteenth century. Meanwhile in Continental Europe, the hand trephine made little or no impact.

Crown saws for both trepan and trephine tended to be cone shaped throughout the seventeenth and eighteenth centuries, even if Sharp (1743) argued strongly for plain cylindrical saws, believing they progressed more smoothly with less resistance, to prove no more dangerous than conical saws. Often the cone or taper was minimal and, increasingly during the nineteenth century, plain cylindrical saws took their place. Variations in the type and arrangement of teeth were common but, in the later nineteenth century, simple end-cutting teeth predominated. An attempt was made by Evans about 1860 to marry trephine and brace, employing a handle with a universal joint and, although still advertised in 1893 (Evan and Wormull, 1893), it never achieved popularity.

3. Circular Saws: With the development of highly geared dental engines and the introduction of electric motors in the late nineteenth century, efforts were made to employ flat circular saws for craniotomy. These high speed saws proved more dangerous than simple head saws and Doyen (1917) devised a circular saw, with an integral protective disc limiting penetration to the outer table, but this was soon displaced by new techniques and instruments.

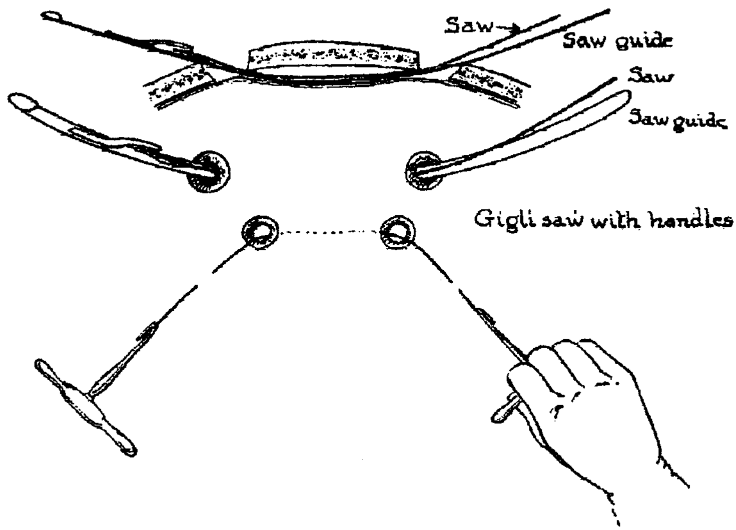


Figure 8. Technique of craniotomy between drill holes with Gigli flexible saw, using saw guides, protectors and T-shaped handles.

4. Flexible Saws: Flexible chain saws were use for symphisiotomy and joint excision throughout the nineteenth century, but were too bulky for cranial surgery (Kirkup, 1995). A much narrower flexible barbed wire saw was introduced by Gigli (1895) for osteotomy of the contracted pelvis in childbirth, and soon it was used for joint resection. It also found a niche for craniotomy by sawing between burr holes, its small diameter permitting insertion by saw carrier and safe application with a brain protector (Fig. 8). Gigli's saw, held by T-shaped handles bimanually, acts by to and fro motion mediated from the shoulder and elbow joints; uniquely downward pressure, associated with other saws, is diametrically opposed by pulling upwards away from the dura, a fundamentally efficient and safe procedure. The technique removes minimal quantities of bone to form large flaps with oblique sides, allowing secure replacement after surgery and proving a popular method of choice for major explorations.

Conclusion

On close examination, many organic instruments for trepanation are serrated but only gravers are manipulated by true sawing; that is, to and fro motion demanding significant shoulder movement. It has been proposed by Rytel (1961) that rectilinear incisions with graving instruments preceded other methods of trepanation but was abandoned in favour of safer methods, a concept supported on ergonomic grounds. Moreover, of the square or rectangular apertures observed, mainly in Peru, little if any evidence of healing has been recorded (Verano, personal communication); perhaps most were made post-mortem. Ortner and Putschar (1981) considered both linear sawing or combined drilling with sawing involved considerable risk, whilst scraping had the lowest risk. On the other hand, Lucas-Championnière (1912) believed scraping was rare whereas sawing was not only safe but frequently undertaken, believing the crenallated appearance of drilling (Fig. 1) rapidly remodelled in the living, to leave a smooth aperture similar to that of scraping. Pictorial evidence for this, even in his own publication, is not at all convincing, and he does not explain the ancient crenellated apertures that have been found. The circular graving technique remains uncertain, although Lisowski (1967) suggested short curved grooves by sawing motion were connected, to produce circular apertures with vertical sides and roundels of bone; this was not without risk and some examples must be post-mortem productions.

The introduction of true metal saws is uncertain but may have origin in the cylindrical modiolus, possibly a form of instrument devised specifically for surgery, and established at the time of, if not before, Hippocrates, much earlier than short flat or head saws. The modiolus was the pre-cursor of short cylindrical saws controlled with bow strings, brace and trephine handles, the brace form dominating trepanation sawing techniques from the early sixteenth to twentieth centuries. Linear flat or head saws may have origin in the tenth century Arabic practice, becoming common place by the sixteenth century for fracture excisions but not for trepanation of intact skull. Flat circular saws had a very brief place in craniotomy when electric power was first harnessed for trepanation, mainly limited to division of the outer table. Flexible Gigli saws revolutionised brain exposure because their small calibre and ergonomics of application enabled large bone flaps to be lifted rapidly, and subsequently replaced; importantly, and for the first time, the skull was sawn from within out, ensuring manual power and pressure was directed away from the dura, and not towards it as all previous instruments had dictated.

Skull opening is still undertaken in Kenya by slow scraping techniques with curved metal saws, but despite many successful trepanations, the practice lacks official approval and may soon cease. In any event, after 2,400 years of gradual evolution, the days of serrated metallic saws, from the Hippocratic modiolus to recent cylindrical and flat examples, may be numbered as developing technology devises competitors, such as mechanised, guarded, oscillating craniotomes. But for how long will these and flexible saws reign, and what will be next? Indeed, as cybersurgery evolves, will major skull openings be required at all?

Note

1. Hilton-Simpson gave some 100 instruments and pieces of equipment to the Pitt Rivers Museum, Oxford and 36 instruments to the Hunterian Museum, Royal College of Surgeons, London. Many of the former and all of the latter are on display (Fig. 4). Both collections provide an informative background to aspects of surgery discussed in his book (Hilton-Simpson, 1922).

References

Adam F (1846): *The Seven Books of Paulus Aegineta*. vol. II. London, Sydenham Society, p. 432

Adam F (1849): *The Genuine Works of Hippocrates*. London, Sydenham Society.

Berengario da Carpi J (1518): *Tractatus de Fractura Calve sive Cranei*. Bologna, Benedictis, Fig. XCVr.

Bourgery JM (1837): *Traité complet de l'anatomie de l'homme comprenant la médecine opératoire*. Paris, Delaunay.

Brodsky I (1938): The trephiners of Blanche Bay, New Britain, their instruments and methods. *Brit J Surg 26:* 1–9.

Brotmacher (1955): Medical practice among the Somalis, *Bull Hist Med 29:* 197–227.

Crooke H (1631): *An Explanation of the Fashion and Use of Three and Fifty Instruments of Chirurgery*. London, Sparke.

DallaCroce GAD (1573): *Chirurgiae Libri Septem*. Venice, Zilleti.

Doyen E (1917): *Surgical Therapeutics and Operative Technique*. London, Baillière.

Evans, Wormull (1893): *Illustrated Catalogue of Surgical Instruments, Apparatus and Appliances*. London.

Fabricius ab Aquapendente HF (1620): *Opera Chirurgica*. Frankfort, Hoffmann.

Gigli I (1894): Über ein neues Instrument zum Durchtrennen der Knochen, die Drahsäge. *Zentralb Chir 21:* 409–411.

Hey W (1814): *Practical Observations in Surgery*. London, Cadell.

Hilton-Simpson MW (1922): *Arab Medicine and Surgery, A Study of the Healing Arts in Algeria*. London, Oxford University Press.

Holländer E (1915): Die chirurgische Säge, *Arch Klin Chir 106:* 316. (Cited by Lisowski FP (1967), in Brothwell D, Sandison AT, eds., *Diseases in Antiquity*. Springfield, Thomas, p. 671.)

Kirkup JR (1995): The ancient lineage and recent evolution of surgical saws. *European Rheumatoid Arthritis Surgical Society Information Bulletin 10:* 4–10.

Kunzl E (1983): *Medizinische Instrumente aus Sepulkralfunden Römischen Kaiserzeit*. Koln, Rheinland Verlag.

Lind LR (1990): *Berengario da Carpi on Fracture of the Skull or Cranium*. Philadelphia, American Philosophical Society.

Lisowski FP (1967): Prehistoric and early historic trepanation. In: Brothwell D, Sandison AT, eds., *Diseases in Antiquity*. Springfield, Charles C Thomas, pp. 651–672.

Lucas-Championnière J (1912): *Les origines de la trépanation décompressive*. Paris, Steilheil.

Margetts EL (1967): Trepanation of the skull by medicine-men of primitive cultures, with particular reference to present day native East African practice. In: Brothwell D, Sandison AT, eds., *Diseases in Antiquity*. Springfield, Charles C Thomas, pp. 673–701.

Meschig R (1983): *Zurr Geschicht der Trepanation unter besonderer Berücksichtigung der Schädeloperationen bei den Kisii im Hochland Westkenias*. Dusseldorf, Triltsch Verlag.

Ortner DJ, Putschar WGJ (1981): *Identification of Pathological Conditions in Human Skeletal Remains*. Washington, Smithsonian Institution Press.

Roney JG (1954): The occurrence of trephining among the Baktiari. *Bull Hist Med 28:* 489–491.

Russu IG, Bologa V (1961): Trepanationem im Gebiet des heutigen Rumänien. *Suhoffs Arch Gesch Med 45:* 34 (Cited by Lisowski (1967) p. 672.)

Rytel MM (1962): Trephinations in ancient Peru. *Bull Pol Med Sci 5:* 42. (Cited by Lisowski (1967) p. 672.)

Sharp S (1743): *A Treatise on the Operations of Surgery*. London, Brotherton et al.

Spencer WG (1938): *Celsus: de Medicina*. London, Heinemann.

Spink MS, Lewis GL (1973): *Albucasis on Surgery and Instruments*. London, Wellcome Institute.

Thompson CJS (1939): The evolution and development of surgical instruments. *Brit J Surg 26:* 457–461.

Tubby AH (1928): Observations on the selection and standardisation of surgical instruments. *Lancet 2:* 735–738.

Woodall J (1639): *The Surgeons Mate or Military and Domestique Surgery*. London, Young for Bourne.

Part 5: Global Perspectives and Future Research

"*The oldest known surgical procedure is trepanning, the removal of a piece of bone from the skull. It was practiced from the late Palaeolithic period and in virtually every part of the world*"

C. G. Gross (this volume)

"*It is to be hoped that we will go away with new views or new projects to consider*"

D. Brothwell (this volume)

Chapter 22

Trepanation from the Palaeolithic to the Internet

CHARLES G. GROSS
Department of Psychology, Princeton University, Princeton, New Jersey, USA

Abstract

The oldest known surgical procedure is trepanning or trephining, the removal of a piece of bone from the skull. It was practiced from the late Palaeolithic period and in virtually every part of the world. It is still used in both Western and non-Western Medicine. We consider the methods and motives of trephining in different times and cultures.

Keywords: Trepanning, Trephining, History of neuroscience, Hippocrates

A Peruvian Skull

In 1865, in the ancient Inca city of Cuzco, Ephraim George Squier, explorer, archeologist, ethnologist and lately US *charge d'affaires* in Central America, received an unusual gift from his hostess, Señora Zentino, a woman known as the finest collector of art and antiquities in Peru (Squier, 1877). The gift was a skull from a vast nearby Inca burial ground. What was unusual about the skull was that a hole slightly larger than a half-inch square had been cut out of it. Squier's judgement was that the skull hole was not an injury but was the result of a deliberate surgical operation known as trepanning and furthermore, that the individual had survived the surgery (Squier, 1877).

When the skull was presented to a meeting of the New York Academy of Medicine, the audience refused to believe that anyone could have survived a trepanning operation carried out by a Peruvian Indian (NY Acad Med, 1865). Aside from the racism characteristic of the time, the skepticism was fueled by the fact that in the very best hospitals of the day, the survival rate from trepanning (and many other operations) rarely reached 10%, and thus the operation was viewed as one of the most perilous surgical procedures (Lisowski, 1967; Majno, 1975; Bakay, 1985). The main reason for the low survival rate was the deadly infections then rampant in hospitals. Another was that the operation was only attempted in very severe cases of head injury.

Squier then brought his Peruvian skull to Europe's leading authority on the human skull, Paul Broca, Professor of External Pathology and of Clinical Surgery at the University of Paris and founder of the first anthropological society. Today, of course, Broca is best known for his localization of speech in the third frontal convolution, "Broca's area", the first example of cerebral localization of a psychological function, but at this time his fame seems to have been primarily for his craniometric and anthropological studies (Schiller, 1992).

Broca and More Skulls

After examining the skull and consulting some of his surgical colleagues, Broca was certain that the hole in the skull was due to trepanation and the patient had survived for a while. But when, in 1876, Broca reported these conclusions to the Anthropological Society of Paris, the audience was also dubious that pre-Columbian Peruvians could have carried out this difficult surgery successfully (Schiller, 1992).

Seven years later a discovery was made in central France that confirmed Broca's interpretation of Squier's skull, or at least, demonstrated that "primitives", indeed Neolithic ones, could trepan successfully. A number of skulls in a Neolithic grave site were found with roundish holes two or three inches wide. The skulls had scalloped edges as if they had been scraped with a sharp stone. Even more remarkable, discs of skull of the same size as the holes were found in these sites. Some of the discs had small holes bored in them, perhaps for stringing as amulets. Although some of the discs had been chiselled out after death, in most cases, it was clear from the scar formation at the wound's edge that the interval between surgery and death must have been years. Trephined skulls were found of both genders and of all ages. Virtually none of the skull holes in this sample were accidental, pathological or traumatic. Furthermore very few of the skulls showed any sign of depressed fractures, a common indication for trepanning in modern times (Schiller, 1992; Sigerist, 1987).

These findings finally established that Neolithic man could carry out survival trepanation but left open the motivation for this operation. At first, Broca thought that the practice must have been some kind of religious ritual, but later he concluded that, at least in some cases, it must have had therapeutic significance (Schiller, 1992; Sigerist, 1987).

Broca actually wrote more papers on prehistoric trepanation and its possible motivation than he did on the cortical localization of language (Schiller, 1992). Since Broca's time, thousands of trepanned skulls have been found and almost as many papers written about them (Lisowski, 1967; Margetts, 1967). They have been discovered in widespread locations throughout every part of the world in sites dated from the late Palaeolithic to this century. The usual estimates for survival of different samples of trepanned skulls ranges from 50% to 90% with most estimates on the higher side (Lisowski, 1967; Margetts, 1967; Saul and Saul, 1997).

Methods of Trepanning

Across time and space five main methods of trepanation were used (Lisowski, 1967; Saul and Saul, 1997). The first was rectangular intersecting cuts as in Squier's skull (Fig. 1). These were first made with obsidian, flint, or other hard stone knives and later with metal ones. Peruvian burial sites often contain a curved metal knife called a tumi,

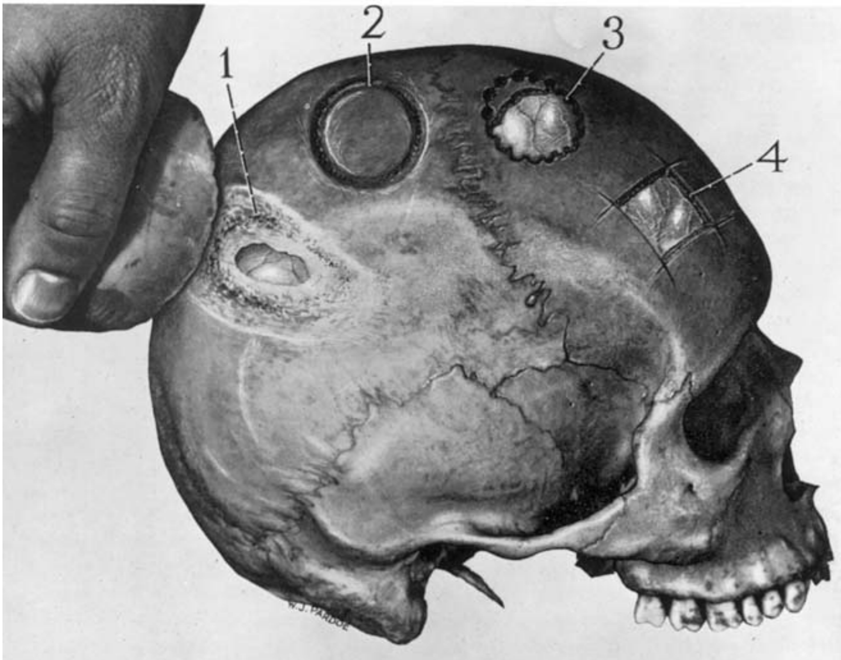


Figure 1. Different methods of trepanning. 1. scraping 2. grooving 3. boring and cutting. 4. rectangular intersecting cuts (Lisowski, 1967).

which would seem to be well suited for the job. (The tumi has been adopted by the Peruvian Academy of Surgery as their emblem). Besides Peru, skulls trepanned with this procedure have been found in France, Israel and Africa.

The second method was scraping with a flint as in skulls found in France and studied by Broca. Broca demonstrated that he could reproduce these openings by scraping with a piece of glass, although a very thick adult skull took him fifty minutes "counting the periods of rest due to fatigue of the hand" (Schiller, 1992, p.160). This was a particularly common method and persisted into the Renaissance in Italy.

The third method was cutting a circular groove and then lifting off the disc of bone. This is another common and widespread method and was still in use, at least until recently, in Kenya.

The fourth method, the use of a circular trephine or crown-saw, may have developed out of the third. The trephine is a hollow cylinder with toothed lower edge. Its use was described in detail by Hippocrates (Hippocrates, 1999). By the time of Celsus, a first-century Roman medical writer, it had a retractable central pin and a transverse handle and looked almost identical to the modern trephine and to many of the trephines used in western medicine in the intervening periods (Wilkins, 1997; Thompson, 1938) (see Fig. 2).

The fifth method was to drill a circle of closely spaced holes and then cut or chisel the bone between the holes. A bow may have been used for drilling or the drill simply

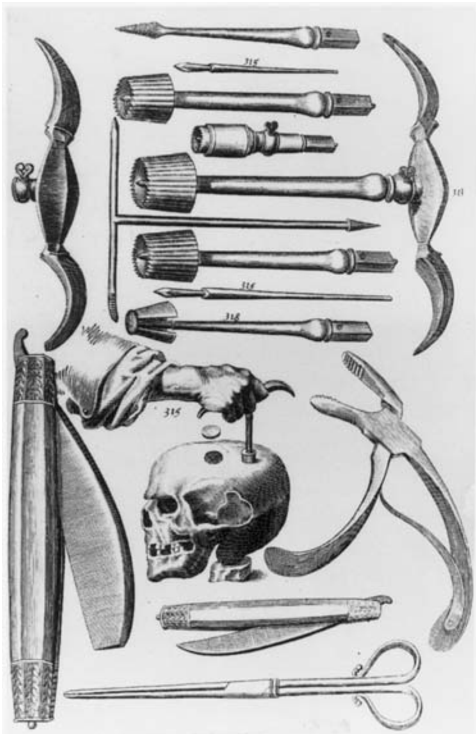


Figure 2. A seventeenth-century naval surgeon’s trepanation kit (Woodall, 1639). The trepans are very similar to both ancient Roman and modern ones (Wilkins, 1997).

rotated by hand. This method was recommended by Celsus, adopted by the Arabs and became a standard method in the Middle Ages. It is also reported to have been used in Peru and, until recently, in North Africa. It is essentially the same as the modern method for turning a large osteoplastic bone flap in which a Gigli saw (a sharp edged wire) is used to saw between a set of small trepanned or drilled holes.

Trepan v Trephine

The relationship between the terms “trepan” and “trephine” is a curious one. The terms are now almost synonyms but have different origins and once had different meanings. In Hippocrates’s time the terms *terebra* and *trepanon* (from the Greek *trupanon*, “a borer”) were used for the instrument that is very similar to the modern trephine. In the sixteenth century Fabricius ab Aquapendente invented a triangular instrument for boring holes in the skull (he was Harvey’s teacher and the discoverer of venous valves). It had three arms with different shaped points. Each of the ends could be applied to the skull using the other two as handles. He called it a “tres fines” from the Latin for three ends, which became *trafine* and then *trephine,* and by 1656 it was used as a synonym for *trepan*, as a term for the older instrument. In another version of the etymology, a quite different triangular instrument for boring a hole in the skull was invented in 1639 by John Woodall, a London surgeon, who also called his instrument a *tres fines*, which became *trefina* and then *trephine* and again, eventually a synonym for *trepan*. More generally, in Renaissance times and later, trepanation was a popular operation and a great variety of instruments for carrying it out were invented (Bakay, 1985; Wilkins, 1997; Thompson, 1938; Mettler and Mettler, 1945).

Why Trepan?

Why did so many cultures in different periods cut or drill holes in the skull? Since most trepanned skulls come from vanished non-literate cultures, the problem of reconstructing the motivations for trepanning of these cultures is a difficult one. However, there is information about trepanning in Western medicine from the fifth century BC onwards as well as about trepanning in recent and contemporary non-Western medical systems. Both of these sources may throw light on the reasons for the practice in earlier times. In the following sections we consider trepanation in Hippocratic medicine, in ancient Chinese medicine, in European medicine from the Renaissance onwards, in contemporary non-Western medicine and on the internet today.

Hippocratic Medicine

The earliest detailed account of trepanning is in the Hippocratic corpus, the first large body of Western scientific or medical writing that has survived. Although there is no question that there was a famous physician called Hippocrates in the fifth century BC, it is not clear which of the Hippocratic works were written by him. The most extensive discussion of head injuries and the use of trepanning in their treatment is in the Hippocratic work *On Wounds in the Head* (Hippocrates, 1999).

