A Hole in the Head
CHARLES G. GROSS

The oldest known surgical procedure is trephining or trepanning, the removal of a piece of bone from the skull. It was practiced starting in the late Paleolithic period and in virtually every part of the world. It is still used in both Western and non-Western medicine. The methods and motives of trephining in different times and cultures are reviewed.

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A Peruvian Skull
In 1865, in the ancient Inca city of Cuzco, Ephraim George Squier, explorer, archeologist, ethnologist, and the U.S. charge d'affaires in Central America, received an unusual gift from his hostess, Senora Zenituo, a woman known as the finest collector of art and antiquities in Peru (1). The gift was a skull from a vast nearby Inca burial ground. The skull was unusual in that a hole slightly larger than a half-inch square had been cut out of it (Fig. 1). Squier's judgement was that the skull hole was not an injury; rather, it was the result of a deliberate surgical operation known as trephining (or trepanning) and, furthermore, that the patient had survived the surgery (1).

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 trephining operation carried out by a Peruvian Indian (2). 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 trephining (and many other operations) rarely reached 10%; thus, the operation was viewed as one of the most perilous surgical procedures (3-5). The main reason for the low survival rate was the deathly infections then rampant in hospitals. Another was that the operation was attempted only 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. At this time, however, his fame seems to have been primarily for his craniometric and anthropological studies (6).

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 caused by trephining and that the patient had survived for a while. But when Broca reported these conclusions to the Anthropological Society of Paris, in 1876, the audience was also dubious that Indians could have carried out this difficult surgery successfully (6).

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 trephine successfully. A number of skulls in a Neolithic grave site were found with roundish holes 2 or 3 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 of both genders and of all ages were found. Virtually none of the skull holes in this sample was accidental, pathological, or traumatic. Furthermore very few of the skulls showed any sign of depressed fractures, a common indication for trephining in modern times (6, 7).

These findings finally established that Neolithic man could carry out survival trephining but left open the motivation for this operation. At first, Broca thought that the practice must have been some kind of religious ritual; later, he concluded that, at least in some cases, it must have had therapeutic significance (6, 7).

Broca actually wrote more papers on prehistoric trephining and its possible motivation than he did on the cortical localization of language (6). Since Broca's time, thousands of trephined skulls have been found and almost as many papers written about them (3, 8). They have been discovered in widespread locations in every part of the world in sites dated from the late Paleolithic period to this century. The usual estimates for survival of different samples of trephined skulls ranges from 50 to 90%, with most estimates on the higher side (3, 8, 9).

Methods of Trephining
Across time and space, five main methods of trephining were used (3, 9). The first was rectangular intersecting cuts as in Squier's skull (Figs. 1 and 2). 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, which would seem to be well suited to the job. (The Peruvian Academy of Surgery has adopted the tumi as their emblem.) Besides Peru, skulls trephined 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 50 minutes, "counting the periods of rest due to fatigue of the hand." (6) 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 (10). By the time of Celsius, 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 (11, 12) (Fig. 3).

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 rotated by hand. This method was recommended by Celsius, was 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 trephined or drilled holes (Box 1).

Why Trephine?

Why did so many cultures in different periods cut or drill holes in the skull? Because most trephined skulls come from vanished nonliterate cultures, the problem of reconstructing the motivations for trephining of these cultures is a difficult one. However, there is information about trephining in Western medicine from the 5th century BCE onward as well as about trephining 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 trephining in Hippocratic medicine, in European medicine from the Renaissance onward, and in contemporary non-Western medicine.

Hippocratic Medicine

The earliest detailed account of trephining is in the Hippocratic corpus, the oldest 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 BCE, it is not clear which of the Hippocratic works were written by him. The most extensive discussion of head injuries and the use of trephining in their treatment is in the Hippocratic work *On Wounds in the Head* (10).

This treatise describes five types of head wounds. Interestingly, however, the only type for which trephination 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 trephining 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 to “...plunge [the trephine] into cold water to avoid heating the bone...often examine the circular track of the saw with the probe...aim at to and fro movements.” Trephining 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 (“...let blood by perforating with a small trepan, keeping a look out for the dura at short intervals...”). Given that they presumably had no notion of intracerebral pressure, why did they want the blood to run out? Although the reasons for trephining are not discussed in *On Wounds in the Head*, they seem clear from other Hippocratic treatises, 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 trephining, or at least one rea-
son, was to allow the blood to flow out before it spoiled. In cases of depressed fractures, there was no need to trephine because there were already passages in the fractured skull for the blood to escape (4) (Box 2).

