Chapter 1

Ancient trepanation

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INTRODUCTION

Trepanation is the oldest surgical procedure known from antiquity, extending back more than 5000 years in Europe and to at least the 5th century BC in the New World (Arnott et al., 2003). Since the recognition of prehistoric trepanation in the mid-19th century, the practice and motivation for cranial surgery have been topics of considerable interest to neurologists and neurosurgeons, as well as to anthropologists, archeologists, and medical historians. According to one recent estimate, more than a thousand articles alone have been published on the subject (Rose, 2003).

The evidence that trepanation was practiced in the Neolithic Period or New Stone Age (a time associated with polished stone tools, community life, farming, and the domestication of cattle; c. 4000–2000 BC in France) was slow to be appreciated (Schiller, 1992). Indeed, trepanned skulls had been found in Western Europe prior to the mid-19th century, but these specimens were misinterpreted with regard to their antiquity and/or it was not realized that human operators had made these openings on the living.

Today we know that a surprisingly large number of ancient cultures actively practiced cranial surgery on the living, but the subject is still highly controversial. One reason for this is that so little is really known about why the surgery was performed so long ago. Was the purpose just to make a hole in the cranium, or was it more closely tied to the brain itself? That many patients survived such surgery is not contested, but were the chosen operated on for medical reasons, such as to treat skull fractures or closed head injuries – injuries that could have affected life or altered behavior?

In addition to the long-held belief that “primitive” cultures lack the capacity for rational, scientific thinking, some of the debates about trepanation reflect surgical statistics. Until the introduction of aseptic techniques in the second half of the 19th century, mortality from infection following craniotomies was very high, particularly when performed in the disease-ridden, city hospitals of the day (Aufderheide, 1985; Martin, 2003). Moreover, prior to the guiding theory of cortical localization of function in the 1860s and 1870s, surgeons had little idea where to open a skull, unless there were external breaks, discolorations, or other clear cranial signs (see Ch. 14). Hence, prominent surgeons concerned with upholding their reputations and not hastening death tended to avoid performing such procedures, even when dealing with seemingly hopeless cases (Wehrli, 1939; Ruisinger, 2003).

Hence, the idea that Stone Age people would have been so bold as to attempt such a dangerous surgical procedure could indeed seem far-fetched from this surgical perspective. Yet two surgeons who operated on the brain, and stand among the most important brain scientists in the 19th century, figured prominently in recognizing trepanation and bringing it to the fore. One of these individuals was Paul Broca and the other was Victor Horsley, and although both tied trepanation to neurological problems, as we shall show, they promoted different theories.

EPHRAIM GEORGE SQUIER AND PAUL BROCA

Paul Broca was born in 1824 in Sainte-Foy-la-Grande, a town east of Bordeaux (Schiller, 1992; Finger, 2000). He attended medical school in Paris, graduated in 1848, and remained there for the rest of his life. A man of diverse interests, Broca published over 500 papers in neurology, neuroanatomy, neurosurgery, comparative anatomy, human evolution, pathology, statistics, oncology, and medical therapeutics.

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To neurologists today, Broca is best known for his landmark paper of 1861 on the frontal cortex language area that now bears his name (the first cortical localization to be accepted [Broca, 1861]; see Ch. 10). He is also recognized for suggesting that the left hemisphere plays the leading role in speech – the concept of cerebral dominance – which he addressed 4 years later (Broca, 1865). Yet another of his contributions from the 1860s was the use of skull landmarks (craniography) to localize underlying regions of the cerebral cortex for neurosurgery, although he did not publish this report until 1876 (Broca, 1876a; Stone, 1991).

Broca was also deeply involved with human prehistory and physical anthropology at this time. In 1859 he founded the first anthropological society, the Société d’Anthropologie de Paris. In contrast to his papers on language, which can be counted on one hand, he published hundreds of papers on human origins, variation, and other facets of physical anthropology.

There was no literature on ancient trepanned skulls when Broca began to write on aphasia and the brain. The situation changed dramatically after he was shown an “Inca” skull with distinct cross-hatched cuts around an opening (Fig. 1.1). The Peruvian skull came from an old cemetery in Yucay, near Cuzco. It had been given to Ephraim George Squier (Fig. 1.2), an American diplomat, writer, anthropologist, and archeologist, who had been sent to Peru in 1863 by President Abraham Lincoln to settle a dispute between the governments of Peru and the United States (Finger and Fernando, 2001; Fernando and Finger, 2003; Finger and Clower, 2003).