This treatise describes five types of head wounds. Interestingly, however, the only type for which trepanation is not advocated is in cases of depressed fracture. Even when there is not much sign of bruising, drilling a hole in the head is recommended. The trepanning instrument was very similar to the modern trephine, except that it was turned between the hands or by a bow and string rather than a crosspiece. The Hippocratic writer stressed the importance of proceeding slowly and carefully in order to avoid injuring the [dural] membrane. Additional advice was:

> When trephining it is necessary to remove the trephine frequently on account of the heat transmitted to the bone and dip it in cold water...and guard against careless application of the trephine, and always fix the trephine firmly at the site where the bone seems thickest, inspecting it frequently, and try, by rocking it back and forth, to lift the bone out. (Hippocrates, 1999, p. 91)

Trepanning over a suture was to be studiously avoided.

Apparently the Hippocratic doctors expected bleeding from a head wound and the reason for drilling the hole in the skull was to allow the blood to escape: “If the bone has suffered any of these injuries [crush-injury or fracture], let blood escape by perforating the bone with a small trephine, taking care to check at short intervals, for the skull of young people is thinner and has less depth than that of older persons” (Hippocrates, 1999, p. 87). Since they presumably had no notion of intracerebral pressure, why did they want the blood to run out? Although the reasons for trepanning are not discussed in *On Wounds in the Head*, they seem clear from other Hippocratic treaties such as *On Wounds* and *On Diseases*. The Hippocratic doctors believed that stagnant blood (like stagnant water) was bad. It could decay and turn into pus. Thus, the reason for trepanning, or at least one reason, was to allow the blood to flow out before it spoiled. In cases of depressed fractures, there was no need to operate since there were already passages in the fractured skull for the blood to escape (Majno, 1975).

Trepanation in Ancient China

The possibility that trepanation was practiced in ancient China is suggested by the following story about Cao Cao and Hua Tuo from *Three Kingdoms*, a historical novel attributed to Luo Guanzhong (Guanzhong, 1991), written in the Ming dynasty (1368–1644) and set in 168–280 at the end of the Later Han dynasty. Cao Cao was commander of the Han forces and posthumously Emperor of the Wei dynasty and Hua Tuo was a famous physician of the time whose works but not fame have disappeared (Lu and Needham, 1980).

> ...Cao Cao screamed and awoke, his head throbbing unbearably. Physicians were sought, but none could bring relief. The court officials were depressed. Hua Xin submitted a proposal: “Your highness knows of the marvelous physician Hua Tuo? ...Your highness should call for him”...
>
> Hua Tuo was speedily summoned and ordered to examine the ailing king. “Your Highness’s severe headaches are due to a humor that is active. The root cause is in the skull, where trapped air and fluids are building up. Medicine won’t do any good. The method I would advise is this: after general anesthesis I will open your skull with a cleaver and remove the excess matter, only then can the root cause be removed.” “Are you trying kill me?” Cao Cao protested angrily ...[and]... ordered Hua Tuo imprisoned and interrogated....
>
> Ten days later Hua Tuo died...his medical text was lost upon his death... (Guanzhong, 1991, p. 591)

Western Medicine

From the Renaissance until the beginning of the nineteenth century trepanning was widely advocated and practiced for the treatment of head wounds (Lisowski, 1967; Bakay, 1985; Mettler and Mettler, 1945; Goodrich, 1997; Dagi, 1997; Wehrli, 1939). The most common use was in the treatment of depressed fractures and penetrating head wounds. However, because of the high incidence of mortality, particularly when the dura was penetrated, there was considerable debate in the medical literature throughout this long span about when and if to trephine (Dagi, 1997). Besides trepanning in cases of skull fracture, the Hippocratic practice of “prophylactic trepanation” in the absence of fracture after head injury continued to persist. For example, in the 1800s, Cornish miners “insisted on having their skulls bored” after head injuries, even when there was no sign of fracture (Rosen, 1939, p. 197).

Until the early nineteenth century trepanation was done in the home (Fig. 3). However, when the operation was moved to hospitals, the mortality was so high that trepanation for any reason, including treatment of fractures and other head injury, declined precipitously (Bakay, 1985). The practice was so dangerous that the first requirement for the operation was said to be “that the wound surgeon himself must have fallen on his head” (Majno, 1975, p. 28) or, as Sir Astley Cooper put it in 1839, “if you were to trephine you ought to be trephined in turn.”(Dagi, 1997, p. 302). It was against this background that the discovery of Neolithic trepanning was so unbelievable to the American and French medical communities in the middle of the nineteenth century. Eventually, the introduction of modern antisepsis and prophylaxis of infection at the end of the nineteenth century as well as an increased understanding of the importance of intracerebral pressure in head injury, allowed trepanation to return as a common procedure in the management of head trauma (Dagi, 1997).

In modern neurosurgical practice, trepanning is still an important procedure but it is no longer viewed as therapeutic in itself. It may be used for exploratory diagnosis, for relieving intracerebral pressure (as from a epidural or subdural hematoma), for debridement of a penetrating wound, and to gain access to the dura and thence the brain itself (for example, to provide a port, through which a stereotactic probe can be introduced into the brain).

Epilepsy and Mental Disease

In the European medical tradition, in addition to its use in treating head injury, trepanning has been an important therapy for two other conditions, epilepsy and mental illness. The tradition of trepanning as a treatment for epilepsy began as early as Aretaeus the Cappadocian (ca 150), one of the most famous Greek clinicians (Aretaeus, 1856) and lasted into the eighteenth century (Temkin, 1971). The thirteenth-century surgical text *Quattuor magistri* recommended opening the skulls of epileptics “that the humors and air may go out and evaporate” (Temkin, 1971, p. 235) However, by the seventeenth century trepanation for epilepsy was beginning to be viewed as an extreme measure as in Riverius” *The Practice of Physick* (1655):

> If all means fail the last remedy is to open the fore part of the Skul with a Trepan, at distance from the sutures, that the evil air may breath out. By this means many desperate Epilepsies have been cured, and it may safely done if the Chyrurgeon be skilful.” (Temkin, 1971, p.235)

Figure 3. A sixteenth-century woodcut of a trepanation in the home. Note the man warming a cloth dressing and the woman praying (Dagi, 1997).

By the eighteenth century the incidence of trepanning for epilepsy had declined and its rationale changed. Now rather than the previous idea of allowing an exit for evil vapors and humors, the purpose was to remove some localized pathology. By the nineteenth century trepanning for epilepsy was confined to the treatment of traumatic epilepsy, that is, cases associated with known head injury (Temkin, 1971).

Another use of trepanning was as a treatment for mental disease. In his *Practica Chirurgiae*, Roger of Parma (ca. 1170) wrote:

> For mania or melancholy a cruciate incision is made in the top of the head and the cranium is penetrated, to permit the noxious material to exhale to the outside. The patient is held in chains and the wound is treated, as above, under treatment of wounds." (Mettler and Mettler, 1945, p.16)

Robert Burton, in his *Anatomy of Melancholy* (1652), also advocated boring a cranial hole for melancholy:

> Tis not amiss to bore the skull with an instrument, to let out the fuliginous vapors...a melancholy man at Rome, that by no remedies could be healed, but when by chance he was wounded in the head and the skull broken, he was excellently cured...Guinerius cured a nobleman in Savoy by boring alone, leaving the hole open a month together by means

of which, after two years melancholy and madness, he was delivered. (Burton, 1652, p. 450)

The great Oxford neuroanatomist and physician Thomas Willis (1621–1675) believed that “threatening, bonds or strokes” were “Curatory” for Mad-men but noted that “Specifick Remedies such as St. Johns-wort as well as Chirurgial Remedies such as Trephining or opening the skull” have been recommended (Willis, 1683, p.192–3).

Trepanning in Flemish Art

Probably the most famous depiction of trepanning for mental disease is Hieronymus Bosch’s (1450–1515) *The Cure for Madness* (or *Folly*), also known as *The Stone Operation* (Fig. 4). This painting shows someone making a surgical incision in the scalp. The inscription has been translated (Cinotti, 1969) as “Master, dig out the stones of folly, my name is “castrated dachshund.’” This is usually interpreted as reflecting a contemporary belief that folly, stupidity and madness were due to stones in the head. “Castrated dachshund” was an epithet for a simpleton (Cinotti, 1969; Gibson, 1973; Harris, 1995; Bax, 1979; Schupbach, 1978).

The art-historical literature is replete with a large number of conflicting interpretations of the details of this painting such as the role of the two on-lookers, the funnel on the surgeon’s head, the book on the woman’s head, the fact that a water tulip, not a stone, is being extracted from the head, the gibbet in the background and other puzzling aspects. In spite of the disagreement on the meaning of the various apparent symbols in the painting, virtually all interpretations of the paintings fall into one of two classes. The first class views the painting as representing (and ridiculing) an actual practice, whereby itinerant medical charlatans deceived people into believing that they could cure mental and “psychosomatic” symptoms by removing stones from the head (Bango Torviso and Marias, 1982; Fry, 1946–7; Grabman, 1975; de Groot and de Moulin, 1974; Klein, 1963; Meige, 1932; Menden, 1969). Supposedly, the quack would make a scalp incision and then pretend to remove stones from the head. The second class of interpretation claims that there is no evidence at all for any such contemporary pseudo-medical practice (Gibson, 1973; Bax, 1979; Schupbach, 1978). Rather, the painting is viewed as an allegory of the extreme stupidity and gullibility of humans, a recurrent theme in Bosch.

After Bosch, there were a number of works, again usually Flemish, depicting the removal of stones from the head as a cure for madness and folly by Peter Brueghel (Fig. 5), Jan Steen, Pieter Huys, Nicolaes Weydmans, Johannes Theodoor de Bry, and others. Following the two overall interpretations of the Bosch mentioned above, these later works have been interpreted either as depicting an actual common practice of medical quackery (Grabman, 1975; Menden, 1969) or simply as imitating Bosch’s allegory of human stupidity (as each of these artists was clearly influenced by Bosch). In both these art-historical interpretations of the depictions of “stone operations,” the possibility that legitimate surgical operations on the head were actually performed to relieve symptoms, was apparently, quite inconceivable (Gibson, 1973; Menden, 1969).

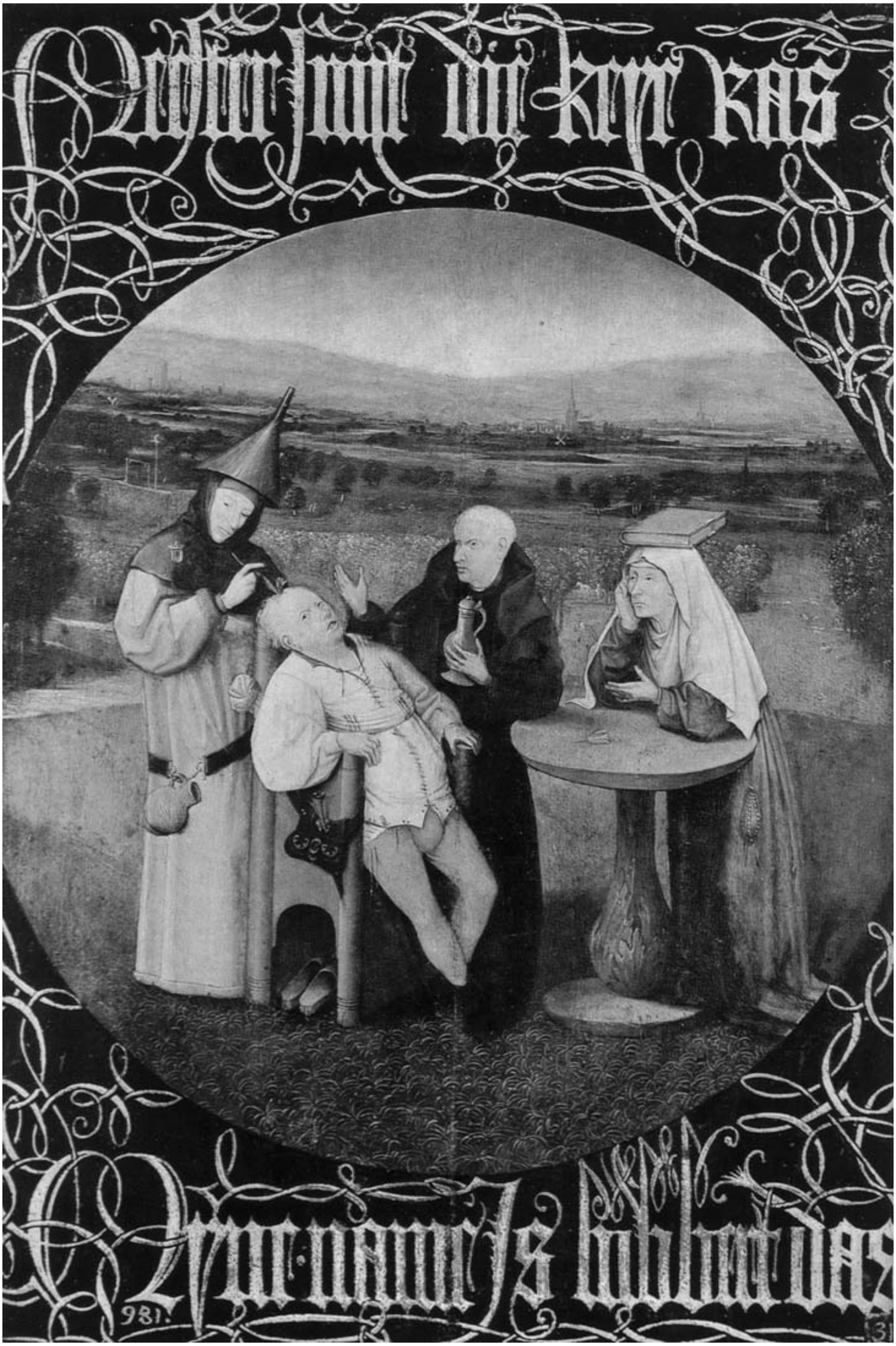


Figure 4. Painting by Hieronymus Bosch, *The Cure of Folly* or *The Stone Operation* (Prado, Madrid). The inscription in translated in the text (courtesy of Princeton University Library).


Ghy lieden van Mallegem wilt nu wel syn gesint
Ick Vrou Hexe wil hier oock wel worden bemint
Om v te genesen ben ick gecomen hier
Tuwen dienste met myn onder meesterssen fier
Compt vry den meesten met den minsten sonder verbeyen
Hebdy de wesp int hooft, off loteren v de keyen.

Trepanation was a standard surgical procedure during the periods in which the various depictions of "stone operations" were made, such as those in Figures 4 and 5. Furthermore, the procedure was used to treat behavioral disorders as well as head injuries. Thus, it seems likely that Bosch, and the other artists who produced the various pictures of stone operations, knew of the existence of the actual contemporary medical procedure of trepanning. Indeed, the details of their portrayal of the "stone operations" were often very close to the detailed instructional diagrams on trepanning found in surgical handbooks such as Joannis Scultetus, *Armamentarium Chirurgicum* (Scultetus, 1655) (see Fig. 6).

Thus, whatever the abstruse symbolism in Bosch's *Cure of Folly*, whether he was ridiculing the church, the medical profession, trepanning or all humanity; or whether it advocates some religious cult, some wild sexual practice, the advantages of trepanning or nothing at all (Gardner, 1975; Cinotti, 1969; Gibson, 1973; Snyder, 1973; Harris, 1995; Delevoy, 1990; Bango Torviso and Marias, 1982; Bax, 1979; Schupbach, 1978), it seems indisputable that the writing of art historians on this and similar works contain a great deal of folly. Apparently, unknown to many these historians, Bosch's painting and derivatives by Bruegel and others, were based on a very real medical practice of their time. Remarkably, art historians have written reams on the symbolic interpretation of these paintings, but appear to remain unaware that they represented, perhaps among other things, a common medical practice of the time.

By the eighteenth century, "most reputable and enlightened surgeons gave up the practice of... [trephination]…for psychiatric aberrations or headache without evidence of trauma. Thus...the skull was never to be trephined for 'internal disorders of the head.'" (Mettler and Mettler, 1945, p. 34).

Trepanning Today in Africa

A second source of information on the motivations for trepanation is contemporary traditional practitioners and their patients. There are literally hundreds of twentieth-century accounts of trepanation, particularly in Oceanic and African cultures (Margetts, 1967). Especially detailed and recent ones concern the Kissii of South Nyanza in Kenya and include photographs of the surgical instruments, practitioners and patients, X-rays of the skulls of surviving patients, detailed interviews, and even a documentary film (Margetts, 1967; Grounds, 1958; Coxton, 1962).

←
Figure 5. Print by Pieter Breughel the Elder, *The Witches of Mallegem,* Yale Medical Library (Courtesy Princeton University Library). Mallegem was an imaginary village populated by the gullible, "mal" meaning crazy or foolish in Flemish. The witch is shown at the end of the table on the right holding up a stone she had just "extracted." She presumably got the stone from the lock-lipped fellow under the table. A poster on the wall shows stones she has removed and her surgical knife. Other patients with stones in the head are shown around her (Klein, 1963; Grabman, 1975). The seated man with a knife tied to his head may represent a technique to "draw out excess blood or bad humors," a custom that seems to have survived into the twentieth century (Grabman, 1975, p. 385).

Figure 6. Detail of figure from a seventeenth-century surgical handbook showing the start of a trepanation (Scultetus, 1655).

Trepanning among the Kissii is carried out primarily for the relief of headache after some kind of head injury. It is apparently not done for "psychosis, epilepsy, dizziness or spirit possession." (Margetts, 1967, p. 683). The operation is carried out by general practitioners of medicine and takes a few hours. Restraint rather than anesthesia is used. The hole in the skull is usually made by scraping with a sharp knife with a curved tip to avoid injuring the dura. Various medicines are administered before, during and after surgery but their nature does not seem to have been studied. Mortality is described as low. The practitioners and patients seem to be quite satisfied with the results of the operation (Margetts, 1967; Grounds, 1958; Coxton, 1962).

Although headache after head injury is the most prevalent reason given for trepanning by contemporary practitioners of traditional medicine in Kenya and elsewhere, other reasons are cited in the literature such as "evil spirits..vapors, humors, pressures and imagined foreign bodies in side the head." (Margetts, 1967, p. 692). Furthermore, the headache itself may be attributed to one or more of these causes, instead of, or in addition to a head injury.

Trepanning on The Internet

Today, the practice of trepanning is not confined to surgical suites or traditional medicine men. It is advocated by the International Trepanation Advocacy Group as a means of enlightenment and enhanced consciousness. Their general idea is that when the skull sutures close in childhood it "inhibits brain pulsations causing a loss of dreams, imagination and intense perceptions and more areas of the brain functioning simultaneously" and "increases originality, creativity and ...testosterone level." Beyond such "physiological" arguments, the group supports the practice by pointing out its ancient, widespread and continuing presence in other cultures. The Group maintains a sophisticated web site, http://www.trepan.com, with links to first person and journalistic accounts of trepanning, reproduction of old drawings of trepanation in Europe, a chat room, several historical papers, and even a paper by Sokoloff on brain metabolism. This particular form of alternative medicine recently gained considerable if not entirely positive publicity: in November 1998 it was featured on "ER", the television soap opera set in an emergency ward.

Much of the defense for alternative medicine treatments is that they must work because they have been around for such a long time, an apparently attractive argument for the increasing popularity of 5000+ year-old Chinese traditional medical practices. However, the case of trepanning suggests that just because a procedure is very old does not mean it is necessarily an effective one, at least for enhanced enlightenment and creativity. Trepanning a small hole, they say, restores the intracranial pulse pressure which leads to a permanent increase of the brain-blood volume which leads to accelerated brain metabolism.

Conclusion

The commonest view of the prehistoric and the non-Western practice of trepanning, especially in the absence of a depressed fracture, was that it represented some kind of "superstition," "primitive thinking," "magic" or "exorcism." Yet an examination of the reason for the practice among the Hippocratic and early European doctors as well as among contemporary Kenyan practitioners suggests a different view. Trepanning may have appeared, in these contexts and cultures, to have been an effective empirical approach to head injury and the headaches that often accompany them. Headaches after head injury often do feel like "a pounding" and "pressure" inside the head, and thus the idea that a hole in the skull would relieve them is not necessarily "magical" or "bizarre." Furthermore, epidural bleeding does sometimes accompany head injury, and in these cases trepanning might have actually reduced intracranial pressure. Finally, the apparently excellent survival rate meant that the procedure, at least until it moved into a hospital setting, may have met the prime requirement of medicine, to "do no harm."

Acknowledgements

I thank the following for their help with earlier version of this article: G. Berman, E. Gould, M. Graziano, and X.T. Hu.

References

Aretaeus (1856): The Book of Cures. In: Adams, F, ed. and trans., *The Extant Works of Artaeus, the Cappadocian*. London, The Sydenham Society.

Bakay L (1985): *An Early History of Craniotomy*. Springfield, Charles C Thomas.

Bango Torviso IG, Marias F (1982): *Bosch: Reality, Symbol, and Fantasy*. Madrid, Silex.

Bax D (1979): *Hieronymus: His Picture Writing Deciphered*. Rotterdam, AA Balkema.

Burton R (1652): *The Anatomy of Melancholy*. London, Cripps and Lod.

Cinotti M (1969): *The Complete Works of Bosch*. London, Weidenfeld and Nicholson.

Coxton A (1962): The Kissii art of trephining. *Guy's Hosp Gaz 76*: 263–265.

Dagi TF (1997): The management of head trauma. In: Greenblatt SH, ed., *A History of Neurosurgery*. Park Ridge, Illinois, American Association of Neurological Surgeons, pp. 289–344.

de Groot IM, de Moulin D (1974): The cutting of the stone, an engraving by Johannes Theodoor de Bry. *Organorama 11* (2): 28–30.

Delevoy RL (1990): *Bosch*. New York, Skira.

Fry CC (1946–7): The sixteenth century cures for lunacy. *Am J Psychiatry 103*: 351–353.

