DISCOVERING TREPANATION: THE CONTRIBUTION OF PAUL BROCA

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Paul Broca was an icon of neuroscience and neurosurgery who also happened to be intrigued by trepanned skulls. His anthropological work established that, thousands of years ago, individuals not only trepanned skulls but also successfully performed these operations on living persons. After first commenting on a pre-Columbian Peruvian skull in 1867 (the first case of trepanning on a living person widely recognized as such), he turned to even older trepanned skulls found on French soil. In the 1870s, he theorized that the procedure originated as a means to treat convulsions in infants. As he saw it, Neolithic man attributed such convulsions to evil spirits, for which trepanation provided a ready means of escape. Because simple infantile convulsions resolve on their own, the practice would have seemed successful, and therefore it would have been propagated and expanded by later generations. Broca’s theory skillfully integrated his anthropological and medical knowledge and helped to create the exciting environment in which scientists pondered what Neolithic and primitive people really knew regarding the brain and surgery.

Key words: Broca, Convulsive disorders, Epilepsy, Horsley, Neurosurgery, Trepanation

During the 1870s, the scientific community was shocked to realize that they had long misinterpreted some fundamental data. The skulls of people living in France as long as 5000 years ago sometimes exhibited holes. For a long time, these openings had been thought to result from weapons, posthumous tampering, or accidental breakage. However, it was realized that some of the openings were actually caused by an intentional surgical procedure performed during the Neolithic or New Stone Age period.

Trepanation (from the Greek τρυπάνων, meaning auger or borer) has garnered the interest of neurosurgeons, neurologists, psychologists, and anthropologists since it was realized that ancient human hands not only made holes in skulls, but they performed the procedure on the living. The individual who deserves the most credit for successfully bringing ancient trepanned skulls to the attention of the scientific community, and for providing an early theory to account for trepanation, was Paul Broca.

Paul Broca first became involved with trepanned skulls, what he thought regarding the origins of the surgical procedure, and how his theory was received are the subject matter of this article.

**Paul Broca**

Paul Broca (1824–1880) (Fig. 1) was born in Sainte-Foy-la-Grande, a town east of Bordeaux (for biographical and scientific information, see Refs. 31 and 65). After graduating from medical school in Paris in 1848, he remained in the French capital for the rest of his life. Throughout his impressive career, Broca published more than 500 scientific articles; he was highly respected for his keen intellect and ability to observe things from many perspectives. In addition, he applied his exceptional talents to a wide array of disciplines, including neurology, neuroanatomy, comparative anatomy, human evolution and diversity, pathology, oncology, and therapeutics. He was instrumental in merging laboratory science with medicine, in revolutionizing thinking regarding the cerebral cortex, and in founding modern anthropology.

Broca began his distinguished scientific career in the 1850s, studying such illnesses as cancer, muscular dystrophy, and rickets. He became even better known during the next decade; first for the discovery of the language area that now bears his name (5), and then for suggesting that the left hemisphere plays the leading role in speech (6).

Broca was elected President of the Paris Surgical Society in 1865 and became Professor of Clinical Surgery in 1868. In the surgical domain, he introduced a procedure known as cranial cerebral topography, which uses cranial and scalp landmarks to localize underlying parts of the brain (9). He successfully applied his new method to one of his patients, a man who exhibited impaired speech after a closed head injury. He was able to localize the site of his inflection, trephine the cranium, and drain the abscess. Although Broca (16) did not report the case until 1876, this was, in fact, the first use of neurosurgery.
Based on the new theory of cortical localization of function (58, 68).

During this same time period, Broca was also deeply involved with physical and cultural anthropology. But just like everyone else before the mid-1860s, he had no reason to think about ancient trepanation practices on French soil, much less in South America. The situation changed dramatically for him, and subsequently for scientists around the world, when he was shown an old Peruvian skull with cross-hatched cuts in 1867 (Fig. 2).

**BROCA AND SQUIER’S PERUVIAN SKULL**

Ephraim George Squier, an archeologist, writer, and diplomat, originally had been sent to Peru by the United States government to settle some conflicting international claims. Once his job was completed, he began to travel to collect material for a book regarding Peru’s geography, people, and past. During his travels, he encountered a wealthy woman in Cuzco who enjoyed collecting and filling her home with fine antiques and artifacts. By far the most exceptional piece in her collection, at least from Squier’s perspective, was an incomplete skull with a rectangular opening near the top. It had come from an ancient Inca cemetery in the nearby Valley of Yucay.