Squier brought the unusual skull to the New York Academy of Medicine in 1865. The members that saw it agreed with him that only human hands could have made such an opening, and that the skull predated the European conquest of Peru (the skull is currently dated between 1400 and 1530 AD). But because not everyone accepted his contention that the operation had been performed on a living person, Squier now sought Broca’s opinion. Thus, the skull was sent to Paris, where Broca studied it and commented on it in 1867.

Examination of the unusual skull left no doubt in Broca’s mind that “advanced surgery” was performed by “aborigines” long ago in the New World (Broca, 1867a, b). The opening was made with a cutting tool like a burin, and signs of inflammation suggested to Broca and a colleague that the individual probably died between a week and 15 days after the operation. But, he wondered, what was the conceptual framework for this operation? Because there were no unusual cracks in the skull, Broca rejected the idea that the surgery was performed to treat a depressed broken bone or a less severe fracture. Instead, he maintained that the operation was more likely to have been performed to relieve “an effusion of blood under the dura mater” – an internal problem causing “functional troubles,” to use more of his own words, “so that the surgical act was preceded by a diagnosis” (Broca, 1867a; trans. in Fernando and Finger, 2003, pp. 10–12).

**THE DISCOVERY OF NEOLITHIC TREPANATION**

To Broca’s delight, hundreds of older perforated crania were soon to be discovered on French soil. In 1868, his friend Prunières recognized the first
trepanned French skull from the Neolithic Era, and Broca soon had many more crania and fragments (Clower and Finger, 2001). In addition, Prunières found small pieces of carefully sculpted human skull bones, some with holes in them, near or even within these skulls. Based on the fact that many had oval shapes, he called them rondelles.

In 1874, Prunières gave two speeches to French scientists, in which he explained that trepanation was practiced in their country thousands of years ago (Prunières, 1874a, b). Today, most of these specimens are thought to be between 4000 and 5000 years old. Moreover, specimens several thousand years older than these have now been found in other parts of the world (Lillie, 1998; Arnott et al., 2003). In contrast, crania from South America, such as Squier's cross-hatched Peruvian skull, are typically between 500 and 2500 years old.

One skull, presented by Prunières in 1874, had three elliptical regions cut out of the bone (Fig. 1.3). Strangely, the middle circle seemed to be more smoothed or polished than the other two. He theorized that the holes were made after death and then worked with care to serve as ritualistic drinking cups (in Scandinavia the word skol can still be heard when drinkers lift their glasses).

Prunières discovered a carefully crafted rondelle, one made from a different skull, in the very same skull. Over time, he gathered more of these rondelles and showed that they often had grooves and perforations fashioned so that they might be suspended from a string. Prunières postulated that they most likely served as amulets or good luck charms.

Although Broca agreed with Prunières about the rondelles, he interpreted the skull openings quite differently. After listening to what Prunières had to say, he opined that at least some of the openings were made while subjects were living (Broca, 1874a, b). The smooth surfaces were not intentionally polished for the eager lips of drinkers; they were the result of a lengthy period of healing and new bone growth. In contrast, the openings with coarse, unhealed surfaces were made after death to produce amulets, or were due to death occurring during or right after a surgery on the living.

Broca became so enthused with these early discoveries that he personally joined in the search for more crania and tried to accumulate as many specimens as he could from all available sources. Not only were many more trepanned skulls now excavated in France, they started to be uncovered throughout Western Europe and in other places as well. It was then realized that some excellent examples of Stone Age trepanned skulls had been in collections for years, although they had been misinterpreted prior to this time. Indeed, a few were simply not thought to be very old, or the openings had been attributed to weapons of war, diseases, or gnawing animals. During the 1870s, Broca published a book, many detailed journal articles, and dozens of shorter commentaries on the newly discovered French skulls and the bone amulets found with them (Clower and Finger, 2001).