Gardner H, (1975): *Gardner's Art Through the Ages* (6th ed.), De la Croix H and Tansey RG, editors. New York, Harcourt Brace.

Gibson WS (1973): *Hieronymus Bosch*. London, Thames and Hudson.

Goodrich JT (1997): Neurosurgery in the ancient and medieval worlds. In: Greenblatt SH, ed., *A History of Neurosurgery*. Park Ridge, Illinois, American Association of Neurological Surgeons, pp. 37–64.

Grabman JM (1975): The witch of Mallegem, print by Pieter Brueghel the elder [c.1528–69]. *J His Med All Sci 30*: 384–385.

Grounds JG (1958): Trephining of the skull amongst the Kissii. *East African Med J 35*: 369–373.

Guanzhong L (1991): *Three Kingdoms.* Trans. Roberts M. Berkeley, University of California.

Harris L (1995): *The Secret Heresy of Hieronymus Bosch*. Edinburgh, Floris Books.

Hippocrates (1999): *On Head Wounds*. Trans. Hanson M. Berlin, Akademie Verlag.

Klein HA ed., (1963): *Graphic Worlds of Peter Bruegel the Elder*. New York, Dover Publications.

Lisowski FP (1967): Prehistoric and early historic trepanation. In: Brothwell D, Sandison AT, eds., *Diseases in Antiquity*. Springfield, Charles C Thomas, pp. 651–672.

Lu G, Needham J (1980): *Celestial Lancets: A History and Rationale of Acupuncture and Moxa*. Cambridge, Cambridge University Press.

Majno G (1975): *The Healing Hand: Man and Wound in the Ancient World*. Cambridge, Harvard University Press.

Margetts EL (1967): Trepanation of the skull by the medicine-men of primitive cultures, with particular reference to present day native east African practice. In: Brothwell D, Sandison AT, eds., *Diseases in Antiquity*. Springfield, Charles C Thomas, pp. 673–701.

Meige H (1932): L'operation des pierres de tête. *Aesculape 22*: 50–62.

Menden JM (1969): Operation for stones in the head, an engraving by Nicholaes Weydmans. *J His Med All Sci 24*: 210–211.

NY Academy of Medicine (1865): Stated meeting (December 6, 1865). *Bull of the NY Acad of Medicine*, 1862–1866, *2*: 530.

Mettler FA, Mettler CC (1945): Historic development of knowledge relating to cranial trauma. In: Browda J, Rabiner AM, Mettler FA, eds., *Trauma of the Central Nervous System*. Baltimore, Williams and Wilkins.

Rosen G (1939): Trepanation in Cornish miners. *Ciba Symposium 1*: 197.

Saul FP, Saul JM (1997): Trepanation: old world and new world. In: Greenblatt SH, ed., *A History of Neurosurgery*. Park Ridge, Illinois, American Association of Neurological Surgeons, pp. 29–36.

Schiller F (1992): *Paul Broca: Founder of French Anthropology, Explorer of the Brain*. Oxford, Oxford University Press.

Schupbach W (1978): A new look at "The cure of folly". *Med Hist 22*: 267–281.

Scultetus J (1655): *Armamentarium Chirurgicum*. Ausg., Kühnen.

Sigerist HE (1987): *A History of Medicine, vol. 1*, *Primitive and archaic medicine*. Oxford, Oxford University Press.

Snyder J (1973): *Bosch in Perspective*. Englewood Cliffs, NJ, Prentice Hall.

Squier EG (1877): *Peru: Incidents of Travel and Exploration in the Land of the Incas*. New York, Henry Holt.

Temkin O (1971): *The Falling Sickness*. Baltimore, Johns Hopkins Press.

Thompson CJS (1938): The evolution and development of surgical instruments IV: the trepan. *Brit J Surg 25*: 726–734.

Wehrli GA (1939): Trepanation in former centuries. *Ciba Symposium 1*: 178–186.

Wilkins RH (1997): Neurosurgical techniques: an overview. In: Greenblatt SH, ed., *A History of Neurosurgery*. Park Ridge, Illinois, American Association of Neurological Surgeons, pp. 83–96.

Willis T (1683): *Two Discourses Concerning the Soul of Brute*s. Trans. Pordage S. London, Dring.

Woodall J (1639): *The Surgeons Mate or Military and Domestique Surgery.* London, Bourne.

Chapter 23

Why Trepan? Contributions from Medical History and the South Pacific

GRAHAM MARTIN
Wakefield Specialist Medical Centre, Wellington, New Zealand

Abstract

Trepanning is incomprehensible now to both doctors and patients, because anaesthesia, antisepsis and X-rays distort our thoughts about surgery before 1880. Before then, wounds were always infected, and the only fractures of the skull diagnosed were only those that could be seen at the bottom of a wound. Then the scalp could not be safely stitched for fear of an abscess under the scalp, so every cut scalp had to be packed open, that pus might drain and not form an abscess

Every fracture then suppurated, forming pus, and one third or more of those with a fractured skull died from an abscess inside the skull. Trepanning done properly made a passage that could drain those fatal abscesses and save lives.

Trepanning was a tradition, often unwritten, a craft passed on by apprenticeship, in many traditions around the world. The traditions of the Mediterranean littoral were written down first in Hippocrates' time, after an oral tradition of at least two thousand years. After that medical texts discuss the operation, and history preserves some facts about particular patients, which throw light on the reasons why and how the operation was done.

Accounts gathered in the nineteenth and early-twentieth centuries, from traditional preliterate trepanners around the world assist the understanding of the role of the operation before historical records. They suggest that trepanning was a practical skill, in societies with an empirical approach to wounds and the head, that could develop locally, and did not need to be taught from a distance.

Keywords: Trepanation, History of surgery, Head injuries, Anthropology

Reasons for Trepanning

To say trepanations were done for magical reasons does not adequately explain the thinking that lead to the operation. "Magic" depends on viewpoint, at worst it may be a condescending approach to the best medicine and science of another society. The reasons for trepanation must be examined, as far as we can, by understanding the way the operator thought.

Technology now distorts our understanding of the past and other societies. Before X-rays, the only fractured skulls that could be diagnosed were those seen or felt at the bottom of a wound. Before antisepsis, all open wounds inevitably became infected. Without antisepsis, the scalp could not be stitched but was left open to drain, for fear of an abscess between the scalp and the skull.

Most trepanning was done in response to a skull wound. Accounts from history and anthropology suggest that it was not often done on intact and healthy heads, unless for chronic headache. (This may seem contradictory, but very few headaches represent serious and life threatening diseases, no matter how disabling they may be at the time.) Neither was "ritual" a common reason for trepanation in recorded history.

The processes involved in wounds of the head before antiseptics can be understood by examining what happens in a head wound now, then what happened before 1880 when antisepsis was introduced. Before the introduction of antisepsis and the understanding of the role of bacteria in wounds, these changes were interpreted so differently that much of what was written and done requires explanation. Traditions of trepanation other than the Hippocratic may be even harder to explain.

Modern Pathology of Head Wounds and Interpretations Before 1880

Modern Interpretations

An *open fracture* is one where the overlying scalp is cut; traditionally they are called *compound*, originally a fifteenth-century term, meaning that the fracture was compounded, or complicated, by a laceration. *Open* is more explicit, as overlying lacerations leave them open to the air, clothing, and dirt, and so to infection by bacteria. Now the scalp is closed as soon as possible to prevent entry of bacteria. The bone fragments join by scar, and after six months bone may form in the scar. Bone does not always grow across the gap, but firm scar tissue can form a closure just as strong as bone. Whether or not bone forms, the fracture always leaves a mark on the skull. Using antiseptic technique, even without antibiotics, if the wound is thoroughly cleaned within twenty-four hours of dirt and blood clot (which would nurture infecting bacteria), then infection is uncommon.

Cracks, or *linear fractures*, in the skull need no surgery to the fracture itself, the scalp need only be stitched over it, and the crack heals with scar or bone. A *depressed fracture* means one or more fragments are driven into the skull, and the brain may or may not be penetrated. The depressed fragments must be elevated, which is not as easy as it sounds, the shattered edges may have impacted into each other, and be impossible to lift out without cutting away the bone. In essence, this is one form of trepanation, though it may not be called so in modern speech (Fig. 1).

Often the in-driven fragments do not penetrate the dura, and the damage to the brain is only some minor bruising, which clears like other bruising. If the dura is penetrated by the fragment, then the damage to the brain can be significant, the sharp edges of the fragment cutting and pulping the brain. The damaged brain must be removed, so it might not form a nest where infection can begin, and so it cannot damage nearby brain by swelling. The pulped area will never function again, but adjacent parts take over the function, as far as they can.

Depressed fragments are generally removed by the surgeon. The younger the patient, the more likely that bone will grow back into the scar to replace the missing bits. Some people do not grow bone easily, leaving their skull closed with scar tissue which becomes as tough as the hardest leather, so the skull is not any weaker.

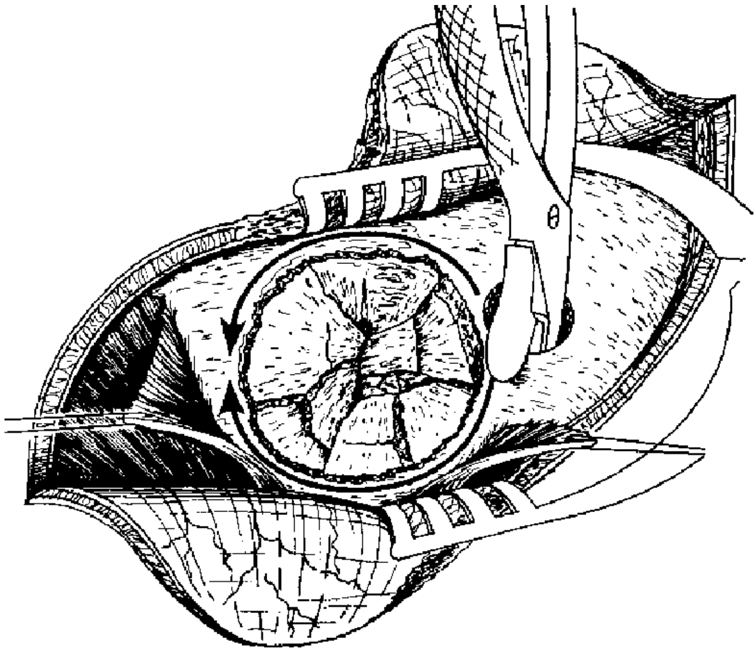


Figure 1. The in-driven fragments of a depressed fracture may be impacted, and impossible to elevate without cutting away normal bone around the fracture to mobilise them.

Pre-antiseptic Events And Interpretations

Antiseptic surgery began in the 1860s and became the norm in the 1880s; it changed surgery so much that understanding of what went before needs special study. The basis of modern antiseptic or aseptic surgery is that bacteria are removed from the wound as soon as possible, by removing dirt and dead material that might contain and nourish bacteria; thereafter, they are excluded from re-entering the wound, until the skin closes over. Before Lister all wounds became infected. Then, surgery was about managing infected wounds, and preventing abscess formation. An abscess is retained pus, so to prevent abscesses, you must leave open some drainage channels, that pus may drain freely from wounds, anything blocking that drainage may cause an abscess. Hence, the scalp was rarely stitched up, but allowed to close slowly over four to six weeks by progressive scarring. Even if there were no fracture, only a cut scalp, it was best packed to stay open, because if pus could not drain, it might form a subgaleal abscess, that is, a spreading infection between the scalp and the bone of the skull. It was safest to leave the cut open and draining. Most pre-antiseptic textbooks of surgery omit to say that the scalp was left open, only occasional texts bothered to mention that the scalp was not closed (Pott, 1790). The obvious was not written down, because then all surgeons were trained first by apprenticeship, even if they later studied formally at a University or hospital school of medicine.

In the presence of pus an open fracture formed a pathway for the spread of pus inside the skull and there it often formed an abscess, which was often fatal. Around 2,400 years ago, “Hippocrates” (Hippocrates himself did not write on surgery; Lloyd 1975) described death from an intra-cranial abscess very clearly. It began with fever about the seventh day in summer, and later in winter. The wound would ooze pus, and convulsions affect the side opposite the wound. Death always followed and the mortality did not change till the 1880s. From reading texts of the times, the author estimates that of those with an open fracture, around one third or more died from infection inside the skull. More accurate figures are not available, and anyway there would be variations in the mortality, according to the lethality of the commonly used weapon of the times.

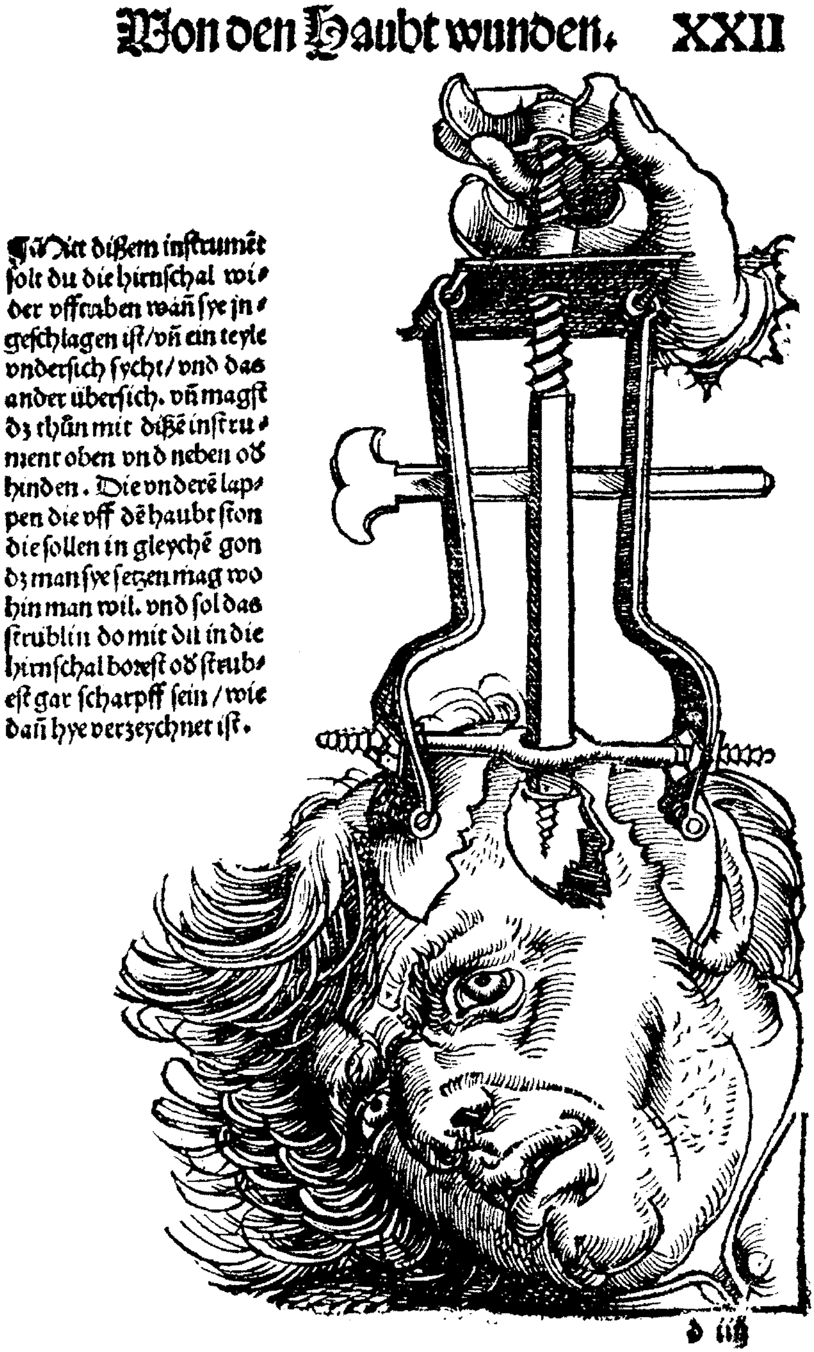
Around any fracture there is normally some bleeding. Trepanning fractures of the skull, open ones that could be seen, made a hole that drained any blood clot around the fracture, inside the skull, so it could not form an abscess. If done early, it can prevent an abscess, but if bacteria gain entry they readily grow in clot, and convert the blood to pus and an abscess in about five days. Before the critical role of bacteria was understood, open wounds would regularly become infected, so surgeons thought blood clot was an early stage of pus.

The Hippocratic or Classical Tradition of Trepanation

The Classical tradition of trepanning began its written life around 390 BC when “Hippocrates” wrote *On Wounds of the Head.* It recorded part of a much wider, older oral tradition of trepanation which seemed to start in Western Europe and spread all around the Mediterranean. The oral tradition flourished alongside the written till modern times, for surgery is a practical art, necessarily described rather than taught by text books. Whoever the author was, it was not Hippocrates. He was a physician, known to Aristotle, in a society where surgeons were manual workers, and upper class Greeks thought such work should be left to tradesmen (Lloyd, 1975). Hippocrates’ name preserved many valuable texts of uncertain authorship, just as Henry Gray’s name gives authority to the latest Gray’s Anatomy. Despite the traditional reverence for Hippocrates’ name, the actual author of *On Wounds of the Head* seems tentative and inexperienced, as though he had been told what to do, but not done it often, or even at all (Figs 2 and 3).

Hippocrates’ Teaching on Trepanation

The earliest treatise, *On Wounds of the Head,* is vague and hard to follow, yet the prestige of Hippocrates confused the discussion of trepanation for 2,000 years. His explanations lack detail, perhaps because he wrote for surgeons who already knew the basics of wound management. His discussion implied that most Greek surgeons were busy with wounds from weapons, and would, for example, know the need to cut open an oblique wound such as an arrow or sword might make, to see if the skull were penetrated. The text (Adams,



Von den Haubt wunden. XXII

¶ Mit dißem instrumēt
solt du die hirnschal wi-
der vffhaben wañ sye in-
geschlagen ist/vñ ein teyle
vndersich sycht/vnd das
ander übersich. vñ magst
dz thůn mit dißē instru-
ment oben vnd neben od'
hinden. Die vnderē lap-
pen die vff dē haubt ston
die sollen in gleychē gon
dz man sye setzen mag wo
hin man wil. vnd sol das
strublin do mit du in die
hirnschal borest od' streub-
est gar scharpff sein / wie
dañ hye verzeychnet ist.

d iiij

Figure 2. Some invented dangerous instruments to pull fragments out. The problem with such devices is that in a complex system of shattered and impacted fragments, you may pull one fragment out at the cost of forcing another deeper into the brain. Instead normal bone should be removed to free the fragments.

The instrument was in fact rarely used, it frightened surgeons as much as the patient in the picture. (Hans von Gerssdorf, *Feldtbuch der Wundtartzeney, von den Hauptwunden.* Strasburg 1517, printed Johannes Schorr.)

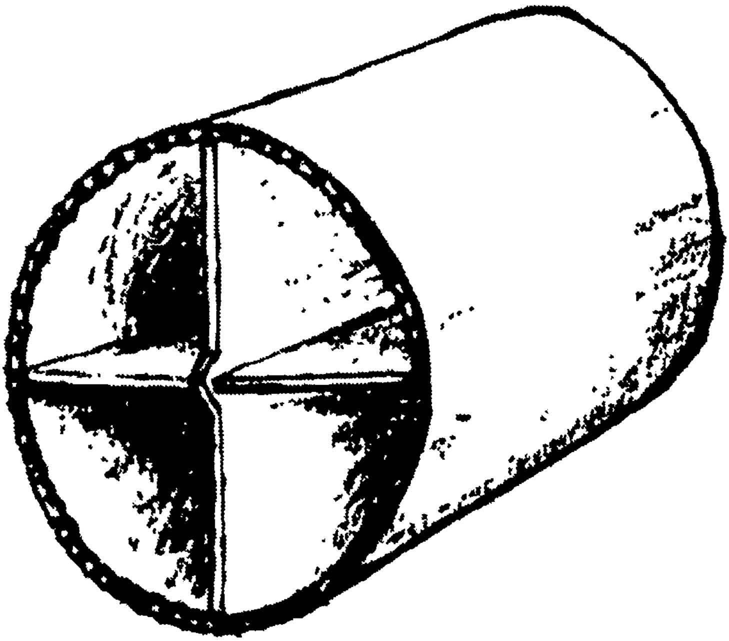


Figure 3. Cylindrical crown saw or trepan such as the earliest "Hippocrates" described in *On Wounds of the Head*. The framework for the centring pin was removable. This one was in the kit of a Roman military surgeon, found at Bingen am Rhein.

1844) mentions in passing that trepanation drained the blood from between the dura and the skull, but not that this was the purpose of the operation, nor that this early trepanation prevented many abscesses.

Death from an intra-cranial abscess following an open fracture is described (Adams, 1844), so well that "Hippocrates" must have seen it often, and his description remained valid for more than two thousand years (see above). Infection spreading under the scalp and into the face (a subgaleal abscess) is described, but not that it might result from stitching the scalp. He did not discuss cutting away depressed fragments to lift them out, that is trepanning for depressed fractures, neither did he mention cutting away dead bone so the skin can heal over it.

Lastly, "Hippocrates" describes how to trepan with a crown saw, that is a cylinder with teeth on one end. "Hippocrates" used a strangely hesitant method, leaving a thin film of bone attaching the disc he had bored out, and waiting some days for the discharging pus to float the disc out. Almost none of those who wrote after him recommended his method.

His curiously hesitant technique suggests that he himself had not trepanned often. Those who have trepanned know that once that last film of bone is reached, the difficult and dangerous part of the operation is over. By then you have either cut the dura or left it intact. There is a feeling of relief, putting in a bone lever and fracturing the disc out from those last retaining strands.