In his monograph of 1877, Squier described the skull with its 15 × 17 mm 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” (65, pp 456–457). Impressed by the potential significance of the specimen, he 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 (65, p 456).

Although a trepanned skull from South America had been depicted in 1839 in a book by Morton on American crania (51), its significance had not been recognized at the time. Morton thought the hole had been made by a blunt instrument, possibly the back of an axe, during battle. Unlike most trepanned skulls, which have smooth, round openings that might not have suggested surgery, the cross-hatched cuts on Squier’s Peruvian skull could have been crafted only by skilled human hands.

Squier brought his skull to New York, where Dr. A.K. Gardner presented it to members of the New York Academy of Medicine in the winter of 1865. 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 (28, p 530).

The audience’s reaction, however, was mixed. Although many members of the academy agreed with Gardner, 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 (28, p 530).

Without uniform agreement regarding the specimen, and perhaps also because Squier wanted to enhance his own fame, he now decided to solicit an expert opinion. The skull was sent to France and shown to Broca, who not only had 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 authority on the brain and its pathology.

After careful examination, Broca concluded that the Peruvian skull represented a case of “advanced surgery” from the New World before the European conquest (7, 8). As he explained to the members of the Société d’Anthropologie, the features of the circle of bone around the opening were denuded of its periosteum, which 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 1 or 2 weeks later.

This knowledge opened up a plethora of new questions. Why, for example, was such an operation performed? Under what conditions? And was it successful?

One possibility was that the bone was removed to treat a cranial fracture. Josiah Nott, an American researcher who was shown the skull, favored this idea, as did Squier, who had also observed other skulls from Peru that had been penetrated by sharp weapons such as lances and arrows (65). But there were problems with the fracture theory, the most important of which was that no unusual cracks or lines were found anywhere on the Peruvian skull to suggest an injury.

Finding no fractures, Broca considered a related medical possibility. It was one that he was familiar with—namely that the operation might have been performed after a closed head injury to relieve a buildup 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 (7, p 407; translated in Ref. 65, 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 (7, p 408; translated in Ref. 65, p 579).

MORE DISCOVERIES

Broca’s observations, insights, and conclusions regarding the Peruvian skull generated considerable excitement. Among other things, they led French anthropologists to look for even older trepanned skulls in their own backyards. To his delight, hundreds of Neolithic skulls with perforations were soon discovered on French soil. Many are now estimated to be 4000 to 5000 years old. The older idea that craniotomies were first performed by the Greeks at the time of Hippocrates in the context of humoral theory clearly was no longer tenable (2, 33, 48).

Additional Neolithic discoveries were made later in the 19th century in Spain, Portugal, Germany, Czechoslovakia, Scotland, Denmark, Sweden, Austria, Poland, Italy, and Russia (34, 41, 52), and in the 20th century, even older skulls were unearthed (29, 38, 39). Many drilled, scraped, and gouged skulls also were unearthed in Peru and Bolivia, and to a lesser extent from other countries in the Americas. Among the most notable of the New World skulls were two found in Peru, one displaying five separate openings and another with seven holes exhibiting healing (44, 53, 56). Especially in some Peruvian burial sites, the operation had a high frequency of occurrence, and overall survival rates were estimated to be in the range of 50 to 60%. But in contrast to the Old World discoveries, the Inca and pre-Inca skulls are less than 2500 years old. Elaborate scraping instruments called tumis and some Mochica pottery exhibiting trepanations being performed also have been uncovered in Peru; these discoveries are without parallel among the older European finds (30, 71, 72). The wealth of new discoveries, beginning with those made in France, forced scientists to reexamine some of the perforated skulls that had been collected years earlier. They were astonished to find that some probable examples of ancient trepanned skulls were already sitting on their shelves.

THE DISCOVERY OF FRENCH TREPANNED SKULLS

With characteristic intensity, Broca immersed himself in analyzing the ancient skulls found in France during the 1870s. Although he found few skulls himself, he studied the findings made by many others, especially those unearthed by P. Barthélemy Prunières, his friend and associate.