In response to the enthusiasm generated by Broca's various papers, a number of museums and universities sent expeditions to highland Peru and Bolivia to search for additional examples of trepanation in the New World (Tello, 1913; Hrdlička, 1914; MacCurdy, 1923). Hundreds of skulls were found in the late-19th and early-20th centuries, revealing that trepanation had been a fairly common practice, with origins that substantially predated the powerful Inca Empire (Yacovleff and Muelle, 1932; Tello and Mejía Xesspe, 1979). In fact, Peru and Bolivia would produce more ancient trepanned skulls than the rest of the world combined, today estimated at more than 1000 specimens (Stewart, 1958; Verano, 2003).

**DIAGNOSING TREPANATION**

Of course, not all holes in the head are trepanations, and this must be kept in mind when evaluating any ancient skull with an opening or defect. A freshly drilled or scraped hole may show tool marks indicating how it was made. An older opening with rounded margins will not be as simple to diagnose. Many pathological conditions (e.g., congenital and developmental defects, neoplasms, infection, trauma) can also produce cranial openings, and post-burial taphonomic

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Fig. 1.3. A trepanned Neolithic skull found in a dolmen in France by Prunières. Broca (1876b) published this illustration and concluded that this skull was trepanned both before and after death.
processes can further cause defects in skulls that could be misdiagnosed as trepanations (Donnabhain, 2003; Ortner, 2003).

Goldsmith, Stewart, and others have, in fact, described a variety of cranial defects that have been mistaken for healed trepanations (Goldsmith, 1945; Steinbock, 1976; Stewart, 1976), and Kaufman et al. (1997) provide an excellent survey of trepanation look-alikes. These studies serve as a cautionary warning about loosely interpreting holes in ancient skulls. For example, the author of a recent re-examination of some presumed trepanned skulls from prehistoric Denmark concluded that most probably they were not trepanned (Bennike, 2003). Hence, as Broca repeatedly stated, a careful diagnosis is absolutely essential to minimize the risk of a mistake.

The best case for trepanation in ancient times can be made if significant numbers of skulls are found that show clear evidence of surgical intervention (cutting, scraping, or drilling of the vault). Especially if these skulls show varying periods of post-operative survival, then it can be concluded with high confidence that the procedure was done on living patients. Bone reaction was, in fact, critical to Broca’s argument in the case of the Squier skull. He knew that the cross-hatched pattern could only have been made by human hands, but had this skull not shown evidence of a vital response, this Peruvian specimen might have been classified as a less interesting post-mortem artifact.

If ancient trepanation can be thought of as a skill acquired through regular practice, and one passed on from generation to generation, the expectation might be that trepanned skulls should be concentrated in particular geographic areas and time periods. To date, the strongest evidence for regional traditions remains in Neolithic Europe and Andean South America (Tello, 1913; Piggott, 1940; Brothwell, 2003; Verano, 2003). These “centers” are distant both geographically and temporally, each has produced large numbers of trepanned skulls, and both are characterized by distinct clusters of discoveries – factors strongly suggesting that local trepanation traditions evolved in certain areas and continued for significant periods of time. In other regions and at other times, trepanation might have been a rare practice, perhaps marking an occasional experiment in a new type of medicine (Richards, 1995; Martin, 2003). Still, accounts of trepanations being performed in recent times by traditional societies in many parts of the world, including North and East Africa, the South Pacific, Polynesia, and South America, serve to remind us that trepanation is a surprisingly widespread and enduring practice (Bandelier, 1904; Hilton-Simpson, 1922; Margetts, 1967; Furnas et al., 1985; Bastien, 1987; Mueller and Finch III, 1994). These reports suggest that the need to treat head wounds, and possibly headache and other neurological complaints, has led many cultures, both ancient and modern, at least to experiment with scraping openings in the skull, in accord with deep-seated spiritual and medical beliefs.

A TEMPORAL AND GEOGRAPHIC SURVEY OF ANCIENT TREPANATION

Scattered finds of skulls with possible healed trepanations have been reported from many parts of the Old World (for a recent survey, see Arnott et al., 2003), but there are relatively few areas (France being one) with a large number of skulls that show convincing evidence of surgery. In Western Europe, the skulls come primarily from Neolithic sites. Approximately 200 specimens were identified in a classic work by Piggott (1940), and since his time many additional discoveries have been made (Roberts and McKinley, 2003; Silva, 2003).