**Western Medicine**

From the Renaissance until the beginning of the 19th century, trephining was widely advocated and practiced for the treatment of head wounds (3, 5, 14, 17–19). 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 (18). Besides trephining in cases of skull fracture, the Hippocratic practice of “prophylactic trephination” 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 (20).

Until the early 19th century, trephination was done in the home (Fig. 4). However, when the operation was moved to hospitals, the mortality was so high that trephination was not started until the patient was well enough to carry the risk for surgical intervention (5). 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” (4), or as Sir Astley Cooper put it in 1839, “If you were to trephine you ought to be trephined in turn” (18). It was against this background that the discovery of Neolithic trephining was so unbelievable to the American and French medical communities in the middle of the 19th century. Eventually, the introduction of modern antisepsis and prophylaxis of infection at the end of the 19th century, as well as an increased understanding of the importance of intracerebral pressure in head injury, allowed trephination to return as a common procedure in the management of head trauma (18).

In modern neurosurgical practice, trephining 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 an epidural or subdural hematoma), for debridement of a penetrating wound, and for 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, trephining has been an important therapy for two other conditions, epilepsy and mental illness.

The tradition of trephining as a treatment for epilepsy began as early as Aretaeus the Cappadocian (ca. 150), one of the most famous Greek clinicians (22), and lasted into the 18th century (23). The 13th-century surgical text *Quatuor magistri* recommended opening the skull of epileptics “that the humors and air may go out and evaporate” (23). However, by the 17th century, trephination 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 suture, 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" (23).

By the 18th century, the incidence of trephining 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 19th century, trephining for epilepsy was confined to the treatment of traumatic epilepsy (that is, cases associated with known head injury) (23).

Another use of trephining 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 ex-hale to the outside. The patient is held in chains and the wound is treated, as above, under treatment of wounds. (24)

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 fulligious 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... Guinierius cured a nobleman in Savoy by boring alone, leaving the hole open a month together by means of which, after two years'
Box 2: Cao Cao and Hua Tuo

... 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 due any good. The method I would advise is this: after general anesthesia I will open your skull with a cleaver and remove the excess matter, only then can the root cause be removed." "Are you trying to 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 . . .

[From Three Kingdoms, a historical novel attributed to Luo Guanzhong (15), 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; his works have disappeared, but not his fame (16).]

Fig. 4. A 16th-century woodcut of a trephination in the home. Note the man warming a cloth dressing, the woman praying, and the cat catching a rat (20).

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. John's-wort as well as Chirurgical Remedies such as Trephining or opening the skull" have been recommended (26).

Trephination for mental disease (and "folly") was illustrated by Bosch ("The Cure for Madness"), Bruegel ("The Witch of Malleghem"), Jan Steen ("Stone Operation"), and other medieval and Renaissance artists. Remarkably, art historians have written reams on the symbolic interpretation of these paintings, but seem to remain unaware that they represented, perhaps among other things, a common medical practice of the time.

By the 18th 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'" (14).
Box 3: Trephining on the Internet

Today, the practice of trephining is not confined to surgical suites or traditional medicine men. The International Trepanation Advocacy Group advocates it 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." Trephining 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 cerebral metabolism and more areas of the brain functioning simultaneously" and "increased 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 website, www.trepan.com, with links to first person and journalistic accounts of trephining, reproduction of old drawings of trephination 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 consideration if not entirely positive publicity: in November 1998, it was featured on ER, the television drama set in an emergency ward.

Much of the defense for alternative medicine treatments is that they must work because they have been around for so long a time, an apparently attractive argument for the increasing popularity of 5000+-year-old Chinese traditional medical practices. However, the case of trephining 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.

Trephining Today: In Africa

A second source of information on the motivations for trephination is contemporary traditional practitioners and their patients. There are literally hundreds of 20th-century accounts of trephination, particularly in Oceanic and African cultures (8). Especially detailed and recent ones concern the Kisi of South Nyanga 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 (9).

Trephining among the Kisi 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." The operation is carried out by general practitioners of medicine and takes a few hours. Restraining 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, by one authority, is described as "low, perhaps 3 per cent." The practitioners and patients seem to be quite satisfied with the results of the operation.

Although headache after head injury is the most prevalent reason given for trephining 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" (8). Furthermore, the headache itself may be attributed to one or more of these causes instead of or in addition to a head injury (Box 3).

An Empirical If Not Rational Procedure

The commonest view of the prehistoric and the non-Western practice of trephining, 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 Hippocrates and early European doctors as well as among contemporary Kenyan practitioners suggests a different view. Trephining may have appeared, in these contexts and cultures, to be 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, trephining 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, "do no harm."

Acknowledgments


References