In the central region of France, Prunières (59) explored and excavated the megalithic granite dolmens (from the Breton language, meaning stone tables). In the dolmens of Lozère, he discovered some skulls with large openings (more than 200 skulls would eventually come from these sites). He also found rounded, polished, and beveled pieces of cranial bones nearby and even within some of these skulls. Prunières (60, p 189) called these fragments rondelles, and both he and Broca (18, 21) agreed that they were probably worn or carried as charms or amulets (Fig. 3; see Ref. 52 for a lengthy discussion of these amulets). In 1873, Prunières presented a notable report on these rondelles, followed a year later by two important articles on the skulls.

Of particular significance was a skull with three elliptical cut-out areas along the parietal wall, the central of which seemed to have been smoothed or polished (Fig. 4). Prunières (61) pondered the significance of the cut-out regions, particularly the smoothed central one, and concluded that this skull once had served as a celebratory goblet. Although the idea may seem outlandish, the word skal, meaning skull, has long been used in Scandinavian countries as a toast to one’s health before drinking.

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Broca praised Prunières for his sharp eyes and mind, and for the care with which he worked. Nevertheless, in the discussion after Prunières’ presentation and elsewhere, Broca (11, 12) offered a very different interpretation for the features characterizing this unique find. To Broca, the central issue was why one of the cut-out regions was smooth and the two others were not. He postulated that the openings had been made by scraping with a sharp stone, such as a piece of flint, and that the smoothed surface resulted not from the use of the skull as a cup, but from an extended period of healing. In short, Broca contended, a large piece of cranial bone had been removed long before this individual died. Most likely, he went on, the operation was performed quite early in life, possibly in some religious or social context. He noted that priestly ceremonies and initiations involving blood and surgery were well known to anthropologists, and therefore completely plausible among the “savages” of the more distant past.

THE FOUNDATIONS AND EMERGENCE OF A THEORY

Broca (13–26) published many articles and gave many talks on trepanation after making these remarks. He now sought to do two things. First, he wanted to convince more people that some of the holes observed in these skulls were not caused by infectious processes, congenital defects, tumors, gnawing animals, accidents, or battle wounds (19). Second, he wanted to incorporate all of the facts into a single theory that could readily account for the reason trepanation was performed in the Neolithic period. Along these lines, he hoped to demonstrate that the surgery was largely or exclusively performed during childhood, that it was associated with some sort of problem, that it could be viewed as curative, and that it and the rondelles could be tied to primitive religious beliefs.

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 diseases. 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 we would preferentially take even from the borders of the healed trepanation opening (19, p 111).

First, Broca established the cultural period in which he was working. He made his assessment on the basis of the artifacts found along with the skulls. On his initial trip with Prunières to the Cavern de l’Homme-Mort (in 1872), he studied the flint and pottery found at the site (10). From these artifacts, and with his knowledge of cremation, he concluded that the skeletal fragments spanned almost the entire Neolithic or New Stone Age era, the era associated with polished stone tools,
community life, farming, and the domestication of cattle (17, 23; see also the opinion of M. de Baye in Ref. 17, p 285).

He next set out to establish that at least some of the cranial openings were made by human hands. 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.” At the time, he was uncertain as whether it resulted from an “aggressive blow,” which would have disqualified it as a potential trepanation opening (10, cranium #8, p 18; see also Ref. 11). He was also suspicious of some skulls with bilaterally symmetric openings that he subsequently interpreted as congenital malformations (13, 14).

Broca was conservative as he culled out the false-positives. Despite this, many skulls and cranial fragments still met his criteria for trepanation during life. The consistency of the characteristic oval holes provided the most convincing evidence that some of the openings were created intentionally during life—as he put it, moved by the patient hand of “a methodical operator, not a furious enemy” (11, p 197).

His proposal also had indirect supporting evidence. No strong sex or laterality biases seemed to exist among the skull openings. Moreover, bone was never taken from a place that would alter or distort the visage. If these were simply battle openings. Moreover, bone was never taken from a place that would alter or distort the visage. If these were simply battle attacks to land a large number of blows to the facial region, which would have disqualified it as an aggressive blow, which would have disqualified it as a potential trepanation opening (10, cranium #8, p 18; see also Ref. 11). He was also suspicious of some skulls with bilaterally symmetric openings that he subsequently interpreted as congenital malformations (13, 14).

Broca now outlined the difference between trepanation on the living, which he called “surgical trepanation,” and trepanation on the dead, which was designated “posthumous trepanation.” The two could be distinguished by the shape and orientation of the openings and whether the edges were smooth. In some cases, the same specimen exhibited evidence of both types of openings.