Two trepanation techniques predominate in Western Europe: scraping and cutting out of pieces of bone by grooving. In the latter case, pieces of skull vault have been found archeologically – sometimes still associated with the skull – or more commonly, as perforated amulets. Some of these charms appear to have been removed from skulls post-mortem, and sometimes they include a portion of a healed trepanation, as was the case with the skull described by Prunières (also see Piggott, 1940, p. 122). But while there is good evidence of post-mortem cutting to make amulets, many Neolithic trepanned skulls also show clear evidence of bone reaction, convincing evidence that operations were performed on living patients. While Piggott did not provide statistics in his survey of Neolithic skulls, he noted that survival rates were “extremely high.”

Trepanations might have been performed in Europe even before Neolithic times, but here the evidence is less secure. There are several reports of possible healed trepanations from Mesolithic contexts, although these are isolated skulls with healed defects of uncertain origin (Alt et al., 1997; Lillie, 1998). One problem with these cases is that in many instances no alternative diagnoses for the defects are considered, and judging from published photographs, there might be more likely and less exciting explanations for the openings.

In the Americas, two centers of ancient trepanation have been identified: the region of South America occupied by modern day Peru and Bolivia, and the less intensively studied Valley of Oaxaca in Central Mexico. Isolated skulls with possible healed trepanations have been reported from some areas of North America, but most of these have been questioned
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(Stewart, 1958), and only one case — a skull from California — has tool marks, demonstrating that it was intentionally scraped (Richards, 1995). The evidence for Central Mexico and South America, however, is unequivocal.

In the Oaxaca Valley, a trepanation tradition developed during the Classic Period (250–900 AD). First identified in simple graves in residential areas surrounding the monumental site of Monte Albán (Romero, 1970; Wilkinson, 1975; Wilkinson and Winter, 1975), additional examples have since been found at other valley sites (Stone and Urcid, 2003). The total sample of trepanned skulls from the Oaxaca Valley is relatively small, numbering about two dozen, but they are interesting nonetheless, and for several reasons.

First, although most skulls from Monte Albán were trepanned by scraping or grooving methods, seven have been found that were trepanned by a drilling technique not known prior to the development of the crown trephine by the ancient Greeks (Wilkinson, 1975). Metal tools were unknown at Monte Albán, but a tradition of drilled lapidary work and dental incrustations had developed centuries before, and it is believed that these trepanations were accomplished with hollow drills of cane or bone, using sand as an abrasive. The end result was a circular drilled hole with an average diameter of about 11 mm (Stone and Urcid, 2003). Although smaller in diameter than holes made with a typical crown trephine, these openings still closely resemble them. Interestingly, skulls from Monte Albán trepanned with this technique tend to show multiple holes, up to five in a single individual. But while innovative, the local technique might not have been very successful. Only one of the seven skulls shows any evidence of bone reaction around its drilled holes, and none exhibit long-term healing (Wilkinson, 1975; Stone and Urcid, 2003).

The burial of groups of trepanned individuals initially suggested that the procedure might have been done for ritual purposes (no clear association with skull fractures was found) or as a possible experiment in surgical technique (Wilkinson, 1975; Wilkinson and Winter, 1975). Nevertheless, this scenario is complicated by later discoveries of trepanned skulls in elite tombs at Monte Albán, as well as in isolated tombs at other valley sites, indicating that trepanation was not limited to a specific social group or site (Stone and Urcid, 2003). Future excavations in the Oaxaca Valley may shed further light on this unusual practice, which disappears from the archaeological record following the collapse and abandonment of Monte Albán, c. 800 AD.

In contrast, trepanation was practiced continuously in the Andean region from roughly the time of classical Greece (c. 400 BC) until the Spanish conquest in the 16th century (Verano, 2003). Isolated reports of trepanations being performed by traditional healers have continued to appear well into the 20th century, suggesting an even longer tradition in some isolated areas of the Andean highlands (Bandelier, 1904; Bastien, 1987).

The earliest known trepanned skulls from South America were discovered in ancient cemeteries on the Paracas Peninsula of southern coastal Peru, and they date from approximately 400 BC to 200 AD (Tello and Mejía Xesspe, 1979). More than 70 trepanned skulls are known from these sites (Allison and Pezzia, 1976; Verano, 2003). Scraping was the method used to make relatively large openings in the skull (Fig. 1.4).