The later pseudo-Hippocratic writers (*Epidemics IV and V*) some seventy years later, around 320 BC, completed the list of reasons for trepanning in the classical tradition. They cut bone away to elevate depressed fractures (*Epidemics* V, 28), to remove bone that was dead, or about to die because the scalp had been stripped off it (*Epidemics* V, 16). Lastly, they trepanned to look for pus under the skull (*Epidemics* IV, 11), when fever and headache after a head injury suggested that pus must be there, even if no fracture had been seen (*Epidemics*, V, 27). It can be difficult to find a fracture at the bottom of a wound. Also these later Hippocratic writers used the small saw, Hey's saw, to cut away the skull, something the first "Hippocrates" had not mentioned. Surgery seemed to have advanced in the 70 years since the first "Hippocrates" wrote.

The Hippocratic Dictum

Hippocrates' most important teaching was that all fractures should have a hole made alongside them in the first three days after the wound. Yet his inexperience at trepanning suggests he had not himself done what he urged others to do – trepan every fracture and adds to the impression that he was inexperienced. For 22 centuries surgeons debated inconclusively around "Hippocrates'" great legacy, the demand that all fractures have a hole made in or near them in the first three days.

Reasons for Trepanning in the Classical Tradition

By the beginning of the third century BC the late "Hippocratic" writers had set out the reasons for trepanation, recording the much older oral tradition. There were three broad reasons for trepanning. The most common was to treat fractures; by draining the blood clot beneath the bone before it became an abscess, or to disimpact bone fragments so they could be elevated. Elevating the fragments also drained blood clots. The first "Hippocrates" emphasised that trepanning should be done in the first three days, implying that the dangers later were greater, as indeed they were. Trepanning an already heavily infected wound carries a significant risk of spreading the infection, whereas in the first few days the wound is relatively clean and safer.

The second common reason for trepanning was to remove dead bone exposed in a wound, or bone about to die because the skin had been stripped off it. When the scalp could not be stitched back safely, then areas of bone would dry out and die. If left long enough, the dead bone will separate from the living and drop out, but this may take six months, or may never happen. Meanwhile the dead bone is a constant reservoir of infection, pus continues to discharge, and the patient remains at risk of death from infection spreading to the brain. Dead bone is easily distinguished, it looks dead, either white, pale and bloodless if it has been kept clean and covered, or if exposed to the air it turns a funereal black from oxidation of the blood pigments. Removing dead bone was safer, and could speed the closure of a wound to about three months. Thirdly, trepanning was done to look for pus when fever and headache suggested there was pus under the skull.

All these reasons for trepanning are those described in the Classical literature. Two more reasons, headache and epilepsy must have been considered, but not recorded, per-

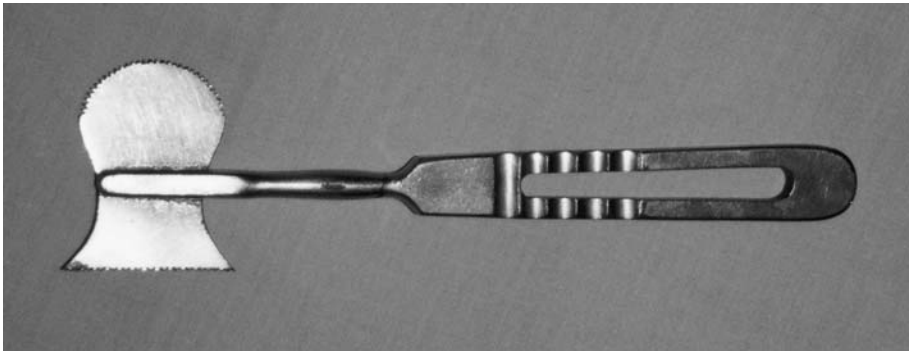


Figure 4. The small saw that late Hippocratic writers used, now called Hey's saw, after an eighteenth century surgeon. It has been found in Celtic graves on the Danube (Brongers, 1969), but this one was made in the twentieth century, and discarded only in the second half of the century.

haps because both were to some extent implicit in the reasons already given. Headache was part of "Hippocrates'" description of the syndrome of an extradural abscess, accompanied by fever beginning seven to fourteen days after an open head injury. Most headaches more than 14 days after trauma are not helped by trepanning, although a few may sometimes be ameliorated if pus or blood has collected within the skull. Epilepsy then meant any repeated convulsion or movement, few of which would benefit from trepanation. Both headache and epilepsy have powerful emotional components, which may be relieved by the drama of trepanation, so the disorder can remit for a while.

The Classical Tradition in Practice: Trepanning for the Next Two Thousand Years

From classical times until 1880 trepanation did not advance, arguments simply went in cycles, from enthusiasm to avoidance and back again. The nineteenth century was a time when surgeons trepanned much less than in previous centuries, because they worked in and taught from hospitals which had become the sinks of infection in their community, and most trepanned patients died from infection. Surgeons often argued from different circumstances, different weapons and types of fighting, and varying risks of infection. During the American invasions of the West, army surgeons treated arrow wounds according to the tribe, stone arrow heads were different to iron (Mays, Parfitt and Hershman, 1994). Wounds injuring both brain and skull are usually fatal, but superficial wounds of the scalp and skull are more survivable, so trepanation would be more useful. These cycles of arguments are not enlightening, it is better to look at when surgeons trepanned, and why they did.

Trepanation for Open Fractures

"Hippocrates" urged that this should be done routinely on all fractures in the first three days. Its value was to drain the clot around the fracture before it turned to an abscess.

In 1517 Lorenzo Duke of Urbino suffered an open fracture of the skull, when a sniper's bullet grazed the back of his head. He was trepanned to drain the clot under the fracture, and survived. His skull shows the fracture and the trepan hole alongside it (Corsini, 1913; Martin, 1996).

Lorenzo's trepanation was delayed, because it was guessed from the grazing musket ball wound that there was not much extradural blood. When fever began on the seventh day (as "Hippocrates" said) he was trepanned, but only a little blood was found which was wiped away with a feather. He recovered well, only to die of syphilis two years later.

Not all trepanations ended happily. In 1214 Enrique, the 14 year-old King of Castille, was hit on the head by a stone falling from the roof, suffering a depressed fracture. The Royal Surgeon, Diego del Villar, removed the depressed piece of bone, but the boy-king died within a few days (Vara-Lopez, 1949). Enrique's skull showed a skillful trepanation, but done over the main draining vein of the brain, the sagittal sinus. Today this would be avoided, as it causes more bleeding than it is worth to elevate fractures over the vein. "Hippocrates" would have declined this one too, as it was over one of the sutures (joins) of the skull, where he knew the dura stuck more closely to the bone, so was more likely to tear. Many ignored "Hippocrates'" rule not to trepan over the sutures, because most operations were done sitting up, in which posture veins do not bleed much. Diego operated to prevent infection, by cleaning the wound and removing detached and non-survivable bone. Infection over the sagittal sinus can be fatal even today, if it gets into the vein, then spreads by the blood stream all over the body.

The story of King Ptolemy VI, Philometor of Egypt, can be put together by combining the histories of Livy, Josephus and the Book of Maccabees I with knowledge of surgical practice at the time (Martin, 1999). In 145 BC Ptolemy was wounded in battle and unconscious for four days, on the fifth he recovered consciousness, but worsened again on the sixth, with the fever "Hippocrates" described so well. On the seventh day a surgeon trepanned Ptolemy, but on the eighth he died. The surgeon was blamed for the death, but it was delay that killed the King. This was one of the major problems with "Hippocrates'" policy. Just because some surgeon said they *might* die, most awake patients would refuse a hole bored in their skull, while they felt well in the first three days.

Enrique's trepanation was done promptly, and Ptolemy's delayed, but both died. Often patients refused permission for early trepanation. Pott (1790) discusses this problem in eighteenth-century London, when about half of those to whom trepanation was suggested refused.

The Hippocratic policy was applied routinely and successfully in the mines of Cornwall. There trepanation and other surgery was a family trade, and a surgeon in 1877 said he trepanned fractures in his rooms, on the way home from the accident, just as his great grandfather had done (Hudson, 1877). The miners expected it, it was probably a relic of traditional European trepanning, as among the Serbs of Montenegro (see below) and there seemed very little trouble from it.

Figure 5. Nineteenth-century Serbian trepan, identical to what some trepanners in the Aurés mountains of Algeria used. Teeth on one end of the cylinder formed a crown saw that was rubbed to and fro between the palms (Trojanovič, 1900).

Trepanation to Remove Dead Bone

If dead bone was not removed it eventually dropped out, but that took nine months to a year, and during that time there was constant danger of a fatal spread of infection. If it were cut away, the wound would heal in several months.

During the retreat from Mexico City, Cortés the Conquistador had dead bone scraped away from the surface of his skull. A stone thrown by Aztecs had torn his scalp badly, leaving the skull exposed, so the bone of the outer table dried out and died (Prescott, 1899; Thomas, 1993). The surgeon was part-time, like many then, being employed as an artilleryman during battle and caring for the wounded after. The wound took two to three months to heal.

Prince Philip of Nassau was trepanned twenty seven times in 1591, but survived, in such good health that he won drinking competitions, once drinking his opponent to death (Nieuwe Nederlandsche Biographische Woordenboek, 1911). The most charitable interpretation of the 27 trepanations was that they were all partial, to remove dead bone. The least charitable is that it was yet another reason for trepanning: securing the surgeon's income.

Trepanation to Look for Pus

Looking for pus could justify trepanning, perhaps more often in the past when infections were more common. Prince Rupert of England was trepanned in 1667 for intense unremitting headache, pus was drained from under the skull, and that day the headache ceased (Martin, 1990). He recovered so well that within ten days he was up and made a better pair of forceps to dress his head (there was little that Rupert did not think he could improve, often he was right).

Rupert's diagnosis was easier because seventeen years earlier a pistol ball had grazed his skull, from then on the bone dripped pus from time to time. The known site of injury and infection suggested where to make the exploratory hole; indeed, exploratory holes under these circumstances continued to be usual until scanning came in the 1970s.

Trepanation for Headache

The classical writers did not advise trepanation for headache alone. Headaches then cannot have been less common than they are now. Anyone practising medicine will quickly learn to distinguish most inconsequential headaches from those of sinister significance by their severity, though in a few the distinction is impossible.

In the tenth century, Heinrich of Erfurt, physician to the Prince Bishop of Cologne, recorded how he trepanned for intolerable headache and saved the patient's life, by draining stinking pus from inside the skull (Steinschneider, 1908). Stinking pus had probably spread under the skull from a chronically infected middle ear.

Trepanning for headache when pus was unlikely must have been done at some times, because headache would have been no less common than now. All medical practice has quackery at its fringes, and trepanning would have been no different. However, migraine or tension headaches are not among the reasons for *recorded* trepanations, though surprisingly trepanning has been known to relieve such headaches (see below, Kisii trepanning). If the headache were due to a tumour, trepanation could not relieve it.

In 888, Charles the Fat, the last of Charlemagne's grandsons, was trepanned because of severe headaches for many months. Trepanning did not stop the headaches, so he resigned his throne, and died three months later (Riché, 1992). Since he was very fat, a tumour is likely.

In Montenegro, until the beginning of the twentieth century, the traditional Serbian trepanners would make a hole in the skull if a headache persisted for more than forty days after a head injury. This may have been justified by finding pus under the skull at times (Trojanovič, 1900).

Trepanation for Epilepsy

As for headache, classical writers did not advise trepanation to treat epilepsy without other symptoms or circumstances. Again, it is a common disorder that can drive sufferers and their families to distraction, so some trepanation for epilepsy must have been done. One nineteenth century American surgeon did trepan for epilepsy of traumatic origin, with some success (Jensen and Stone, 1997), but, like headache, epilepsy is deeply affected by emotional factors, and anything dramatic can influence it.

When Not to Trepan

Learning when not to operate is more difficult than teaching how to do the operation, so a discussion of "why operate?" must include when not to operate. Often these reasons are less obvious and not written down. The first reason not to operate is when the patient refuses, the next and harder one is when it is not needed. Lorenzo de Medici's trepanation was delayed, because at first he refused, and moreover the surgeons guessed from the grazing musket ball wound that there was not much extra-dural blood. When fever began this was not a safe assumption, so he was trepanned, but the guess proved right, and little blood was found (Martin, 1996, quoting Corsini, 1913). Don Carlos, the heir to the Spanish throne had an abscess spreading under his scalp (O'Malley, 1964). Because he was alert but confused, it was thought there was no abscess inside the skull. An abscess would have made him drowsy by compressing his brain, and events proved this assessment correct. Henry II of France had a splintered lance thrust into his eyeball and orbit. Because pus was draining freely, the two most famous surgeons of the Renaissance, Vesalius and Paré, agreed trepanning him would be pointless examination, there was no need for a hole to let out pus, when it was already draining. Post-mortem showed this to be correct (Martin, 2001).

Opposition to Trepanning

Most textbooks and famous surgeons advised trepanning, quoting some version of the Hippocratic policy. However a minority of the famous, and their books, doubted the value of trepanning.

Until antisepsis came, surgery did not advance generation by generation, but went in cycles of advocacy and opposition. Boldness and timidity are personality characteristics when surgeons operate, and also when authors advise. Moreover, surgeons" experience of wounds varied according to what wounds and weapons were commonest, so they reached different conclusions because they saw different types of head injury. Favourable fractures to trepan would be no deeper than a centimetre or two, such as those made by slingstones, spear thrusts or arrows at the end of their range, where the injury was more to the skull than the brain.

Unfavourable fractures for trepanning were those with diffuse brain injury or deep penetration. Heavy rounded clubs, or large rounded stones, send a disrupting mechanical shock wave through the brain. Deep penetrating cuts and stabs cause unstoppable bleeding within the brain. For these cases, trepanning is useless. For 21 centuries doubt and decision alternated.

Alternatives to Trepanation

The alternative to trepanation was to dress the wound and let nature take its course, probably two thirds or a half will survive. Free bone fragments can be lifted out in many fractures creating a hole to drain pus, so trepanning would not be needed. Some even said it was better waiting for the fragments to float out on the pus, because pus dissolves small bone fragments and sometimes loosens impacted fragments. Often it did not, but that depended on what sort of wound was commonest.

One historic head injury which was *not trepanned* teaches much about how scalp wounds can leave their mark on the skull, without involving it. Large scalp wounds expose uninjured bone, which had to be removed before the wound would close. A Union Pacific Railroad conductor, William Thompson, hunting in 1867 near Cheyenne, was attacked by Sioux, scalped, and left for dead (Barnes, 1875). Normally, the skull was crushed by a tomahawk if the vanquished still lived, but Thompson was thought to be dead. Nine by seven inches of skull was bared. It was dressed with surgeons" lint, and pure olive oil – a relatively simple and sensible dressing, in marked contrast to the elaborate and sometimes positively harmful dressings sometimes used in the past. As usual, the outer layer of bone died, and split off spontaneously from the middle layer, which has a good blood supply. This outer layer was not chiselled, rasped or "ruginated" off, but could have been if the surgeon wished; perhaps the patient did not want it. Once the outer layer was shed spontaneously, the much more vascular middle layer had enough blood supply to support scar tissue, over which healing skin could spread. So the enormous gap closed in about three months! If Thompson's skull could be seen now it would show a very wide healed area of partial thickness "trepanation", even though no instruments were used on him.

Oral Traditions of Hippocratic Trepanning

Oral traditions of Hippocratic trepanning existed before, alongside and long after Hippocrates, even into the twentieth century. Others have discussed the prehistory of trepanation.

The Last Traditional Trepanners in Europe

Trepanning for head injuries continued into the early twentieth century in Serbia and Kosovo, despite the efforts of the King of Montenegro to suppress it. The reasons were broadly those of the Hippocratic tradition (Trojanovic, 1900), but it could also be a punishment. If the victim of an assault needed trepanning, and the guilty party could not afford compensation, the matter could be settled by the aggressor himself being trepanned.

Orally transmitted trepanation continued alongside the classical in many literate regions of Europe, and is known from the archaeology of the area. In Ireland the Celtic preliterate tradition continued and was taken into the monasteries (Walmsley, 1923). The scholar, poet and judge, Cennfaelad, was wounded in the battle of Moyrath in 637 AD, and the wound dressed by St. Bricin, at Tuam Brecain, County Cavan. Though some brain protruded and was removed, he recovered. Before antisepsis, penetration to the brain was usually fatal, but survivors were known. If the dura had been torn, injured brain beneath it sometimes protruded out through the wound, and swelled forming what was called "brain fungus". To prevent this, the trepanners of New Britain (who operated under unusually aseptic conditions), scooped out any visibly pulped brain, and closed the defect in the dura with an implant of bark cloth.

A few patients recovered after a wound where brain oozed from the cut, da Carpi knew of six in his professional life (1519, translated by Lind,1990).

Trepanation in Algeria

In the Aurés Mountains of Algeria, trepanning continued into the early twentieth century, part of the same tradition that the Greeks and Arabs transmitted (Védrènes A, 1885;

Hilton-Simpson MW, 1913). The trepanners insisted they were not Berbers, among whom they lived, but Arabs; their ancestors came from Egypt.

They used an unusual method of opening the skin. With a white hot iron cylinder about three centimetres in diameter, they burnt a round hole through the scalp. The Greek writer Oribasius, in the fourth century AD, recommended this to stop bleeding from skin edges, which it did quite well, but it was not widely used – perhaps it added the fear of fire to the danger of drilling the head.

Their reasons for operating were broadly Hippocratic, making holes around fractures, removing impacted fractures and dead bone, and looking for pus. Most open wounds of the skull and fractures were trepanned, a surgeon with a good practice would do five or six a year and the operation was not thought to be unusually dangerous.

The Techniques of Trepanning

In general trepanners have been eclectic in their methods and instruments; while one surgeon or group may have strong preferences, most traditions use any suitable style or instrument. Most instruments resembled woodworking tools, only in the last fifty years have surgical instruments differed much; indeed if "surgical" tools are found, only the context can show they were surgical.

The Incision

Most patients, but not all, sat up, because the usual position for surgery until the eighteenth century. Usually the scalp was shaved first, it is hard to cut accurately through hair, and blood in the hair is messy. The incision is designed to heal slowly, so it may be a cross, or have three arms, and the tips of the flaps are often cut off to slow healing. Some turned back **U**-shaped flaps and left them loose and hanging, others cut out and discarded circles of scalp. A few burnt a hole in the scalp with red hot irons to reduce bleeding.

The scalp bleeds profusely and blood obscuring the depths of a trepan cut can make real difficulties, even now. In former times without suction and strong lighting this was more troublesome. A small tear of the dura could cause the patient's death. "Hippocrates" advised not to cut over the temporal muscle because the superficial temporal artery bled too much and the muscle made it harder to cut down to the bone. The Tolai trepanners of New Britain had assistants who blew the blood away. Prince Rupert's surgeon normally made the incision on one day, packed the wound with lint, and waited till the next day, when the bleeding had stopped, before cutting the bone.

The last step of the incision was to scrape the bone clean of tissue and to lift the periosteum. Mostly this was done with a scraper, but Ambrose Paré was said to keep the nail of his little finger long, especially for this.

Cutting the Bone

"Hippocrates", the writer of *On Wounds of the Head,* used the trepan, a cylinder with teeth at one end, rotated to and fro between the palms, or turned by a bowstring wrapped around it. It cut out a disc, which was discarded. The late Hippocratic writers, in *Epidemics*, also used a small saw that could open the skull by cutting out a square plate of bone.

The surgeons of the Aures Mountains used their saws on other bones, to cut off the projecting bits of a limb fracture they could not reduce, to permit skin closure over the bone. Some were quite casual about their instruments, they used any suitable saw, gouge, chisel or drill, that at other times they might use for woodwork.

A method of chemical trepanning was unique to the Aurés. Grooves on three sides of a square were cut on the surface of the skull, going no deeper than the middle layer of bone. On one corner was put some sugar, on the others, butter, saffron and honey. The lot was covered with resin to prevent the entry of air, then a cloth covered in wax and a poultice of herbs. For three weeks the dressing was changed daily, till a square of the outer layer of bone came off. The resin had killed the outer layer chemically, but kept it sterile because the resin killed bacteria too. Finally natural processes of bone separated off the dead bone at the middle layer of the skull.

If the cut scalp exposed much bone but there was no fracture, trepanning was limited to the outer layer. If left exposed the bone would dry, die and become infected. Hence, the outer table was removed to expose the middle table, which had more blood supply, could survive, stay moist, and resist infection better.

Removing the outer table was often done with a "rugine", a rasp or gouge that could remove dead bone, or bone that seemed likely to die. Hernando Cortés' skull (see earlier) was "ruginated" by his artilleryman surgeon to remove dead bone. This leaves a mark on the skull which has been called "partial" trepanation.

The intention of some operations was to find and drain blood from within the skull under the fracture. If any were found, it was wiped away with a bit of wadding on the end of a feather, as in Lorenzo de Medici's operation (Martin, 1997) and in the Serbian tradition (Trojanovič, 1900).

Wounds were dressed with a variety of substances, mostly benign, practical and unsurprising—honey, butter fat and powdered herbs for instance. In reality, a few dressings were strange, exotic or disgusting. They make good stories, and so gain more prominence than they deserve. If the scalp sewn up at all, it was only one or two stitches, left very loose, to let the wound drain. Only the Tolai of New Britain (see below) sewed the scalp up to close it.

Non-Hippocratic Traditions of Trepanation

Trepanation in Africa and the Pacific will be surveyed, to examine its reasons, technique and development. The best bibliography of trepanning is still in Brothwell and Sandison 1967 (chapters by Courville, Lissowski and Margetts).

The East African Tradition

Trepanning on the North African shore is part of the tradition of the Mediterranean littoral and Eurasian land mass, a practice founded in the care of head wounds. In East Africa is a separate tradition based on the management of headache. Among the Kisii of Kenya and Uganda trepanning survived, at least till the 1990s (one of the neurosurgeons in Kampala told the author in 1997 that it was still done), despite intermittent Government efforts since the 1950s to stamp it out. Similar trepanning was done, and perhaps continues, in Tanzania, southern Sudan, Somalia and Ethiopia (Margetts, 1967; Coxon, 1962; Grounds 1958; Fraser 1989). It is done for headache, and though the holes are wider than usual, they avoid going right through the bone. A channel or ellipse, about 5 inches long (15 cm), and a little more than an inch wide (3 cm), is gouged into the crown of the head, and the scalp wound allowed to close by scarring. Without hats, the trepanned are obvious.