Bifacial, flaked obsidian knives, which have been recovered from these sites, were used to make these openings. Copper and bronze tools were unknown at this time, so early South American trepanations were performed with chipped stone tools similar to those used in New Stone Age Europe. Following this early period of trepanation, the practice seemed to fall out of favor on the south coast of South America for reasons unknown (Verano, 2003).

The second reason that Oaxaca trepanned skulls are unusual has to do with the archeological contexts in which they were found. While a few isolated trepanned skulls were found in excavations at Monte Albán in the 1930s and 1940s (Romero, 1970), in 1972 a grouping of five skeletons — all of them trepanned — was found buried in an area with domestic architecture. A year later, a second group of four trepanned individuals was discovered. Few goods were associated with any of these simple graves, indicating that these individuals were of relatively low status.

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Skulls trepanned after 200 AD have appeared at numerous archaeological sites over a broad area of the Peruvian and Bolivian highlands. The precise dating of most of these skulls is uncertain, as the majority were collected from disturbed tombs in the late-19th and early-20th centuries, when insufficient attention was given to identifying cultural context (Tello, 1913; Hrdlička, 1914). In recent years, a small but growing number of more carefully excavated specimens has come to light, and they have allowed researchers to assign approximate dates to the collections lacking good contextual data.

Many ancient trepanation techniques were used in South America: scraping, linear cutting, circular grooving, and boring and cutting (Lastres and Cabelles, 1960; Lisowski, 1967). The linear cutting technique (seen in Squier’s skull) is characteristic of the central highlands of Peru, although trepanations by the scraping and boring and cutting techniques are also found here, as well as in the southern highlands and high jungles of northern Peru. Some central highland trepanations show a combination of more than one technique, suggesting that some experimentation might have been occurring. Circular grooving appeared later, and might have evolved in the southern highlands during the height of the Inca Empire.

Copper and bronze knives and chisels have been recovered from late central and southern highland sites, and these may have been the tools used to trepan skulls, although this can be difficult to prove. Nevertheless, in an experiment conducted in 1944, a Peruvian surgeon demonstrated that these ancient tools were quite capable of cutting through crania. He performed a successful craniotomy on a living patient to drain a subdural hematoma using archeological specimens from Peru’s National Museum of Anthropology and Archaeology (Anónimo, 1945).

As is the case of trepanned skulls from Neolithic Europe, a significant percentage of Peruvian trepanned skulls show evidence of healing, indicating good survival following the procedure. Success rates improved from the earliest south coast trepanations to the later central highlands and southern highlands surgeries, reaching an impressive long-term rate of 78% by Inca times (Verano, 2003). Some of the most evocative cases of multiple trepanations with long-term healing are from Inca Peru, where an impressive seven healed openings have been found on one skull (Brothwell, 1959).

**WHY DID THEY TREPAN?**

Depressed skull fractures are commonly observed in skeletal collections from Ancient Peru. Most breaks were probably produced by blows from clubs or stones from slings, weapons widely used in the Andes prior to the Conquest, although some could have resulted from falls or other accidents. Beginning with the earliest studies of Peruvian trepanned skulls by Tello and Hrdlička, the frequent co-occurrence of skull fractures and trepanations has been noted (Fig. 1.5).

In a study of the largest sample of central highland Peruvian trepanned skulls to date, 26.2% of 457 trepanations were directly associated with visible skull fractures (Verano, 2003). The collection included a number of examples where trepanning was initiated at the site of a depressed fracture but never completed, perhaps because the patient died during the procedure. Incomplete operations suggest that evidence of many fractures and penetrating wounds could have been removed by the trepanation procedure itself, and that the incidence of trepanation to treat acute head trauma might have been quite high.

Although a clear relationship between skull fracture and trepanation has been found in some sites in Ancient Peru, the larger picture remains quite complex. For example, there are a number of skulls with multiple trepanations of consistent size and shape associated with the late prehistoric period in the Cuzco region (Fig. 1.6).

In these cases, it is hard to imagine that each trepanation is in response to a distinct crack or penetrating skull wound. Hence, alternative explanations, such as an attempt to treat recurring headaches or some other neurological symptom, also have to be entertained. Modern ethnographic examples are known of patients receiving multiple trepanations to treat recurring headaches, for example among the Kisii of Kenya (Furnas et al., 1985). These Inca skulls may represent a similar attempt to treat a problem of unknown cause, and perhaps one not relieved by previous interventions, although this cannot be stated with certainty.
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Fig. 1.6. An Inca skull with five healed trepanations (four are visible in this photograph) of similar size and shape. From the site of Patallacta, near Cuzco, Peru.

In Neolithic Europe, the motivation for trepanning is obscure, because relatively few trepanations are associated with recognizable skull fractures. It was this absence of hard evidence for why Neolithic practitioners operated that led Paul Broca and Victor Horsley to speculate on the motive.

Paul Broca devoted a great deal of time to try to determine why trepanation was so common in his native France and in Neolithic Europe in general (Clower and Finger, 2001; Finger and Clower, 2003). He flatly rejected the hypothesis that the procedure was performed for depressed skull fractures. If this were the case, Broca thought, a greater percentage of Neolithic skulls would have been found with fracture lines close to the openings. He also noted that healed openings were not found on the skull bones in the facial region, which he presumed would be a common site for injuries and concussions, whether from weapons of war or head accidents. Interestingly, Broca also discarded the notion that the operation was routinely performed to treat closed head injuries in Neolithic times. The ratio of male to female trepanned skulls did suggest that combat, the usual cause of closed head injuries, was not involved to a significant degree.

Thus, Broca turned his attention to diseases, and how they might have been perceived by the "primitive mind." He had by now learned that these operations were still being performed in Africa, the South Pacific, and other parts of the world, to exorcise demons thought to cause convulsions and other frightening disorders. He did not consider it a large jump to hypothesize that earlier humans also believed in evil spirits and probably reasoned in similar ways.

Broca now concluded that skull openings might have been made by Neolithic healers to give intrusive and confined demons affecting the brain a noticeable exit from the head. In particular, cranial surgery could have been the method of choice for seizures, since the afflicted would have been hard to hold down, as if possessed by demons of superhuman strength. With a large hole, and perhaps some accompanying rituals and incantations, the thought was that these demons could be coaxed, lured, or forced out.

From this anthropological starting point, and stimulated by one exceptional specimen, Broca theorized that trepanations were usually, if not always, performed on children during the Stone Age. His hard evidence was the markedly deviated suture on the side of the hole in the very first skull presented by Prunières. It could only mean that the surgery had to have taken place very early in life in this case, and he was ready to generalize.

Broca combined this evidence with the fact that children between the ages of 9 months and 5 years are commonly affected by "benign" seizures, like those occasionally observed during teething and fevers. In doing so, he developed the idea that these "simple" convulsions provided the motivation for ancient trepanation. He now explained that the convulsions were probably not true epilepsy, because epilepsy is not very common before the age of 10. But more importantly, he reasoned that the trepanation procedure would not have persisted unless it was deemed a success, and opening the skull would not have lessened the fits if the children were truly epileptic. In contrast, children with simple convulsions recover. Thus, the operation would have provided the illusion of success, even if it were not causal.

Broca further argued that the surgery would have been more easily performed on infants, because the thin young skull is easier to penetrate and its wounds would heal more rapidly. To drive home his point, he even conducted some experiments to show just how quickly an immature skull could be trepanned with flint or glass (Broca, 1876c). 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 was even forced to rest his hands because of fatigue and pain that accompanied opening an adult skull.

Broca also trepanned living dogs. He showed that it was relatively easy to avoid damaging the dura mater — the penetration of which surely would have caused more fatal infections and dramatically lowered survival rates. His canine subjects, with dura intact, survived the operation with no detectable problems.
Finally, but not to be overlooked, Broca also brought forth historical support for his infant convulsion theory. He made reference to Jean Taxil’s *Traité de l’Épilepsie*, his treatise from 1602. Taxil discussed how epilepsy was then ascribed to demon possession, and he wrote that scraping a hole in the cranium down to the dura was a good treatment for it. Taxil not only presented the surgical approach as common, but also referred to the use of human cranial bones as a non-surgical approach for epilepsy. In his day, the bones were applied as plasters, given as potions, and, of even more interest to Broca and the anthropologists, worn or carried as protective amulets (Taxil, 1602).

Broca took what Taxil wrote as good support for the belief in the curative powers of cranial bones in cases with convulsions. He was careful to point out, however, that Taxil and others had mislabeled childhood convulsions as epilepsy. By Broca’s day, it was understood that epilepsy was a distinct form of convulsive disorder. Thus, as noted, Broca reasoned that Neolithic trepanation was performed for childhood convulsions, but probably not for true epilepsy.