The operation is learned by apprenticeship, to one's father or another surgeon, for one to five years, and helping at some 25 to 50 operations. At the end of the 1950s, there was one surgeon to every eight or twelve thousand people (about 500 operations a year were done by 20 to 30 trepanners among about 250,000 Kisii). The death rate from operation was about six per thousand operations because the dura was not penetrated. Repeat operations and dural tears cause most deaths, because scarring makes normal structures harder to find and easier to tear.

To trepan for headache is not unreasonable. Headaches after injury to the skull are common, and a cut in the scalp will relieve many headaches for months. Probably a new source of pain in the scalp suppresses the old headache, by competing for, occupying and blocking, the same pain pathways to the brain, just as acupuncture or the old mustard plaster did. Probably most of the trepanned benefitted, because at least for a while, if the headache came back, some returned for a second or even third operation.

The technique is fairly standard. The patient lies or sits on a bed of leaves, with the head on a small log. Relatives usually held the patient, but one surgeon was an innovator, he operated with the patient on one bed and another upside down on the patient, on that, two relatives sat. A special traditional trepanation instrument was used, a U-shaped gouge with a blunt curved tip, cutting on the sides of the U but not the bottom, so as not to cut the dura mater around the brain. Great stress is laid on that for very obvious reasons. Not all surgeons use this traditional blunted instrument, others use a small saw. Quite large areas of bone may be removed, up to five inches in diameter, sometimes in several sessions of three hours or more. The dressing at the end of the operation is melted fat or butter. As in Europe in the past, the scalp is not sewn up, but allowed to heal by scarring.

Trepanning in the South Pacific

From Indonesia and Australia a vast scatter of islands spreads eastwards towards South America, aptly called "The Watery Continent" (Fig. 6). Trepanation is done on only a few islands, which raises the question "Can you invent trepanation by yourself, or must you be taught by a trepanner?.[1]

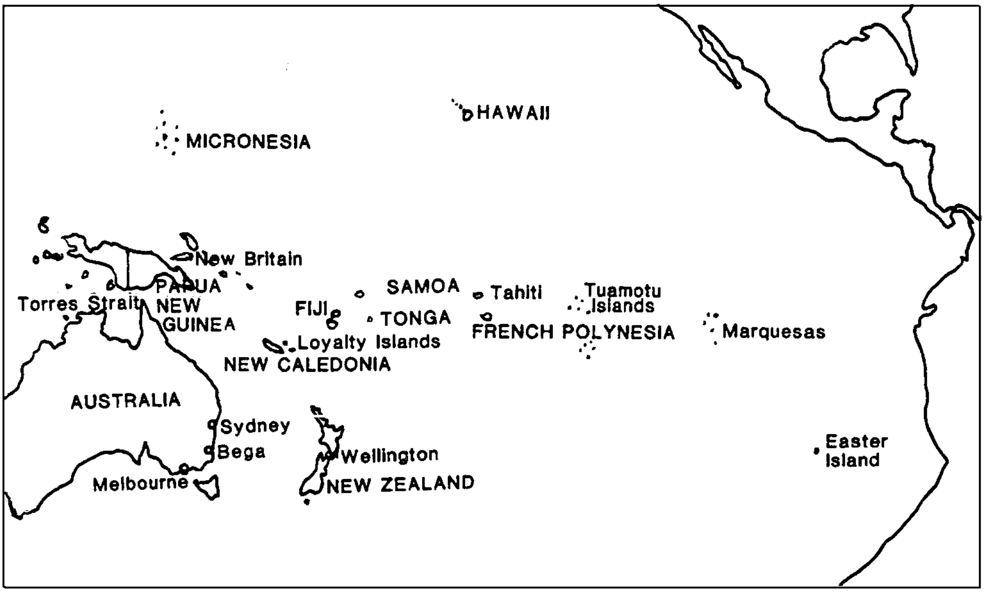


Figure 6. Map of the South Pacific.

The Trepanners of New Britain, New Guinea

The most successful trepanners of the nineteenth century were the Tolai of New Britain, an island off the coast of New Guinea. Though Neolithic and unknown to the rest of the world, for open fractures of the skull they had 75% survivals (Martin, 1995; Brodsky, 1938; Parkinson, 1907). While the Tolai had good results, surgeons in London had a mortality of 78% for trepanations at the teaching hospitals of Guys, St Thomas and St George. In the eight years around 1870, only 86 trepanations had been done, eleven a year, in the whole of London (Ballance, 1922).

The Tolai secret was they used completely casual instruments, not re-used on other patients, so they could not spread infection. Moreover, they did not operate in infection-soaked hospitals, but in the open air. The knives were of split bamboo or obsidian and the bone was cut by gouging with a sharp bit of shell or stone. The wound was washed out with fresh coconut milk, which is sterile. The dressings were of fresh leaves and vines. They stitched the skin with coconut fibre and a needle of bone from a bat's wing. All these had bacteria adapted to their own environment, not proliferating in human wounds.

Both slingers and cannibals, the Tolai had many open fractures, and knew their anatomy. Trepanning continued into the 1930s (Brodsky, 1938), but after the Second World War the knowledge died. About 1989, a surgeon working among the Tolai asked his surgical trainees, but none knew that trepanning had once been a local art (Hamilton, 1990).

Parkinson (1907) recorded why the Tolai thought the operation worked. Two especially healing substances, *mailan* and *aurur*, must be blown into the air, hung around the patient's neck, or fixed somewhere else on the body. Without these the operation was unfinished and could not end favourably.

"Ritual" Trepanation in New Ireland

The idea of operation being a powerful force for good was perhaps why, in nearby New Ireland, women trepanned their children so they would grow up tall and straight. If the child were sickly, some tried it several times. Luckily, nothing much went wrong with the operation, and no one thought any children died from it (Parkinson, 1907). The trepanning was only superficial. In the shallows of a stream the mother cut the forehead, and with a broken shell, gouged a groove in the bone, about a centimetre long and a millimetre wide, but not through the skull. They told Parkinson (1907) they did nothing magical or mysterious, this was normal upbringing, not a ritual of social or individual significance, it should be done now, so it was not needed later. Doing it early, the children would grow up free from headaches, madness or epilepsy. The fact that so few suffered these, meant they were right.

New Caledonia

The trepanners nearest the Tolai of New Guinea were 1,600 miles distant, in New Caledonia, on the islands of Uvea and Lifou (Nicholas, 1908). Their surgical methods were similar, and they trepanned for the same sort of open depressed fractures, but also for other reasons, in the hope that it might do some good. They thought much illness was due to cracks in the head, so trepanation was the cure for headache, epilepsy, depression and sometimes even just poor health.

Could the trepanners of Uvea and Lifou in New Caledonia have learnt from the Tolai of New Guinea? Possibly. The islands are 1,600 miles apart, as far as London and Crete, or New York and Yucatan, and no one trepanned on the islands in between. About 2,000 years ago, traders sailed between the two regularly, carrying natural volcanic glass, or obsidian, from the volcanos of New Britain to the islands of New Caledonia (Finney, 1985; Bellwood, 1987). With that trade, the idea of trepanation could have travelled, though the only evidence is that the surgical techniques were similar. Also, in both New Caledonia and New Guinea slingshots were used. They make the sort of in-driven head wound that most benefits from trepanation, so both places needed trepanners.

Tahiti and French Polynesia

Yet another 3,000 miles to the east of New Caledonia, is the third island group where trepanation was done, French Polynesia. Tahiti is its jewel and capital. There, and especially on nearby Bora, the healers trepanned and replaced any bone lost from the skull by a piece of coconut shell (Ellis, 1829). Polynesian medicine and surgery were as good as ancient Greece (Ella, 1874). Abscesses were opened, wounds stitched, broken bones well set, backs manipulated and massaged, and trepanations done. For things that surgery could not help there were native herbs and medicines.

Could the Trepanners of Eastern Polynesia have learnt from South America?

In the early 1920s, a visitor to the easternmost islands of Polynesia, the Marquesas, photographed a trepanned skull there (Handy, 1923). Another visitor, Thor Heyerdahl, in 1936, met a trepanner's son, who knew his father had trepanned, but not how (Heyerdahl, 1974).

The Marquesas are the last Polynesian islands, before the great water gap to South America. Some, including Heyerdahl, have thought that both potatoes and trepanning may have reached these islands together from South America (Wölfel, 1925). Genetic research has proved the earlier opinion that Polynesia was populated from East Asia, from Taiwan through Indonesia, with a contribution from Melanesia (Underhill et al., 2001). The same group is examining the evidence for a genetic contribution from South America.

The potato certainly came from South America, where it has its wild origin (Bellwood, 1987). Throughout Polynesia, the sweet potato has the same name, *kumara*, as it had in Quechua, the language of the Incas. The potato appeared first in Eastern Polynesia about 500 AD, after Polynesian sailors reached South America and brought it back. Their great double hulled canoes were seaworthy enough, and the constant easterly Trade Winds would take them easily to South America (Finney, 1985). Getting back was the problem. Normally the winds would be against them in every season, but in some years, El Niño years, the weather is opposite to normal throughout the Pacific, and the winds reverse for a season. Then sailing back is easy. El Niño years are now about once every ten years, but may have been commoner in past centuries.

From East Polynesia, after 500 AD, the last remaining uninhabited lands of the Pacific were settled. Until the weather changed about 1,300 AD, colonists planned voyages to settle distant lands, taking the potato and other useful plants with them. To Hawaii they sailed, 2,500 miles north, to Rapa Nui (Easter Island) 3,500 miles east, and 3,000 miles west to Aotearoa (New Zealand) (Bellwood, 1987). The potato went with the colonists, but no trepanners went to any of those lands.

Thus, trepanning must have developed locally in French Polynesia, after the last of the great migrations left, about 1,300 AD. It did not travel from South America with the potato, neither did it accompany the potato around the Pacific.

Australian Trepanation

Most Australian indigenous culture is extinct and lost. Two trepanned skulls are now the only memorial to a vanished skill in surgery. We are not sure from what tribe, or even from where, the skulls came (Webb, 1988). In the Museum of Victoria is a trepanned skull from the Northern Territory, but who collected it, and from where, is unknown. The forgotten surgeon gouged a U-shaped groove across the crown of the head. The hole in the inner surface of the bone, about half an inch wide, was not so much bored down into the skull as scraped tangentially across it. Its symmetry and neatness suggest that a shell was the gouge. The patient survived the operation and the wound healed.

The second skull came from Bega, New South Wales, and little is known of its history either. The technique of trepanation was different from the first. On the crown of the head a wide, boat-shaped area had been scraped away. Four inches long and two wide, it spread from just behind the hair line to the back of the head and resembled the method of trepanation used by the Kisii of Uganda and Kenya. Also, like the African tradition neither of the two Australian skulls had a fracture. So, among the Australian Aborigines two different styles of trepanation developed in widely separated areas. Thus, trepanning can be invented locally.

Conclusion

Why would you teach yourself to Trepan?

When accidental scalp flaps and lacerations are not stitched immediately, the sight of bared skull becomes familiar to someone interested in wounds. The healer would then get to know the cycle; the outer layer of the bone dries out and dies, then months later drops off in the constant flow of pus. Only after the dead bone drops out can the scalp begin to close over the living bone that remains. For weeks or months before the bone is cast off, the demarcation between living and dead bone is obvious. While the open wound pours pus, some will die with the headache, fever and convulsions "Hippocrates" described.

It is technically simple to take a sharp flint and start picking away at the dead bone. Surprisingly it is painless; once the skin is cut, skull surgery does not hurt. Speeding up the closure by cutting away dead bone is then simple and obvious. Removing projecting fragments from recent open skull fractures, so the wound can close, is the next step. You could teach yourself to trepan.

The Mythology of Trepanation

Perhaps trepanation has no theoretical background. Searching for a deep mythical meaning may miss the point that trepanning was something practical, a skill. De-horning cattle, surprisingly, may be an apt analogy. This involves cutting off, not just the horn, but also the bony core of the horn growing out from the bone of the skull. Cutting the core exposes the vascular middle table of the skull, which heals as scar and skin close over it. It is just like removing the outer table of the skull in trepanation, and has a similar low mortality (if it rains in the next couple of days a few may die, because a good scab does not cover the bone). If cattle were bred without horns, the practice abandoned as cruel, or the population stopped eating meat, the practical details would be quickly forgotten.

Likewise, if tribal fighting stops, there are no longer so many head wounds, and indigenous surgery is replaced by hospital surgery, then the skills of tribal surgery will die with their practitioners, practical arts displaced by global change. If this is so, then it would explain why in the 1980s the Tolai surgical trainees were unaware their ancestors had been trepanners. In the fifty years since the last trepanner in the 1930s, they had been conquered by the Japanese, returned to Australian rule, a local hospital service set up, and become independent. So much had changed that a practice without deep social roots had died out. In contrast, trepanation persists among the Kisii of East Africa, because it is normal health care for bad headaches, something for which even the most sophisticated health service has no answer.

Our culture is the exception. To us the brain is a high status organ, so operating on its box is very important. In other cultures the brain is less significant; the Egyptians threw it away when making mummies (Nunn, 1996), Aristotle thought it a sponge to cool the blood; emotions were in the heart (Singer, 1957). Indeed, it may be more to the point to discuss why some people never trepanned. Perhaps some think fatalistically about the wounded, and for others the head is too socially important to be touched. In our society trepanation was never routine because we were awed by the idea of surgery to the coverings of the brain. Also, advice from "wise men" was viewed sceptically.

Note

1. The Japanese seem not to have trepanned; the author has lectured in Japan on "Trepanning in the South Pacific", yet not heard of any traditional Japanese trepanning (but lack of evidence does not prove absence). The Ainu in Northern Japan were said to, perhaps part of a Siberian tradition of trepanning, but the reference has not been obtainable (Boev, 1959).

References

Adams F (1844): *The Genuine Works of Hippocrates, Translated from the Greek. On Wounds of the Head*. London, printed for the Sydenham Society, reprinted for Huntington, New York, Krieger, 1972.

Ballance C (1922): *The Thomas Vicary Lecture: A Glimpse into the History of the Surgery of the Brain.* London, MacMillan and Co Ltd.

Barnes JK (1875): *The Medical and Surgical History of the War of the Rebellion (1861–5).* Washington, Government Printing Office, 1875. Vol II part 1.

Bellwood P (1987): *The Polynesians, Prehistory of an Island People*. Revised edition. London, Thames and Hudson.

Berengario da Carpi J (1519): *Tractatus perutilis et completus de Fractura Calvi sive Cranei,* (Thoroughly Useful and Complete Description of Fractures of the Brain Pan or Skull), translated by Lind LR (1990). *Trans Am Philosoph Soc 80*: 1-1-163.

Boev P (1959): Trépanations d'interêt historique (Trépanations historiques). *Bull Inst Morph Acad Sci Bulg 3*: 197.

Brodsky I (1938): The trephiners of Blanche Bay, New Britain, their instruments and methods. *Brit J Surg 26*: 1–9.

Brongers JA (1969): Ancient old world trepanning instruments. *Berich Rijks Oudeheit Bodemondezoek 19*: 7–16.

Brothwell D, Sandison AT (eds.) (1967): *Diseases in Antiquity*. Springfield, Illinois, Charles C Thomas.

Corsini A (1913): *Malattia e morte di Lorenzo de" Medici, Duca d'Urbino; studio critico di medicina storica.* Florence, Istituto Micrografico Italiano.

Courville CB (1967): Cranial injuries in prehistoric man. In: Brothwell D and Sandison AT (eds.), *Diseases in Antiquity*. Springfield, Illinois, Charles C Thomas, pp. 606–29.

Coxon A (1962): The Kisii art of trephining. *Guy's Hosp Gaz 76*: 263–266.

Ella S (1874): Native medicine and surgery in the South Sea Islands. *Medical Times and Gazette,* January 10: 50–1.

Ellis W (1829): *Polynesian researches (during a residence of nearly six years in the South Seas Islands; including descriptions of the natural history and scenery of the islands – with remarks on the history, mythology traditions government arts manners and customs of the inhabitants).* London, Fisher and Son, Jackson, 2 vols.

Fraser AG (1989): Medicine in rural Kenya: a personal perspective. *NZ Med J 102*: 15–7.

Finney BR (1985): Anomalous westerlies, El Niño and the colonisation of Polynesia. *Amer Anthrop 87*: 9–26.

Grounds JG (1958): Trephining of the skull among the Kisii. *E Afr Med J 35*: 368.

Grounds JG (1958): Trephining of the skull among the Kisii. *Current work in the History of medicine, 35*: 368.

Gomez JG (1973): Paleoneurosurgery in Colombia. *J Neurosurg 39*: 585–8.

Hamilton D (1990): personal communication. Mr David Hamilton was then the senior surgeon in Rabaul, Papua-New Guinea, the capital of New Britain where the Tolai live.

Handy ES (1923) The native culture in the Marquesas. Beatrice C. Bishop Museum, Bulletin 9, Honolulu, Bayard Dominick Expedition.

Heyerdahl T (1974) *Fatu hiva*. London, George Allen and Unwin.

Hilton-Simpson MW (1913) Some Arab and Shawia remedies and notes on the trepanning of the skull. *J Roy Anthrop Inst 43*: 715–21.

Hudson R (1877): On the use of the trephine in depressed fractures of the skull. *British Medical Journal*, July 21: 75–6.

Jensen RL, Stone JL (1997): Benjamin Winslow Dudley and early American trephination for post traumatic epilepsy. *Neurosurgery 40*: 263–8.

Lissowski FP (1967): Prehistoric and early trepanation. In: Brothwell D and Sandison AT (eds.) *Diseases in Antiquity*. Springfield, Illinois, Charles C Thomas: pp 651–72.

Littré É (1846): *Oevres complètes d'Hippocrate*. Traduction nouvelle, Tomes V et VI. Paris, JB Baillière.

Lloyd GER (1975): The Hippocratic Question. *Classical Q 25*: 171–92.

Margetts EL (1967): Trepanation of the skull by the medicine men of primitive cultures, with particular reference to the present day native East African practice. In: Brothwell D and Sandison AT (eds.), *Diseases in Antiquity*. Springfield, Illinois, Charles C Thomas: 637–701.

Martin GT (1989): Successful drainage of an extradural abscess in 1667. *Brit J Neurosurg 3*: 211–6.

Martin GT (1990): Prince Rupert and the surgeons. *Hist Today 40*: 39–43.

Martin GT (1995): Trepanation in the South Pacific. *J Clin Neurosci 2*: 257–64.

Martin GT (1996): The trepanation of Lorenzo di Medici, 1517. *Proc Int Conf Recent Advances in Neurotrauma*. Rimini, Italy.

Martin GT (1997): Trepan and Trephine, letter. *Brit J Neurosurg 11*: 588.

Martin G T (1999): Craniotomy in first case records. *J. Clin. Neuroscience 6*: 361–363.

Martin GT (2001): A sporting death and post mortem, Henry II of France. *Aust NZ J Surg 71*: 318–20.
Mays B, Parfitt A, Hershman MJ (1994): The treatment of arrow wounds by nineteenth century USA army surgeons. *J Roy Soc Med 87*: 102–3.
Nicholas C (1908): Pratiques chirurgicales des Canaques des îles Loyalty. *Soc path exot Bull 1*: 582–9
Nieuw Nederlandsch Biographische Woordenboek, Leiden (1911): Entry for Filip van Nassau.
Nunn JF (1996): *Ancient Egyptian Medicine*. London, British Museum Press.
Oakley KP, Brooke W, Akester AR, Brothwell DR (1959): Contributions to trepanning or trephination in ancient and modern times. *Man,* 59–93.
O'Malley CD (1964): *Andreas Vesalius of Brussels 1514–1564.* University of California Press, translations of Vesalius' records concerning Don Carlos.
Parkinson RH (1907): *Dreissig Jahre in der Südsee*. Stuttgart, Schrecker u. Schroeder.
Piggott S (1940): A trepanned skull from Dorset, and the practice of trepanning in prehistoric Europe. Part II, Trepanning in prehistoric Europe. *Proc Preh Soc 6*: 112–32.
Prescott WH (1899): *History of the Conquest of Mexico*. London, Routledge.
Pott P (1790): *The Chirurgical Works of Percival Pott* (3 vols). London, J Johnson.
Riché P (1992): *Les Carolingiens. Une famille qui fit l'Europe*. Paris, Hachette.
Rifkinson-Mann S (1988): Cranial surgery in ancient Peru. *Neurosurgery 23*: 411–6.
Singer C (1957): *A Short History of Anatomy and Physiology from the Greeks to Harvey*. New York, Dover Publications Inc.
Spencer WG (1961): *Celsus de medicina* (with an English translation). London, Heinemann.
Steinschneider M (1908): Trepan eines Melancholischen im XIII Jahrhundert, aus einer hebraischen handschrift mitgeheilt. *Archiv path Anat klin Med 71*: 131–2.
Stone JL and Miles ML (1990): Skull trephination among the early Indians of Canada and the United States. *Neurosurgery 26*: 1015–20.
Thomas H (1993): *The conquest of Mexico*. London, Hutchinson.
Trojanovic S (1900): Die Trepanation bei den Serben. *Corr Blatt Deutsch Gesell Anthrop Ethnol Urgeschichte Munich 31*: 18–24.
Underhill PA, Passarino G, LinAA, Marzuki S, Oefner PJ, Cavalli-Sforza LL, Chambers GK, (2001) *Human Mut 17*: 271–80.
Vara Lopez RI (1949) *La craniectoma, a través de los siglos*. Valladolid.
Védrènes A (1885): La trépanation du crâne, chez les indigènes de l'Aurès (Algérie). *Rev de Chir 5*: 817–38, 907–28, 974–96.
Velasco-Suarez M, Martinez JB, Oliveros RG, Weinstein PR (1992): Archaeological origins of cranial surgery, trephination in Mexico. *Neurosurg 31*: 313–19.
Walmsley T (1923): A trephined Irish skull. *Man, 23*: 180.
Webb SG (1988): Two possible cases of trephination from Australia. *Am J Phys Anthropol 75*: 541–8.
Wölfel DJ (1925): Die Trepanation. Studien über Ursprung, Zusammenhänge und kulturelle Zugehörigkeit der Trepanation. *Anthropos 20*: 1–42.