Broca’s contemporaries described him as a highly informed, brilliant thinker, and he combined anthropological, medical, and historical information to come forth with his explanation for why Stone Age people engaged in trepanation. But his theory was still controversial, and others did not hesitate to propose alternative hypotheses. Some of the opposing ideas had more to do with tribal rituals and rites of passage than with the brain and medicine (Muñiz and McGee, 1897). Other theories were based on medicine, and the cranial fracture notion that Broca doubted was not about to be discarded by everyone.

The idea that trepanation might have originated as an attempt to treat fractured skulls had been championed by Squier, who had seen pre-Columbian skulls from Peru that were penetrated by sharp-pointed weapons. In his book from 1877, Squier mentioned a second supporter of the fracture idea, Josiah Nott, a leading American researcher and cataloguer of skulls.

It was Victor Horsley, however, who adopted the fracture idea and raised it to a new level with Broca’s own Neolithic finds (Finger and Clower, 2001, 2003). Unlike Broca, whose involvement with trepanned skulls came from anthropology, Horsley was drawn to these crania because of what he had learned as a laboratory scientist who did physiological experiments on monkeys and other animals, and because he had just boldly operated on the human brain in London.

Horsley was born in Kensington, London in 1857, and he studied medicine at University College (Paget, 1919; Lyons, 1966). There he fell under the influence of Edward Albert Schäfer, a world-class physiologist who promoted animal research as the basis on which to build a truly modern medicine (Sparrow and Finger, 2001). Together, the two men conducted important mapping studies on the motor cortex of monkeys, with Horsley skillfully performing the surgeries (Horsley, 1885; Horsley and Schäfer, 1888).

After graduation, Horsley served as Surgeon to the National Hospital for the Paralysed and Epileptic, Queens Square, in addition to accepting several other research, teaching, and administrative posts. He believed in Lister’s new principles of asepsis, and he became adept at performing difficult new surgical techniques based on what he had learned from his research on animals.

In 1886, he began to operate at the National Hospital on his first patients with severe epilepsy. Among the outstanding brain scientists and practitioners who aided with the diagnoses, were at his side during the surgery, or helped in other ways were John Hughlings Jackson, David Ferrier, and Charles Beevor.

Unlike previous surgeries for epilepsy, Horsley’s operations were based on John Hughlings Jackson’s (Jackson, 1870, 1873) revelation that epilepsy can originate at the cortical level, and on what had been learned about cortical localization of function during the previous two decades. Also contributing to the new, more optimistic environment were better anesthetics, which minimized the chances of infection.

Horsley’s first and third cases had skull breaks that helped him localize the source of the convulsions. His second case, however, was considerably more notable, because the patient had suffered a severe seizure disorder caused by a tuberculoma that could only be localized on the basis of signs and symptoms. Jackson, the dean of British neurology, suspected a tumor and advised surgery. Because he had worked on movements of different body parts elicited by cortical stimulation in monkeys, Horsley knew just where to open the skull and probe. Like his other two cases, this man survived the surgical removal of a small part of his motor cortex, and he was thereafter cured of his epilepsy.

Horsley received accolades when he presented these cases at a meeting of the British Medical Association in 1886 and had his results published that year (Horsley, 1886). Never before had people successfully diagnosed and removed diseased pieces of cerebral cortex as a means to combat epilepsy. One admirer even commented that these successful surgeries were “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 epilepsy, and then promoting it and using it for related problems, registered with the pioneer neurosurgeon. In effect, it led him to his fracture-based theory of ancient cranial trepanation.

Horsley’s theory originated during the same period in which he was still studying the motor cortex in monkeys
and now beginning to operate on patients with Jacksonian epilepsy. At this time, he took a trip to Paris, where he saw many of the Neolithic crania studied by Broca, who had died in 1880. In addition to archeology, Horsley enjoyed photography as a hobby, and he examined and took many photographs of these specimens for further study.

As put by Stephen Paget (1919, p. 124), one of Horsley’s biographers:

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.

Horsley recognized that the cranial holes made during the Neolithic Period did not seem to be randomly placed. As Broca had noted, the face was always avoided. He even drew a composhe map of the holes, and it showed that the openings were centered more or less above the motor cortex (Horsley, 1887, 1888).

This was a part of the brain Horsley knew extremely well. It had been and still was the subject of some of his most important stimulation and ablation experiments on monkeys. He would call it the so-called motor cortex because he thought it had both motor and somatosensory functions (Horsley, 1909). In addition, Horsley had just shown the medical world that this part of the brain is very likely to be damaged or compromised in cases of motor (Jacksonian) epilepsy, and that these seizures could be eliminated by surgically ablating diseased or injured parts of it.

In short, Horsley was convinced that depressed fractures above the motor region would have caused considerable surface pain and probably epilepsy. From this premise, he suggested that the tender flesh and bone might first have been treated surgically to control the pain, only to find that operating on the broken skull bones also controlled the epilepsy. “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).

THE FATE OF TWO THEORIES

The more general theory that trepanation might have been performed by Stone Age people for seizure disorders gained broad acceptance after Broca and Horsley gave their talks and saw their ideas in print. Nevertheless, there was never good agreement about whose theory did a better job explaining how the practice started in the Old World. Some favored Broca’s explanation, with its emphasis on the role of the supernatural in disease states, whereas others sided with Horsley, whose emphasis was on the probable consequences of cranial fractures without recourse to terrifying demons or the supernatural world.

Sir William Osler, one of the most respected men of medicine at the beginning of the new century, clearly favored Broca’s view. Sounding very much like Broca himself, he told his audience: “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” (Osler, 1923). Over the years, many people agreed that the surgery had to be linked to demonology and probably to convulsions, although other disorders, such as migraine headaches and mental illnesses, might also be treated in this way (see Wakefield and Dellinger, 1939, p. 167; Lisowski, 1967).

To some of these people, the weakest part of Broca’s theory was his belief that the surgery was largely, if not exclusively, performed on children. Late in 1879, one year before he died, he was interviewed by an astute female British anthropologist, A.W. Buckland, who examined the skulls in the Anthropological Museum with him and 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)

Broca responded that children’s skulls are not as durable as those of adults, especially if mutilated. Buckland knew this was true, but was not entirely swayed by this defense of the theory. In fact, she noted that the skull that showed the aberrant suture growth indicative of surgery early in life was still unique. Without additional skulls showing abnormal suture development, and without any children’s skulls exhibiting trepanations, she, for one, could not accept the part of Broca’s theory that held that trepanation was for the young.

As for Horsley’s hypothesis that traumatic injury was the initial reason for the surgery, here too one can find many supporters, both past and present (Stewart, 1958; Gross, 1999). Today, it is generally agreed that the best empirical support for the fracture or trauma theory comes from two sources, one old and the other new. The older data come from Peru, not Europe, Asia, or Africa. Many of these skulls, as noted, exhibit evidence of fractures and cranial injuries, and the ratio of males to females in some samples is as high as 4:1 (Moodie,
In addition, Peruvian trepanations are found most frequently on the left side of the skull, which is just what would be expected if wounds were sustained from right-handed adversaries (Stewart, 1958; Verano, 2003). Among the ancient Peruvians, treating fractures by trepanation seems to have been commonplace, although it was probably not the only reason for the surgery, so why could this not also have been true in Europe?

As for the newer material, anthropologists and medical historians have studied traditional societies, whose members still practiced trepanation into the 20th century (Ackemecht, 1947; Lisowski, 1967; Margetts, 1967; Rawlings III and Rossitch Jr., 1994). They found that the natives of some South Pacific islands performed these operations to treat fractures, epilepsy, insanity, and headache, but also for preventative reasons. The operation was also found to be commonplace in Kenya and Tanzania, where it was performed for headache with or without cranial fractures (Margetts, 1967). From all indications, these surgeries were done for medical problems—not for rites or rituals alone. But while fractures and post-traumatic epilepsy were important reasons for trepanning, they were not the only reasons.

Hence, there is indirect evidence to suggest that Neolithic trepanation might well have been an early intervention for treating neurological problems. Still, this is hypothetical and even modern scientists can do no more than speculate about the paradigms or the motives for these early surgeries in France and other locations thousands of years ago. In the absence of hard evidence, the theories of Broca and Horsley will probably continue to generate debate well into the future.

REFERENCES