Chapter 24

An Overview from Neolithic Times to Broca

F. CLIFFORD ROSE
London Neurological Centre, London, UK

Abstract

The literature of trepanation is large with over 1,000 references. Although the terms of trepanation and trephination have been used interchangeably, the former is derived from the Greek *trypanon* meaning a borer whilst the word trephine is of more recent French origin, being derived from the Latin words *tres* (three) and *finis* (ends). Both techniques are more than making a depression or perforation of the calvarium since they entail removing a piece of bone. Not all holes in skulls were made by human hands and these have been grouped as pseudo-trepanation. The earliest known trepanned skulls date from 10,000 BC and were found in North Africa. A distinction is made between the trepanned skulls found in Europe and those found in South America: the former are from about 3,000 BC, while the latter are from the two millennia between 500 BC and 1,500 AD. Although most of the literature has concentrated on the Peruvian and French finds, trepanned skulls have a widespread geographic distribution and different surgical techniques have been used. The hypotheses for the rationale of these ancient operations are conflicting but the therapeutic indications have varied from the Graeco-Roman epoch through the Middle Ages until recent times. Broca, the father of anthropology, initiated the modern studies, particularly by his recognition of healing as indicating ante-mortem surgery.

Keywords: Broca, Pseudo-trepanation, Peru, France, North America, Africa, Europe

Introduction

The finding of skulls with openings has intrigued mankind since Broca showed that many were made during life. By 1985, 1,500 ancient trepanned skulls had been reported and papers on this subject, of which there are now more than one thousand, are scattered throughout clinical, archaeological, anthropological, ethnological and historical writings. In this chapter we consider the definitions, epochs, geography, surgical techniques and rationale of this ancient procedure.

Definitions

The etymological derivation of the word trepanation is from the Greek *trypanon* meaning a borer, an instrument used in operations on the skull since Neolithic times where the head is kept still by “a frame or brace similar to, and used in the manner of, the carpenter's wimble, ie a gimlet or auger used to bore a hole" (Walker, 1959).[1] The word trephine is derived from the Latin *tres* meaning three and *finis* for end, a term introduced by Woodall in the seventeenth century when he added a handle to a trepan; it has been used, however, to indicate any instrument ending in a sharp point, so that trephination "implies using a cutting instrument rotating around a centre" (Walker, 1959), i.e., a hole made by a circular saw. Both techniques entail removal of a piece of bone with a saw-like instrument (Rose, 1997). Pait (Stone and Miles, 1990) states that trepanation now refers to any hole made in the skull, irrespective of method, whereas trephination implies removal of a disc of bone. The terms trepanation and trephination are, however, often used interchangeably.

Pseudo-Trepanation

Trepanned skulls have to be distinguished from perforations due to such diseases as mycoses, trepanomatosis and tumours, as well as variations in size of foramina and bone thickness; holes can also be due to post-mortem changes from erosion, trauma or the process of excavation. "Pseudo-trepanation" could also have been due to developmental defects or gnawing by animals.

Epochs

The oldest trepanned skulls were found in North Africa, dating from about 10,000 BC (Ferembach, 1962) and in the Jericho area of the Near East, from about 7,000 BC. The operation had been performed approximately 3,000 BC by tribes on the banks of the Danube and had spread to central Europe and the Balkans. Prunières (1872) gave evidence of antemortem operations in the Neolithic period (ca 3,000 BC) in skulls from stone tombs in Southern France. Trepanation was first recorded in the Graeco-Roman literature by Hippocrates in the fifth century BC, when it was known that, by perforating the skull, blood within the cranial cavity could be removed. If a fracture were present there was no need for trepanation since, although not explained, this would allow an exit for any fluid accumulation, be it blood or pus. If there were no fracture, prophylactic trepanation was then advised, but not over a suture or the temporal region, but again no rationale for these prophylactic operations was given.

Celsus in the first century AD was familiar with extradural haematoma, even in the absence of a skull fracture. Heliodorus also mentioned the operation as did Galen, both in the second century AD, but without relating the operation to "disease of the head" which Pliny the Elder considered to be the third most painful illness of mankind.

Geography

South America: Peru

Ancient Peruvians were highly cultured, tilled fields, mined quarries, wove materials, grew grain, built roads and were renowned for their architecture and astronomy. They introduced the treatment of quinine in fever, copper sulphate for pyogenic processes, and mercury for disease that may have been trypanosomiasis.

That the practice of trepanation was widespread is undoubted since two thousand Peruvian trepanned skulls have been found from 500 BC to 1,506 AD. There is no real evidence that the operation was practised after the Spanish arrived in 1532 (Verano and Williams, 1992). Of these 2,539 had been reported by the year 1988 (Rifkinson-Mann, 1988).

The estimated rate of holes in the skulls found in Peru varied "…from zero in Machu Picchu to nearly 40% in certain valleys, averaging 5% overall" (Aufderheide, 1985). Most skulls were found in or near the Andes where the environment is conducive to burial preservation. Manuel Antonio Muniz, when Surgeon-General of the Peruvian Army, collected about a thousand skulls, only nineteen of which showed trepanation. After an exhibition in Chicago, two were left in the United States, one in the Army Medical Museum (McGee, 1894).

Skulls from the necropolis of Paracas, a desert strip south of Lima, date from the fifth century BC to the fifth century AD, the earlier ones resembling the Neolithic skulls of France. Of the two hundred and fifty skulls studied intensively, 68% were male, 17% female and 15% of undetermined sex.

Elsewhere in South America

Non-Peruvian specimens in South America are comparatively rare, e.g. three from Columbia (Gomez, 1973) all of which showed parietal trepanation. The rarity of trepanned skulls in the Columbian Andes may be due to the heavy ground moisture causing organic material to decompose rapidly, as opposed to desert climates which favour archeological preservation (see Verano, this volume).[2] Trepanned skulls have also been found in Bolivia and Ecuador.

Mexico

Until 1992, 34 trepanned skulls had been found in Mexico and Central America, the number from Mexico varying from 16 (Velasco-Suarez et al., 1992) to 12 (Marquéz Montín and Gonzáles Licón, 1992). The tribe of Tlatilcas, from the high plateau of Mexico, left trepanned skulls which have also been found in Chichen Itza, Yucatan; Palenque, Chiapas; and in Oaxaca at Monté Alban and Monté Negro.

North America

Up to 1990, there were 19 reports of perforated skulls from North America, excluding Mexico; of these 19, eight were from the United States, two of which came from New Mexico (Stone and Miles, 1990).

Of the 11 Canadian skulls, eight came from British Columbia; they were all adults with an estimated age of between 20 and 60 years (Stone and Miles, 1990); the majority were male and, of those dated, most were pre-Columbian. The shape of the holes was circular or oblong with an average diameter of 3 cm (range of 1–5 cm). No fractures were found in any and nearly all were considered to have survived the operation.

France

The first trepanned skull in France was found in 1685 in Cocheral and the second in 1816 in an ossarium of 900 skeletons in Nogent Les Vinages, France. The realisation that they were man-made was recognised only much later by the findings in the Neolithic grottoes of the Lozère region (Prunières, 1872). There was perhaps a locus in southern France from 1,900–1,500 BC and later in the Paris area. By 1911, eight trepanned skulls had been found in a Neolithic tomb in Vendrest, 80 miles east of Paris (Rogers, 1930). The Broca Museum of Anthropology in Paris contains 60 specimens of perforated skulls, ten of which are fairly complete. Although Walker (1959) wrote that the number in the rest of Europe "could be counted on the fingers", this statement is no longer true (Finger, 1994).

Italy

There are few reports of trepanned skulls from within the confines of the Roman Empire (Brothwell, 1974; Jackson, 1988). Three trepanned skulls have been found in Italy (Scattarella et al., 1996; Capasso et al., 1995), only one of which was in a child (Belelli Marchesini, 1986; Mariani-Constantini et al., 2000).

Elsewhere in Europe

Trepanning has been found in Norway (Dietrichs and Stien, personal communication) and Bohemia as well as the Baltic states (Ruffer, 1918–19). Of 4,000 human skeletons found in the latter sites, there were ten possible trepanations of skulls carried out between the Bronze Age and the seventeenth century AD. One found in Latvia in the early 1970s dates from the middle Neolithic period (ca 2,500 BC) and shows an extensive trepanation of 120 x 60 mm. It is estimated he survived at least a year after the operation (Derums, 1979). Trepanned skulls have also been found in Southern Serbia (Murphy, this volume) as well as the UK (Roberts and Mckinley, this volume).

Africa

A few trepanned skulls have been found in Africa, most commonly in Algeria, where the blonde Kabyles tribe have practised the operation for headache, even to modern times. Trepanned skulls have occasionally been found in Kenya and Ethiopia but none in South Africa. It is debatable whether the operation was practised in Egypt.

Asia

The operation is limited to Melanesia where it is still carried out, but there is no evidence that it was practised in China or India, although trepanations have been reported from Mongolia (Bazarsad, this volume) and Russia (Mednikova, this volume).

Surgical Techniques

Anatomy

Usually, but not always, the fenestrations were round, varying in size up to half the skull. The number varied from one hole to several, the latter especially in skulls considered as subjected to trauma. Trepanations often cross suture lines.

The techniques used varied, depending on time (epochs) and space (geography). The perforations from Inca and other late cultures in Peru were made using a metallic instrument of bronze or copper called a *tumi,* but earlier cultures did not use metal. Since about half the patients survived, it is likely that the operation was stopped when the dura was reached.

Many skulls show multiple healed trepanation openings, the record being seven in a skull from Cusco, dated ca 1,000 AD, now in the British Museum. The multiple (usually 3–5, sometimes 7) craniotomy defects were usually over the convexity but occasionally over the posterior fossa, not excepting the sutures. Up to 12% of the cranial vault could be removed by a single defect, but 16% had multiple defects (Bakay, 1985). They were of four main types:

1. *Scraping*: This technique penetrated the outer table and diploë reducing the inner table to a slither. This clearly indicates that great care was taken to avoid penetrating the dura.
2. *Grooving or Sawing*: This was either in a circular or linear style. In the latter instance, four linear incisions in parallel pairs intersecting at right angles were made to form a rectangular hole. The grooves at the corners of the rectangular openings would overlap (Froeschner, 1992). "Square opening" trepanation, made by cutting from rectangular grooves and prying loose a piece of skull, is typical of South American trepanations. In Peru, four cuts were occasionally made in noughts-and-crosses (tic-tac-toe) fashion leaving a square or rectangular hole. The incisions were narrow, V-shaped in cross section, and gradually increasing in depth from ends to centre, thus indicating that the in-

strument was a pointed bit of stone or arrow-head held vertically and operated by reciprocal motion, i.e. a to and fro motion (McGee, 1894, p. 1). The incisions extended about half an inch beyond the fenestration. An elliptical fenestration could be made by two curved incisions; there was evidence that there was some scraping of the jagged surfaces left by the cuts.

3. *Drilling or Boring*: One particular method was to obtain a hole by removing walls between several small bore holes. In the latter case, a type of hammer and chisel was used, initially stone and often obsidian (volcanic glass), which provides a smooth edge that may promote healing and could be as effective as modern steel. The handle was wooden and the instrument was called a mochica, after the Mochica culture that preceded the Incas. This instrument continued in the south of Peru, in Paracas, but in the north was replaced by metal tumis, and multipurpose curved knives with straight or crescentic blades and a short, central, T-shaped handle (Trelles, 1962). Other cutting tools were made of flint or quartz, chipped to produce sharp edges. Later in the operation a tumi was used for repeated scraping, which involved the gradual removal of the layers of cranial bone until the inner table had been opened and the dura exposed. This produced fairly large, mainly oval, openings but, in all cases, it is assumed that the dura was not penetrated and hence the brain spared.

4. *Chiselling*: A technique using a stone hammer and flattened nail was employed by the Aymara in highland Bolivia, whilst Melanesians used shark's teeth or shells as instruments. North American trepanned Indian skulls were probably made by scraping with a flint or obsidian knife or stone so that the outer table was larger than the inner table; trepanation with removal of a disc of bone was performed much later by white immigrant doctors.

Stewart (1956) reports the studies he made of 75 trepanned skulls in the United States National Museum. The angular type of trepan opening was favoured in the central areas of Peru, as was the rarer type of a series of drilled holes. The circular trepan opening was seen in the south of Peru where scraping was more commonly seen than elsewhere. The operation was rare in the north and central coasts with a localised centre in Paracas on the south coast, and common in the central and southern highlands.

In the autumn of 1972, 25 human skeletons were found at an archaeological site in Monté Alban, Oaxaca. One, dated ca 650 AD, was of a 30 year-old male, whose skull had openings on the right parietal bone. Smooth circular holes with vertical walls are suggestive of drilling, which is virtually unknown in Peru and Europe (except Mallorca). Such drilling was restricted to the southern highlands of Mexico, where drilling of teeth was common, derived from jewellers' techniques (pre-classic period of 900–600 BC) which involved incrustation, i.e. providing an inlay for the drilled hole. Besides highland Mexico, prehistoric drilling may have been seen in a skull found in a cave in southern Chihuahua (probably from the post-classic period). Since none of the drilled skulls showed closure of diploë, considered evidence of post-operative healing, it suggests that this form of operation was not as successful as the techniques of scraping and cutting (see Stone, this volume).

Position

The patient may have been held between the knees of the operator with further fixation by the left arm while the right hand was used for the operation.

Anaesthesia

In Peru, topical application or chewing the leaves of *Erythoxylon coca* could have produced anaesthesia, as could other herbal preparations, such as yucca and datura. Alcohol prepared from grapes or maize might also have been used; other alcoholic drinks included "chicha" and "Masata", but whether such agents were used is not certain.

Haemostasis

Crushed dry leaves giving a large surface area may have helped with haemostasis, as would compression with limestone or application of plant abstracts such as "ratania" and *Pumacbuca* shrub, rich in tannic acid (Rifkinson-Mann, 1988). Instruments such as broad-jawed pinchers have been found in Peruvian instrument kits.

Healing

Survival following operation is indicated by vital bone reactions due to healing or infection. Healing is recognised by closure of the diploë at the margins of the trepanation, as well as smooth incisional borders and the presence of osteophytes. The evidence that the patients survived the operation is that there was partial absorption of the surrounding outer table and diploë, as well as "spicules of regenerative growth". Post-operative death within a few days is indicated by porosity of the bone surrounding the cuts.

Osteitis

The bone reaction to damage has been called "osteitis", which "is usually septic, but may be due to other irritants. I am not sure that it is always possible to distinguish the bone changes due to these different causes" (Stewart, 1956). Previously osteitis had been explained in three ways:

1. post-operative and hence a cause of death,
2. pre-operative and hence the reason for the operation and,
3. post-mortem, ie caused by agents of decay following death (Stewart, 1956).

Grana et al. (1954), stated that the "first extensive description of American trepanned skulls is that by Muñiz and McGee (1897)", and pointed out that "Muñiz was simply the collector of the specimens and McGee – a self-trained anthropologist – was the writer. Lacking a medical training, McGee failed to appreciate the evidence of bone infection"

(Grana et al., 1954). They reviewed a monograph by three members of the Faculty of Medicine of Lima, Peru, which detailed 250 trepanned skulls, then "probably the largest number in any one study".

Stewart (1956) points out septic osteitis spreads irregularly unless limited by anatomical barriers, such as muscle attachments and suture lines, where there are periosteal attachments. The angular patterning of osteitis suggests that another barrier to irregular spreading of osteitis is the surgical opening in the scalp. It may be that the ancient Peruvian surgeons completely removed a large angular piece of scalp preparatory to trepanning the scalp, but this is uncertain (Stewart, 1956).

Rarely is "the pock-marked deformity characteristic of suppurative osteomyelitis" seen (Aufderheide, 1985). The reason infection was rare is that wound infection is a relatively modern complication, perhaps because of congregating patients in hospitals.

Survival

As a research illustrator on the staff of the Smithsonian Institution Museum of Natural History, Froeschner (1992), studied two trepanned skulls; one was a male Peruvian warrior in his early twenties who showed infection around the cranium, seen as a reddish-brown area on the surface and in the dipole. There was no definite evidence of healing and death was estimated to have occurred within two weeks of trepanation. The second was of an old man who showed complete healing of the operative site and was estimated to have survived the operation by several years.

Survival rates throughout the relevant literature have varied between 23.4 and 62.5%. Other mortality rates have been estimated from 5–20% as compared to 75% in 1900 in London (Schiller, 1992), where death was usually due to pyogenic infection. One example showed a depressed fracture as produced by a sling-stone or blow from a spiked club, known to be used by the ancient Peruvians; another showed a silver plate over the aperture with indications of prolonged post-operative survival. Of the nineteen skulls in the Muñiz collection, at least five survived one or more operations; the instruments used indicate that the epoch in which the operations took place was pre-Columbian (McGee, 1984).

Rationale

The opening of the cranium for neurosurgical treatments is now commonplace. This is very different from trepanation when modern techniques of anaesthesia, haemostasis, antibiotics and intravenous drips were unknown.

It is still difficult, on the basis of archeological skulls, to be certain as to why they were trepanned. The broad division of indications is divided into two: the first is therapeutic for an underlying disorder or trauma, and the second is magico-religious, ritual or thaumaturgic (ie, miracle-working).

Thaumaturgic

In 1872, Prunières, a medical practitioner of Marvejols and a member of the Société d'Anthropologie, published in its Bulletin findings of skulls found under Neolithic dolmens in the Lozère Department of Central France. These skulls showed bone defects two to three inches wide that were not square and had scalloped edges. Inside the skulls were discs of bone polished by human hands which, because of their differing thickness, came from skulls other than those in which they were found. Such discs were also found on the floors of the grave and in other graves where there were no skulls. Both Prunières and Broca agreed that these holes and discs of skulls were not traumatic, pathological or accidental. Ceramics portray the operation, e.g. that by Marales Macedo in the Museum of Lima, and this could represent preparation of a trophy head. In favour of the this explanation is that these ceramics come from the "Chimu" culture, in which no trepanned skulls have been found. Amulets were found in France but not in Peru.

Those with signs of healing suggested, because of scar formation, an interval of months or even years between operation and death. The skulls came from people of all ages and one in particular had been worked on in early life and again after death, suggesting survival after operation may have given "an aura of sanctity" (Schiller, 1971). These rondelles were small discs of bone taken at post-mortem from a skull that contained an antemortem trepan defect; the discs were cut in such a way as to include an arc of the trepan defect edge and were then perforated to accomodate a necklace cord, presumably worn as an amulet (charm). These pieces of bone had smooth edges suggestive of chronic friction against the skin (Ruffer, 1918–19).

It was also suggested that the bone amulets found inside the trepanned skull was the result of a funeral rite "to compensate the deceased… and to ready him for the after-life" (Schiller, 1971). Yet another thaumaturgic hypothesis was to resurrect the dead but there is little objective evidence to support this. Campillo (1984) examined more than 3,000 trepanned skulls in 14 years and concluded that the indications were ritualistic and not therapeutic.

McGee (1956) thought that initially trepanation in the Muñiz Mexican series was performed post-mortem to obtain amulets, and this was later extended to living captives. In the latter case, it may have had beneficial results that led to empiric surgery, a view rebuffed by "Julio Tello, a Peruvian Indian with medical and anthropological training…" (McGee, 1956) who assembled a new collection of trepanned skulls. Tello (1913) considered that the surgery was performed for therapeutic reasons and listed four indications:

1. An antecedent fracture,
2. Trauma denuding the cranial periostium that may have been followed by inflammation,
3. A circumscribed periosteitis, perhaps also of traumatic origin,
4. Lesions probably of a syphilitic nature.

Therapeutic

Broca at first doubted any therapeutic intention, but the acts of trepanation of the modern savage indicated that prehistoric ancestors might have had similar views. Since, unlike the skulls of ancient Greeks, Broca found no evidence of skull fractures, it seemed possible to him that these surgical interventions were for such disorders as headache, epilepsy or insanity, which, previously to the Hippocratic Greeks, had been considered as due to supernatural causes. Broca thought the basic idea was to let demons escape, especially in the case of children. This was supported by the well-healed bone edges, the elliptical shape of the openings and the sloping edges, presumably due to “removal in layers by scraping with flint chisels, easy only in children’s skulls” (Schiller, 1971).

Trauma

The predominance of males in Peruvian findings suggests wounds from battle combat, as most of them were found on the left side of the skull, presumably made by right-handed warriors. Courville (1937) quoting Moodie (1929) writes:

> The possible military significance of the procedure is suggested by the frequency of trephine openings in the skulls found in the burial grounds of the great mountain fortresses of the Incas, while in the agricultural or pastoral communities of the coastal plains no trephined crania have been found. The findings of trephined openings in fractured skulls lends further support to this supposition since injuries to the head were probably sustained largely in battle.

Trepanned skulls are more likely to be found in those groups using weapons for smashing, rather than stabbing or slashing (Wilkinson, 1975). Two of 14 Peruvian skulls examined were associated with fractures of the skull.

Other Putative Therapeutic Indications

Osler (1921) considered that “the operation was done for epilepsy, infantile convulsions, headache and various cerebral diseases believed to be caused by confined demons, to whom the hole gave a ready method of escape”, but he provided no evidence for this view.

One therapeutic indication could be frontal sinusitis causing intracranial infection, but this is a modern interpretation as is the suggestion that it was undertaken for subdural haematoma.

In 1960, Lastres, a neurosurgeon working with Cabrezes, thought that headache, rather than epilepsy or insanity, was the chief indication for the operation, as is the case with the modern Algerian Kabyles who consider it “a minor intervention and charge less for this service than for the setting of a fracture” (Schiller, 1971). In the South Sea Islands, for the treatment of such illnesses as headache and dizzy spells, a T-shaped scalp incision was made in order to scrape the underlying bone down to the dura.

From the Byzantines to Broca

Much of the original ancient Greek literature has largely disappeared but we know of a great deal of it because of its translation into Arabic. The Arabic translations of Greek fragments were later translated into Latin, thus returning once more to Europe.

Following the Graeco-Roman period, the Byzantine writers mentioned trepanation, for example, Paulus Aeginata (seventh century AD), having studied in Alexandria, settled in Rome to write, and in his sixth volume describes his drill for trepanation. The *terebra* was a pointed, gimlet-like instrument which had a collar – *ab aptista* – which was the first to have self-arresting projecting nubs to prevent penetration of the meninges: this was used in conjunction with a flat instrument – *meningophylax* – that protected the dura.

Albucasis (936–1,013 AD) lived all his life in Cordoba and his book "*Altacrif*" (Collection) was based on Paulus Aeginata's writings (Al-Rodhan and Fox, 1986). He used a drill for trepanation that would not penetrate the brain, an operation where "you cut through the bone in the confident knowledge that nothing inward can happen to the membrane even though the operator be the most ignorant and cowardly of men: yet even if he be sleepy" but, if the dura turned black, "you may know that he is doomed" (Albucasis, 1532).

The Salernitan, Medieval and Renaissance surgeons were interested in this field: Roger of Salerno (Ruggiero Frugardi, ca 1170) recommended finger palpation to detect fractures, and wrote:

> On the Treatment of the Skull: If the wound is small it should be enlarged unless bleeding or other complication prevents. The trephine should be cautiously applied close to the fissure on each side and as many perforations made as seem necessary. Then with a chisel a cut is made from one hole to another, so that the opening reaches from end to end of the fissure and exudation can escape and should be carefully cleaned away with strips of the finest linen inserted by means of a feather between the brain and the skull (Ballance, 1922).

At the end of the thirteenth century, Lanfranco (Lanfrancus, Guido Lanfranchi, died ca 1306) thought there was only one indication for trepanation, viz. dural irritation by depressed bone fragments (López Piñero, 2000).

In the fourteenth century, trepanning was also done by Guy de Chauliac (1300–1368). He was one of the first to remove a part of the brain successfully. He also recommended removal of debris by trepanation but only with severe fractures on the most dependent site and avoiding sutures (Rose, 1997). In the sixteenth century, the techniques and operating techniques for trepanation were renewed by such surgeons as Della Croce (López Piñero, 2000).

Wilhelm Fabry Von Hilden (1560–1624) was a barber-surgeon who treated chronic headache by trepanation and, without delay, elevated depressed fractures. This operation was done with a three-legged instrument – the *torcular* – which speared into the depression but could push it further into the brain, and he designed an instrument to avoid this (Hildanus, 1646).

Johannes Scultetus, born in 1595, in his standard surgical text in the last half of the seventeenth century illustrated a comb-like saw – *serrula versatilis* – used on the skull in preference to a burr-hole or even trepanation which was done to evacuate blood and pus but also prophylactically to prevent compression and inflammation after a head injury (Scultetus, 1655).

Percival Pott (1713–1788) was one of the first to emphasize that it was the neurological status and not the skull fracture that determined whether surgical intervention was indicated. He was on the staff of St Bartholomew's Hospital, London (from 1744), and categorically stated that symptoms arising in head injury were due to affection of the brain and that the indication for trepanation was depressed fracture. He also disapproved of the idea that extradural or subdural blood would inevitably become pus, and advised early trepanation (Pott, 1773).

Injuries that did not result in severe damage to the calvarium, e.g. contusions, fractures of the outer table, and linear fractures, were trepanned more often than depressed or comminuted fractures. This led to the principle replacing the Hippocratic idea: "An injured skull should have a hole made in it if there is not one already" (Flamm, 1981).

Throughout the eighteenth century there was much controversy as to the management of concussion, some arguing for radical prophylactic trepanning if there were such localising signs as pain, while others treated conservatively, pointing out that compression can come on slowly and go without therapy. The radicals did not necessarily know that there could be raised intracranial pressure even without a skull fracture, a view permeating the laity so that murder by blows to the head was not punishable unless there was an associated skull fracture. This was in spite of a case report by Alexis Littré (1658–1725) where a convict committed suicide by striking his head against the wall but without sustaining a fracture (Mettler and Mettler, 1945, pp. 881–47).

Francois Quesnay (1694–1774), physician to Louis XV and his mistress, Madame de Pompadour, took particular interest in trepanation stating: "As a general rule, we should apply the trepan whenever there is a fracture", a view not generally held. He preferred to do the operation at the patient's home rather than in hospital, "… on account of the unwholesome state of the air" (Rose, 1997).

John Hunter made accurate observations and stated:

> Fractures of the skull of themselves produce no symptoms respecting the brain, only those of broken bones. We do not trepan for concussion alone. In young people a depression fracture may give rise to no symptom at the time, but as the patient grows up bad symptoms may arise. In all cases of depression the trepan is necessary. We must not divide the dura unless we are certain that there is fluid effused under it (Hunter, 1835–1837).

Each of these succinct sentences incorporates years of experience and is typical of the scientific philosophy that characterised John Hunter's work. His famous pupil, Sir Astley Cooper (1768–1841) would not perform preventive surgery on the skull except in the case of compound fracture. "It might be thought that it would be time enough to (trephine) when inflammation had appeared, but this is not the case, for if inflammation comes on the patient will die whether you trephine or not" (Rose, 1997).

There were two army surgeons who had tremendous experience with head injuries during the Napoleonic wars, each on opposing sides. One was Baron Larrey (1766–1842), a great favourite of Napoleon, who thought that trepanning was indispensable in a depressed fracture (Rose, 1997). On the British side was George James Guthrie (1788–1856), who wrote an excellent, beautifully written monograph of his experience with head injuries:

> Injuries of the head affecting the brain are difficult of distinction, doubtful in their character, treacherous in their course, and for the most part fatal in their results… The rule in surgery is absolute to trepan in extradural haemorrhage… when operation is necessary in fractured skull, it should be done at once – delay is fatal (Guthrie, 1842).

Broca

On 28 June, 1824, Paul Broca was born in Sainte-Foy-la-Grande, arrondissement of Libourne, in the Department of Gironde in the Dordogne area of south-west of France.[3] His interest in anthropology began as a child because there was "a natural storehouse of prehistoric material" in the Dordogne, where he had grown up, and he became familiar with fossil bones even before deciding to become a doctor. One of his friends wrote: "…we loved to explore natural caves… and when we discovered some old bone… he compelled us to dream…" "…the kind of objects Broca had seen, and read about, was to make famous not only the Dordogne country – one of the world's richest paleontological areas as it turned out – but his own name" (Schiller, 1992). He thus became familiar with the prehistoric caves of this area and their wall paintings.

His father had a country medical practice. In 1841, at the age of 17, he went to Paris to study medicine and lived in the College of Sainte Barbe for six months. During this time he attended clinics at Hotel-Dieu, where he later became an externe and also at La Pitié. "At present I study the skull. I do not find osteology very amusing… A nuisance to be gone through" (letter of 21 January, 1842).

Whilst an anatomical aide to Thierry, Broca was chosen to describe the remains of an ecclesiastical cemetery found on further demolition of a Benedictine monastery on the Right Bank of Paris. This work had revealed a number of skeletons and the Municipal Commission asked Broca, to take stock of the osseous findings. This study later became the basis for his first anthropological publication (Schiller, 1991). Following this, while occupied with medicine, he had read all the available literature on palaeontology.[4]

A committee of the Société de Biologie was formed to check Brown-Séquard's work on the spinal cord. Broca was chosen to Chair this although he was not a neurologist but a surgeon-anthropologist.[5] Holidaying often in the Pyrenées, he passed his birthplace Sante-Foy and nearby, at Sante-Jean-de-Luz, would discuss topics with his larger family, including locals with the same intellectual interests.[6] This resulted in 60 Basque skulls being gifted to the Société d'Anthropologie from Zaraus cemetery in Guippuizcoa province.

Broca and Trepanation

About 40 miles south-east of Sante-Foy-la-Grande, near Les Eyzies at a spot called Cro Magnon, there were natural grottoes unearthed by railway workers who were widening the tracks. In these caves were found human skulls, and Broca (1868) gave an account of these skeletal remains. Of the three most complete skeletons, one was that of a female, about 35 years old, "which had a hole in the left frontal bone, 33 x 112 mm, probably due to a blow by a flint axe". On the inside of the skull around the hole there were signs of increased vascularisation with the formation of new bone, so that she must have survived her injury, at least for two to three weeks (Schiller, 1971).

In 1839 Samuel G. Morton, published his book from Philadelphia on *Crania Americana*, the most extensive collection of skulls yet collected, and reported a perforated skull from Peru which he considered had been inflicted by a blunt instrument, such as the back of a war axe. In 1868 Prunières discovered a mutilated human skull in Arginières, France, and, two years later, Broca declared the defects found in skulls were the result of prehistoric surgical procedures on living patients, some of whom survived.

Carefully made perforated defects of human skulls had recently become known through the efforts of Ephraim George Squier, the United States Commissioner to Peru who, according to Broca, was the prime expert archaeologist on the American Indian. When he left Peru in 1865, he took with him a perforated skull from a tomb of Yucay, Peru which he had received from Mrs de Romainville of Cuzco. He interpreted the hole in the skull as due to trepanation. The skull was shown in the following year to the New York Academy of Medicine as a "supposed case of trepanning of the calvarium of one of the tribes of South America" (Schiller, 1971). In order to get a further opinion, Squier took this skull to Paris and Broca showed it both to the Société d'Anthropologie and the Académie de Médecine in 1867.[7]

Broca was convinced the hole was due to trepanation and not trauma. The margins of the perforation were regular, so that there had to be a definite surgical operation with four straight incisions made with a sharp instrument allowing a square of bone 15 by 17 mm to be removed, a technique which differed from the ancient Greek perforations that were probably performed with a circular, serrated iron trepan (*Vide supra*). Because of signs of inflammatory response, survival must have lasted at least a week or two.

Broca's conclusion that it was due to intentional trepanation was accepted. In the Neolithic finds in France, Prunières and Broca also considered that some holes in skulls might have been chiselled out after death to produce amulets with religious significance; such amulets were not found in South America. Broca became fascinated by trepanation and, using pieces of cut silex, made a perforation in the skull of a dog in just over eight minutes. He also worked on human cadavers using a piece of glass, taking four minutes in a two year-old child but fifty minutes in an adult skull.

Broca was most famous to the lay public as the father of anthropology. He became a Senator but had only 17 days to live when he took his place in the French Senate. On July 17, 1880, he had developed pain in the left shoulder when he was 56 and diagnosed "intercostal neuralgia". On the next day he developed chest pain in the Senate and had to leave. He went home to lie down and died in his sleep. He was buried in the same cemetery as Charcot in Montparnasse, Paris.

Notes

1. It was the prehistorian Sir John Lubbock (later Lord Avebury), who introduced the terms Neolithic and Palaeolithic in 1865. In the 1830s C.I. Thomsen of Denmark, another banker, classified the Stone, Bronze and Iron Ages.
2. Carbon-14 studies date the oldest Chibcha relic from about 350 AD, the Chibcha civilisation of Columbia survived until the Spanish Conquest in 1538 and its work can be found in the Gold Museum of Bogotá.
3. The name is derived from Gascon word, *brouca*, meaning a place covered with *broc*, ie thorns, brush or heather. The family was Huguenot and Broca was born in an area where Calvinist Protestantism was concentrated. Henri IV converted from Protestantism to Catholicism on ascending the throne in 1598 and his Edict of Nantes eventually sealed the fate of French Protestants, especially after Louis XIV revoked the Edict in 1685. Non-Catholic marriages were not legalised again until Louis XVI gave his Edict of Versailles in 1787. Calvinism again flourished in Broca's birthplace Sainte-Foy-la-Grande in the nineteenth century when one third of the local population was Protestant.
4. In 1847, Broca bought his own microscope and in his doctoral thesis of 1849 stated "Any observation unconfirmed by The Microscope must be regarded as null and void" (Schiller, 1971, p. 61). He became an expert on cancer and published 46 papers on tumours. An anatomist trained in the surgery of the day, he first applied in 1850 to become *Chirurgien des Hôpitaux.* Broca published in 1851 a "Description of the muscles in a case of club foot".
5. Neither Vulpian, a neurologist, nor Claude Bernard, physiologist, chaired the committee but Broca did, indicating he had "… the requisite reputation as a specialist in neurological matters" (Schiller, 1971, p. 113). Broca writes in an open letter "… I do not regret having abandoned my surgical work for a few days in order to concern myself with this important physiological question" (Schiller, 1971, p. 144).
6. At that time, much debate centred about the differences between brachycephalic (broad-headed) and dolichocephalic (long-headed) skulls.
7. After collecting 18 signatures, Broca, with much persistance over two years, eventually obtained official recognition for the Société d'Anthropologie in 1859, the first society in the world to call itself anthropological.

References

Albucasis (1532): *Libri* tres chirurgiae in T Priscianus *Octavii Horatiani rerum medicarum libri iv*. Strasburg, J Schott.

Al-Rodhan NRF, Fox JG (1986): Al-Zahrawi and Arabian neurosurgery, 936–1013 AD. *Surgical Neurology 26*: 92–95.

Aufderheide AC (1985): The Enigma of Ancient Cranial Trepanation. *Minn Med 68*: 119–122.

Bakay L (1985): *An early history of craniotomy: From antiquity to the Napoleonic era*. Springfield IL, Charles C Thomas.

Ballance CA (1922): *A glimpse into the history of surgery of the brain*. London, Macmillan.

Belelli Marchesini B (1986): Via Salaria. Fidene. Resti degli impianti urbani sud-oriental. *Bullettino della Commissione Archeologica Comunale di Roma*, XCI: 698–700.

Broca P (1867): Cas singulier de trépanation chez les Incas. *Bull Anthrop Soc Paris, 2e sép. 2*: 117–130.

Brothwell DR (1974): Osteological evidence of the use of a surgical modiolus in a Romano-

British population. *J Archaeol Sci*, *1*: 209–11.
Campillo D (1984): Neurosurgical Pathology in Prehistory. Acta. *Neurochirurgica 70*: 275–290.
Capasso L, Capelli A (1995): A trephined skull from Central Italy (Alba Fucens, Abruzzo) dated to Roman time (1st-2nd century AD). In: Proceedings of the IXth European Meeting of the Paleopathology Association, Barcelona: Museu d'Arquelogia de Catalunya: 103–06.
Celsus (1971): *De Medicina, III, VIII*. London, Heinemann: pp. 1–4.
Claudii Galeni (1965): *Opera Omnia X, VI. VI*. Hildesheim, Olms.
Courville CB (1937). Prehistoric Trepanation: A note on two doubly-trephined Incan Skulls. *Bull L A Neurol Soc 1*: 42–46.
Derums VJ (1979): Extensive Trepanation of the skull in ancient Latvia. *Bull Hist Med 53*: 459–464.
Dietrichs E, Stien R (2000): The Saga of Norwegian Neurology, poster presentation to the 5th congress of the European Federation of Neurological Societies, Copenhagen.
Ferembach D (1962): La Nécropole Epipaléolithique de Taforalt (Maroc Oriental, Etude de Squeleites Humains). Rabat: Centre National de la Rechericheche Scientific.
Finger S (1994): *Origins of neuroscience*. Oxford, Oxford University Press.
Flamm ES (1981): In (eds Rose FC and Bynum WF): *Historical aspects of the neurosciences*, Raven Press, New York, pp. 243–253.
Froeschner EH (1992): Two examples of ancient skull surgery. *J Neurosurg 26*: 550–552.
Gomez JC (1973): Paleoneurosurgery in Columbia. *Neurosurg 39*: 585–588.
Grana F, Rocca ED, Grana LR (1954). Las Trepanaciones Craneanas en el Peru en la Epoca Prehispánica. Lima: 340.
Guthrie GJ (1842): *On injuries of the head affecting the brain*. 4th edition. London, John Churchill.
Hildanus WF (1646): *Opera quae extant omnia*. Frankfurt, Am J Beyer.
Hippocrates. Hippocrates VI, V (1994): London, Harvard University Press (Loeb Classical Library). 16: 27–28.
Hunter J (1835–1837): *Work*, J F Palmer, editor. London, Longman.
Jackson R (1988): *Doctors and diseases in the Roman Empire*. Norman and London, University of Oklahoma Press.
López Piñero JM (2000): Nine centuries of cranial surgery. *Lancet 354*: 35.
McGee WJ (1894). Primitive trephining illustrated by the Muniz collection. *Bull Johns Hopkins Hosp 5*: 1–3.
Mariani-Costantini R, Catalano P, di Gennaro F, di Tota G, Angeletti LR (2000): New light on cranial surgery in ancient Rome. *Lancet 355*: 305–307.
Márquez Montín L, González Lícón E (1992). La trepanación craneata entre los antiguos Zapotecos de Monte Albán. *Cuadernos del Sur 1*: 25–50.
Mettler FA, Mettler CC (1945): Historic development of knowledge relating to cranial trauma. In Trauma of the central nervous system. *Res Publ Ass Res Nerv Ment Dis 24*: 1–47.
Moodie RL (1929): Studies in Paleopathology 23: Surgery in pre-Columbian Peru. *Ann Med Hist 1*: 698–728.
Osler W (1921): *The Evolution of Modern Medicine*. Newhaven CT, Yale.
Pliny the Elder (1974): Pline l'Ancien. Histoire Naturelle, XXV, VII. Paris, Les Belles Lettres (Collections des Universités de France).

Pott P (1773): *Observations on the nature and consequences of those injuries to which the head is liable, from External Violence, Volume, 3rd edition.* London: L Hawes, W Clarke and R Collins.

Prunières M (1872). Sur les cranes perforé et les rondelles craniennes de l époque néolitique. Comp. *Rend Assoc France pour lavancement des sci 3*: 597–635.

Rifkinson-Mann S (1988): Cranial Surgery in Ancient Peru. *Neurosurg 23*: 411–416.

Rogers L (1930): The History of Craniotomy, An account of the methods which have been practised (sic) and the instruments used for opening the human skulls during life. *Ann Med Hist 2*: 495–514.

Rose FC (1997): The History of Head Injuries: An Overview. *J Hist Neurosci 6*: 154–180.

Ruffer A (1918–19): Some recent researches on prehistoric trephining. *J Path Bact 22*: 90–104.

Saul FP, Saul JM (1997): Trepanation: Old World and New World in (ed: SH Greenblatt) A History of Neurosurgery. *The American Association of Neurological Surgeons*, Park Ridge, Illinois: pp.29–35.

Scattarella V, Sublimi Saponetti S, Cuscianna N, Gattulli A (1996): A case of skull trepanation from late Imperial Rome. *J Paleopathol 8*: 85–88.

Schiller F (1992): *Paul Broca: Explorer of the Brain*, Oxford University Press, Oxford.

Scultetus J (1655): *Armamentarium chirurgicum*, Ulm, C. Kuhner.

Stewart TD (1956). Significance of osteitis in ancient Peruvian trephining. *Bull Hist Med 30*: 293–320.

Stone JL, Miles ML (1990): Skull Trepanation among the Early Indians of Canada and the United States. *Neurosurg 26*: 1015–1020.

Tello JC (1913): Prehistoric trephining among the Yauyos of Peru. *Proc 18th century Intern Congr Am London* (1912), pp. 75–83.

Trelles JO (1962): Cranial Trepanation in Ancient Peru. *World Neurol 3*: 538–544.

Velasco-Suarez M, Bautista Martinez J, Garcia Oliveros R, Weinstein PR (1992): Archaeological Origins of Cranial Surgery: *Trephination in Mexico 31*: 313–319.

Verano JW, Williams JM (1992). Head injury and surgical intervention in pre-Columbian Peru. *Am J Phys Anthropol Supp 1*: 167–168.

Walker AE (1959): The dawn of neurosurgery. *Clin Neurosurg 6*: 1–38.

Wilkinson RG (1975): Trephination by drilling in Ancient Mexico. *Bull N Y Acad Med, 51*: 838–850.

Chapter 25

The Future Direction of Research

DON BROTHWELL
Department of Archaeology, University of York, York, UK

This international colloquium has provided a wealth of information on trepanning (or trephining) – ancient and modern, from both the Old and New Worlds. Although it is beyond my brief to review all the comments made at this meeting, I would like to bring out various points, and particularly if they seem to suggest how future work in this field might progress.

If I might begin by going back to the comments by Stanley Finger, it seems to me that Paul Broca (1876) was very lucky to have had a relatively well preserved trepanned skull handed to him by the French physician Prunières. Had Broca been alive today, I would have liked to start his trepan studies with a very different case from a British Neolithic long barrow called Millbarrow in Wiltshire (Brothwell, 1994). To begin with, it is a frontal bone, which would have immediately stopped him saying that it was basically parietal surgery. But compared with his Dolmen skull it is a far more challenging fragment, with only the remnants of two smooth craters, which can only be reasonably interpreted as healed trepanations (Fig.1). The endocranial surface is normal and there is no evidence of trauma.

Regarding the Cuzco, Peruvian specimen, Broca is still to be applauded for identifying very early inflammatory changes (Broca, 1867), and I wonder if we have improved at all on his skill to detect the very earliest changes. But is macroscopic examination enough? Should we not at least check apparent unhealed cases now by scanning electron microscopy?

The Neolithic in the Aegean and northern Europe indeed takes the history of trepanning back 6,000 years (Arnott, 1997), but can we really establish that this ancient surgery began in the Neolithic? Archaeology and medical history have found this a comfortable view to hold, and there seems to have been no challenge to this view. But why shouldn't attempts at surgery be earlier? Stone tool technology would not argue against it being earlier, and indeed Upper Palaeolithic people were skilled at working animal bone.

So should we be challenging the current view of its antiquity? Personally I think so. First, we should remember the two proto-Neolithic cases found at Zawi Chemi Shanidar, in Iraq, with dates of about 11,000 BP, which is twice the age of the European Neolithic cases (Ferembach, 1970). The trepanations, if that is what they are, are round in form, but shallow in depth, and some might argue that these lesions are simply evidence of trauma (Fig. 2). But there are no breaks in the bone, encircling or radiating from the craters, which would have suggested trauma. To continue the argument, if surgery is present in the Proto-Neolithic, why not in the Palaeolithic? Surely it is the mind and the

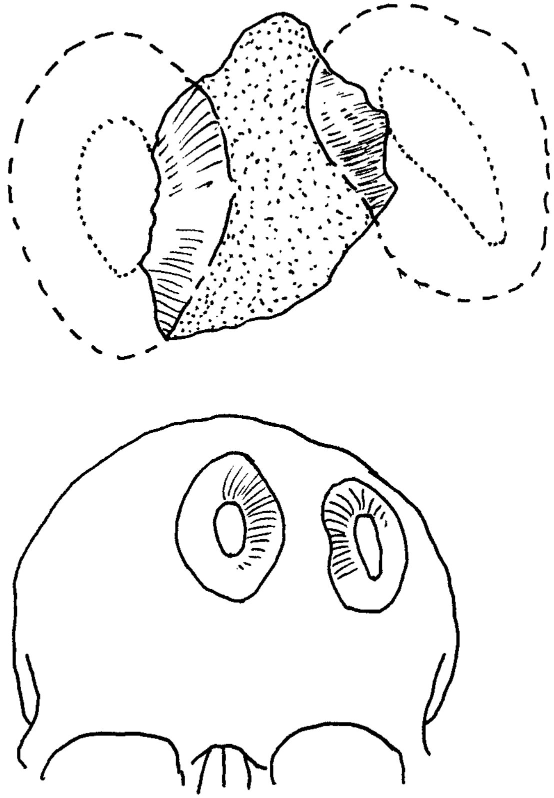


Figure 1. Reconstruction of the trepanations in a Neolithic frontal bone from Millbarrow chambered tomb.

need to innovate which has driven the development of surgery along, not the high-tech state of equipment? Thus, perhaps we should be rethinking the status of the so-called injury in the Upper Palaeolithic female skull from Cro-Magnon, in France (Joly, 1887).

This woman displayed a long narrow wound in the forehead, with no evidence of trauma, but signs of healing (Fig. 3). The impact of a heavy stone axe would surely have caused circular or radiating damage near the hole, but this is absent here.

The importance of correct diagnosis is increased the earlier the find, particularly if the crater is healed and shallow, as in the Middle Pleistocene Swanscombe skull, for instance (Brothwell, 1964). Identification of shallow partial or pseudo-trepanation is less problematic in more recent examples, where a scalp incision is possibly followed by shallow bone scraping, perhaps also followed in some instances by some "stone" producing trickery. From medieval Winchester, it seems possible to suggest from a number of partial or symbolic trepanations that it became a vogue for a time. This series deserves radiocarbon dating, to see how close the specimens might be in date. Indeed, there is a need for other cases of surgery to be more precisely dated, including the Neolithic trepan clusters in prehistoric France and samples from regions of Peru.

Perhaps I could move on to the general question of correct identification, which

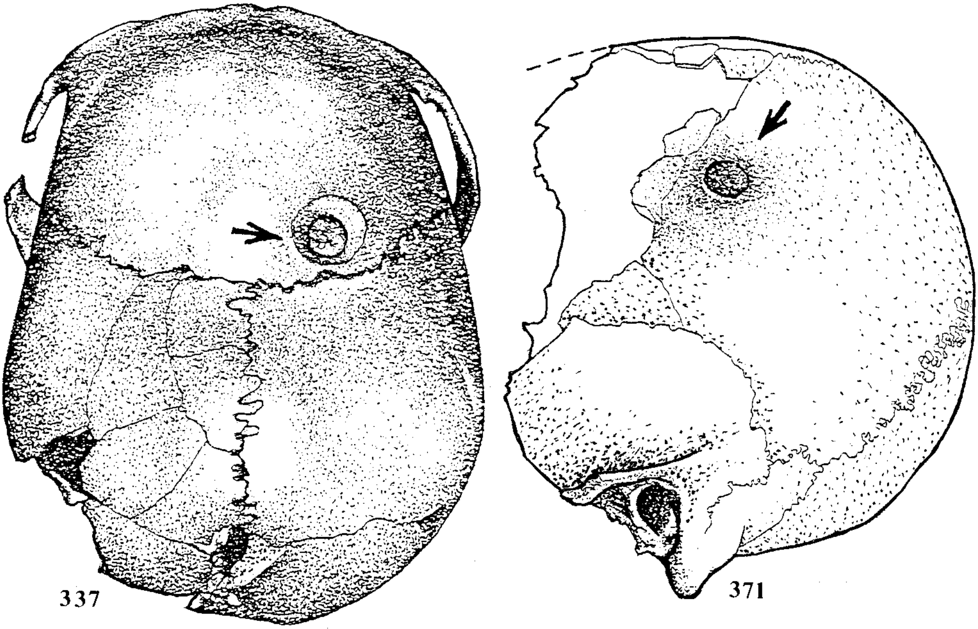


Figure 2. Proto-neolithic trepanning from Iraq (modified from Ferembach, 1970).

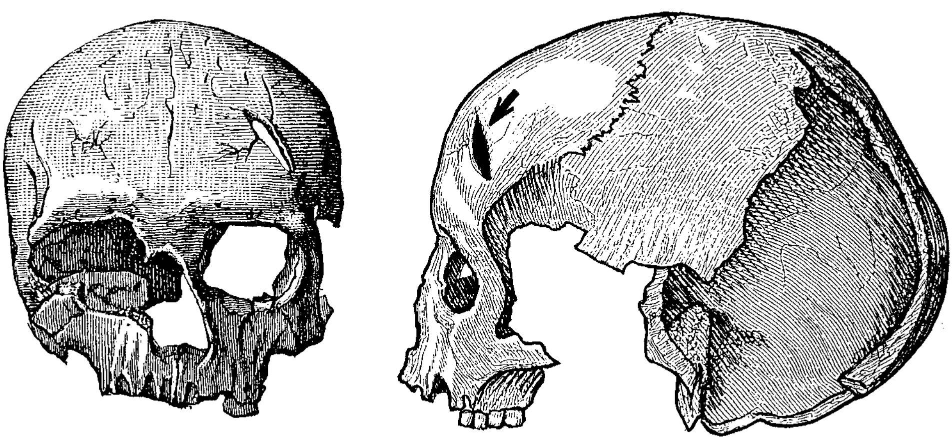


Figure 3. The cranial “injury” in the Upper Palaeolithic female skull from Cro-Magnon, France. (After Joly, 1887).

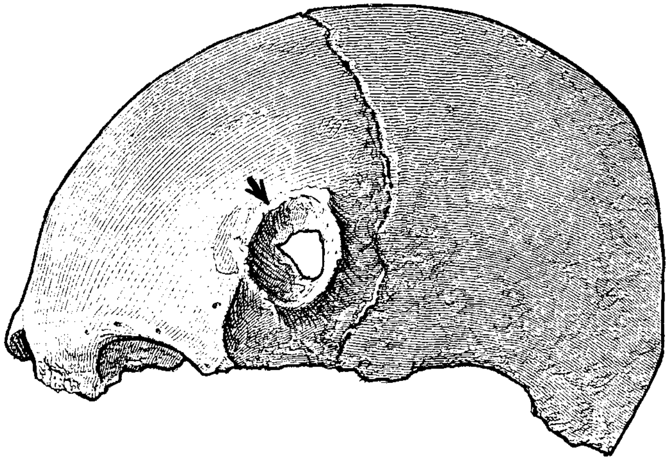


Figure 4. The skull from a stone cist at Mountstuart, Bute, showing a claimed trepanation over bone pathology (after Munro, 1897).

takes us beyond matters of medical diagnosis. Root action and other such factors cannot be ignored, and a differential diagnosis will also influenced by geography. For instance, in regions where the parasite *Onchocerca* infects human groups and produces tumour-like masses in the scalp (Strong et al., 1934), bone remodelling may occur which looks remarkably like a healed trepan crater.

Some other confusion has occurred, even recently, with regard to the rounded form of holes which can be produced by rodents. Gnaw marks and bone destruction are usually easy to identify, but post-mortem changes may obscure detail and give rise to incorrect theorizing about unusual surgery or mutilation.

Charlotte Roberts and others at this meeting mentioned the question of possible associations between trepanning and pathology – especially trauma. More effort, I think, could usefully go into this research area. The early dynastic Egyptian skull from Tarkhan comes to mind (Oakley et al., 1959), as the trepanation was on the parietal above clear evidence of ear infection. But how close in time were these two events? The Bronze Age skull from Mountstuart in Scotland (Fig. 4) has been described as having a pathological bone mass, which was trepanned centrally (Munro, 1897). But was it? Further study is needed.

In the case of the Bronze Age Crichel Down skeleton (Piggott, 1940), one could suggest that trepanation might have been linked to back pain, associated with the congenital hemivertebrae, scoliosis and later osteoarthritis. But was it, and why was the large roundel left in position, unhealed? And was it totally without bone reaction?

To me, the most impressive evidence of cranial surgery to alleviate distress was in the young Jewbury male from medieval York (No. 2577). In life, he had received a deep sword cut into the frontal bone (Brothwell and Browne, 1994). Following this, the scalp had been slightly pulled back from the injury, and there was a mild inflammatory reaction close to where the scalp margins remained attached to the bone. The medieval

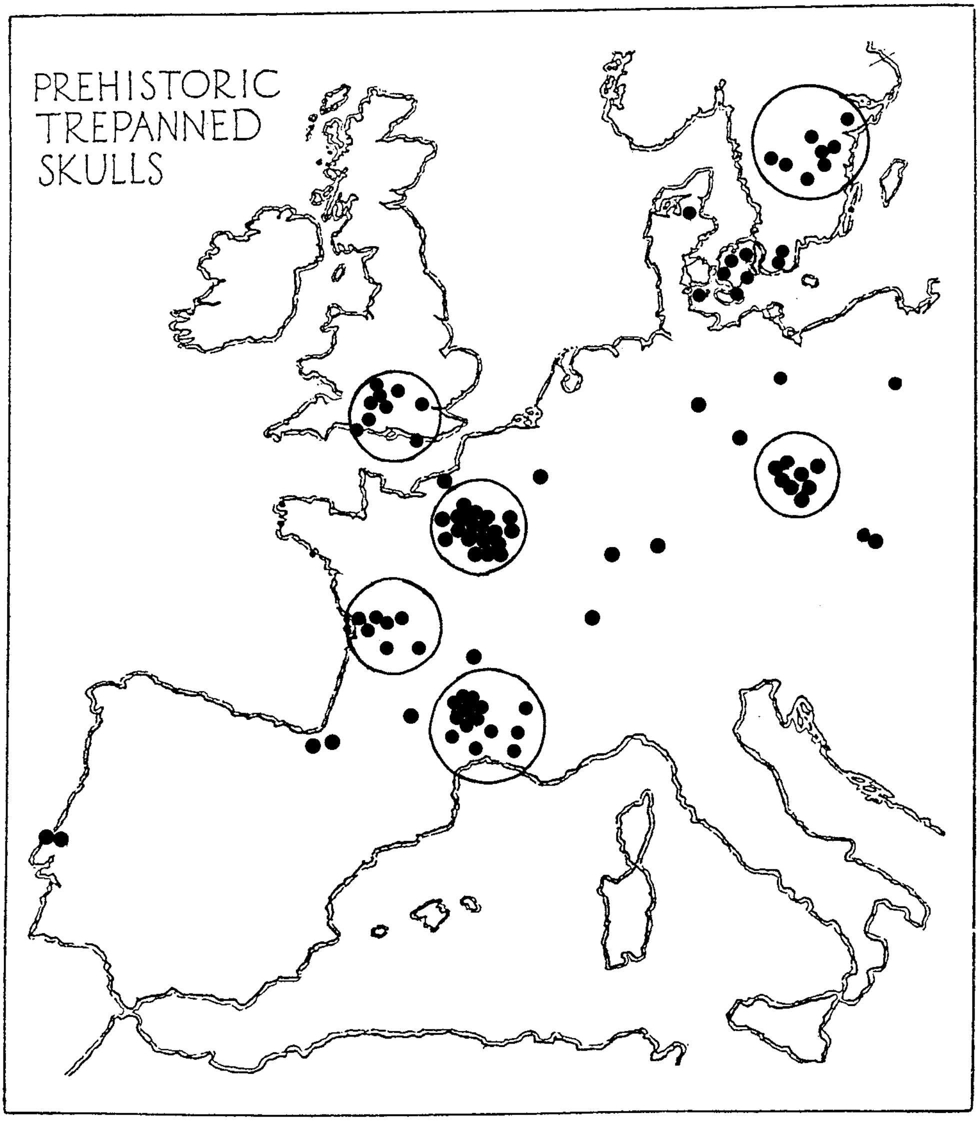


Figure 5. Neolithic trepanations from Europe, showing some regional clustering. Modified from Piggott (1940).

surgeon had managed to cut back the sword cut bone edges, presumably with a view to taking out hair, bone fragments or other material driven into the endocranial area. Bone remodelling in the cut zone indicates that the individual survived for some weeks, at least.

The various regional contributions to the history of trepanation, given at this meeting, indicate clearly that we need more on the geography of this surgery through time.

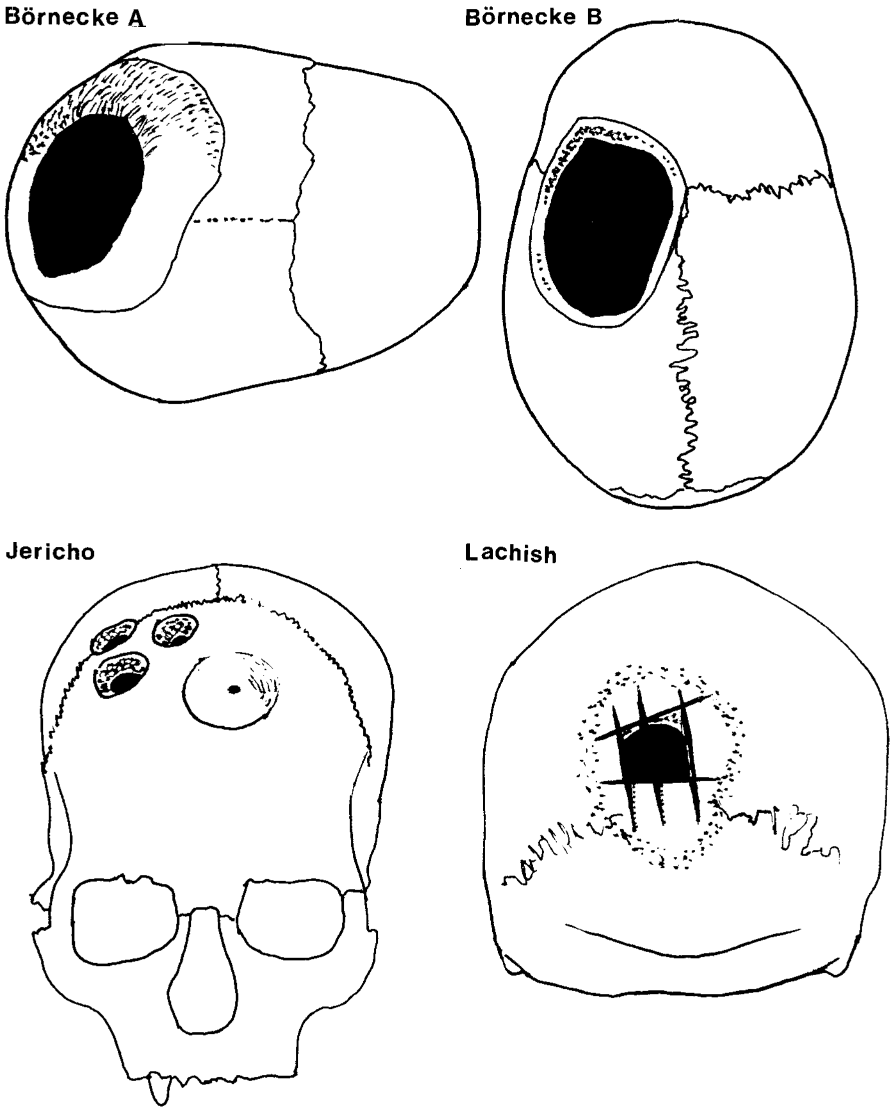


Figure 6. Examples of prehistoric trepanation in Europe and the Near East, showing size and shape variation.

Looking at a modification of Piggott's (1940) original trepan map of Neolithic Europe (Fig. 5), interesting clusters emerge which must surely be indicating surgical centres or local tribal family traditions favouring trepanning. Certainly, this tradition in Neolithic France is likely to have arrived with the farming traditions from the Near East, if it hadn't arrived earlier with the expansion of Upper Palaeolithic society through Europe. And if we see this ancient surgical knowledge dispersed in Europe, North Africa and

Asia, then why not into the Americas? I am getting dangerously close to supporting world diffusionism, but the fact is that over the past 50,000 years or more, people spread around the world, and they could have taken a very basic surgical knowledge with them. Is it significant that the same trepanning techniques, scraping, drilling, round or square, are present in both the Old and New Worlds?

During this meeting, it has become clear that we are still busy assembling a database on earlier trepanations worldwide, and we still need far more before a variety of questions can be sensibly answered. Why is there so much size variation in trepanations, and it is especially interesting that some of the largest holes are of Neolithic and Bronze Age (Fig. 6). And is there really a bias towards males, or only in some areas perhaps?

Historical sources, and particularly Galen, have been discussed at this meeting, but few of us I suspect have a good grasp of the range of relevant literature, including Arab writings and more recent works; for instance by Richard Wiseman, surgeon to Charles the Second in the 1600s. His comments on gun-shot wounds, trepanning and survival have at least given me cause for thought, regarding links with warfare.

We also need a better database on recent ethnographic evidence. Much of the literature is now pre-1940s, which makes any recent records even more important – especially if we can still return to the area for further information. We have seen a video of a Kenyan people, still busy with an array of cutting tools. And here is treatment which is mainly a direct response to headache, head trauma, even epilepsy.

Edward Margetts (1967, 1998), now emeritus professor of psychiatry, has done more than most of us to stimulate interest in ethnographic examples. In 1967 he described his personal experience of the Gussii people in Kenya, and met an *omobari*, tribal surgeon, as well as patients. Twenty–five years later, he returned and witnessed further surgery by another *omobari*. He estimates that there may now be 100 such surgeons offering their services (Margetts, 1998). The young woman he more recently saw trepanned had previously tolerated the treatment, both cases of surgery being for head trauma. A new innovation was a scalp injection of anaesthetic first. Blood flow was not prevented and hygiene was as usual minimal. A flat steel scraper was the main instrument. Two hours later, bone had been removed, the scalp closed by sutures and then dressed. The father retained the bone for magico-medical purposes.

The fact that so many of these cases heal up is surely also telling us that people in these tribal societies have a robust immune system, but no follow-up study of such cases has ever happened. While surgical instruments in more advanced societies may have been relatively clean, usually in the past and in tribal cases they must have been of poor quality. But do such contrasting qualities literally leave their mark on unhealed trepanations?

Microwear and micro-cuts are now being seriously considered in archaeology for other reasons and there is no reason why this research should not be extended more and more to trepanations – indeed a start has been made. I wonder whether the next step is to look for microscopic fragments of any metal tools used in trepanations. Scanning for metal dust, using for instance PIXE (proton-induced x-ray emission), or CT scanning could well pick up evidence, and we could begin by controlled experiments.

In all, this has been, for me, a broad ranging and stimulating meeting, and it is to be hoped that we will all go away with new views or projects to consider.

References

Arnott R (1997): Surgical practice in the prehistoric Aegean. *Med Hist J 32*: 249–278.
Broca, P (1867): Cas singulier de trépanation chez les Incas. *Bull Soc Anthrop* (Paris) 2: 403–408.
Broca, P (1876): Sur la trepanation du crâne et les amulettes craniennes à l'époque néolithique. *VIII Cong Intern Anthrop et Arch Préhist*. Budapest: 101–196.
Brothwell DR (1964): Further comments on the right parietal from Swanscombe; anomalies and endocranial features. In: Ovey CD, ed. *The Swanscombe Skull*. London, Royal Anthropological Institute, pp. 173–174.
Brothwell DR (1994): The Neolithic human remains. *Wilts Arch and Nat Hist Mag* 87: 36–38.
Brothwell DR, Browne S (1994): Pathology. In: Lilley JM, Stroud G, Brothwell DR, Williamson MH, eds., *The Jewish Burial Ground at Jewbury*. York, York Archaeological Trust, pp. 457–494.
Ferembach D (1970): Etude anthropologique des ossements humains Proto-neolithiques de Zawi Chemi Shanidar (Irak). *Sumer 26*: 21–65.
Joly N (1887): *Man Before Metals*. London, Paul, Trench.
Margetts E (1967): Trepanation of the skull by the medicine-men of primitive cultures, with particular reference to present-day native east African practice. In: Brothwell D R, Sandison A T, eds., *Diseases in Antiquity*. Springfield, Thomas, pp. 673–701.
Margetts E (1998): Trepanning the skull in East Africa, a follow-up of Gusii (Kisii) folk surgery after 35 years. *Anthologica Medica Santoriana 1*: 5–10.
Munro R (1897): *Prehistoric Problems*. Edinburgh, Blackwood.
Oakley K P, Brooke W, Akester A R, Brothwell D R (1959) Contributions on trepanning or trephination in ancient and modern times. *Man 59*: 93–96.
Piggott S (1940): A trepanned skull of the Beaker Period from Dorset and the practice of trepanning in prehistoric Europe. *Proc Prehist Soc 6*: 112–132.
Strong RP, Sandground JH, Bequdert JC, Ochoa MM (1934): *Onchocerciasis With Special Reference to the Central American Form of the Disease*. Cambridge, Harvard University Press.
Wiseman R (1676): *Of Wounds, of Gun-Shot Wounds, of Fractures and Luxations* (1977 edition). Bath, Kingsmead Press.

Subject Index

Author Index

Name Index