Broca’s “textbook” case was Prunières’ specimen exhibiting both smooth and rough openings (Fig. 4). When he first saw it, he noted that the coronal and lambdoidal sutures were fused, indicating that the person had lived to a reasonably mature age. But dark material obscured the bone over the midline sagittal suture and had to be cleaned off with an alkaline solution. When Broca did this, he observed that this suture was abnormally deviated. The deviation was maximal (12 mm) at the level of the smooth trepanation hole, and not aligned with either of the other two more rugged openings. Broca argued strongly that, to sustain this type of marked deviation, the smooth opening must have been made when the cranial bones were still developing. As for the other two rough openings, they were probably made after death.

Although Broca concluded that “surgical trepanation” must have been performed largely, if not entirely, on infants, there is no evidence to demonstrate that he came across either additional specimens with abnormal sutures or the skulls of trepanned children. Nevertheless, he argued that his conclusion made a certain amount of practical sense. After all, an infant’s soft, thin cranium is much easier to penetrate than an adult’s, and it also heals far more rapidly.

To drive home the first point, he conducted experiments to demonstrate just how quickly immature crania could be penetrated with “primitive” flint or glass scrapers (22). He found that he could scrape a hole in the skull from a deceased 2-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). Craniotomy experiments also were performed on living dogs, further demonstrating that it is relatively easy to trepan a skull, avoid damaging the dura mater, and still leave the subject alive and healthy (25, 26).

Finally, Broca commented on the oval amulet that was found in the earth inside the same skull. By its thickness and color, Broca concluded that the amulet was not cut from the same skull that housed it. Rather, it could have been a charm carried by or given to the deceased.

Thus, Prunières’ one cranial specimen illustrated all the points Broca had hoped to make: 1) on the basis of the deviated sagittal suture line, the trepanation procedure was performed very early in life, 2) this person survived to old age, as evidenced by the fusion of the lambdoid and coronal sutures, 3) the amulet placed inside the skull indicated that this individual might have had special significance in the tribe, 4) the goal of posthumous trepanation was the fabrication of these cranial amulets, and 5) the amulets were protective, serving to ward off evil spirits and acting as a source of good luck.

As Broca put it:

“It is therefore natural to think that these individuals were considered in their tribe as having a character of sanctity, and it is this idea that represents the spirit of what I would present. … The cranium where 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 (19, pp 162, 168).

WHY TREPAN? COMPLETING THE THEORY

Broca and Prunières agreed that a therapeutic component must have been the reason for surgical trepanation. Their specific ideas, however, were quite different. Prunières contended that cranial fractures or depressed bone pieces would have caused serious problems, including convulsions and delirium. He maintained that surgical trepanation originated to remove the source of these problems and alleviate the symptoms (20, 61). He envisioned the Neolithic surgeon using something like observation-based medicine, similar to that practiced in his own day.

Broca disagreed. “I think for my part that they were inspired, not by observation, but by superstition” (19, p 164). After all, he explained, the French skulls with surgical trepanation display no evidence of fractures. In addition, the anthropologist in Broca did not think for a moment that Neo-
lithic people had any understanding of the physiological functions of the brain or, for that matter, anything like a sophisticated medical surgery.

Still, surgical trepanation must have addressed a practical problem. It was “a goal with an immediate utility, and because 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” (19, p 162). With this in mind, Broca thought about infantile convulsions.

He knew trepanation had been a common treatment for spontaneous epilepsy in the past. Even in his own day, trepanation was still being performed in some parts of the world to exorcise demons thought to cause seizures. It made sense, therefore, to propose that Stone Age humans probably thought much like modern aborigines. “That which engenders superstition,” he reasoned, “is the unexplainable diseases” (19, p 166). Indeed, disorders such as uncontrolled convulsions invite the speculative mind to insert whatever explanations are supported by its belief system.

In a lengthy article published in Budapest in 1876, Broca (19) cited Jean Taxil, a physician from Arles who lived in the early 17th century. Taxil wrote an entire chapter on the connection between epilepsy and demonic possession (69, p 149–159). He maintained that it was not possible to find a demoniac who was not an epileptic (see also Ref. 70). To Taxil and others at the time, the unconscious and powerful movements of epilepsy created the image of an imprisoned spirit. If one could create an opening, these physicians reasoned, the mischievous spirits would have a means of escape.

Taxil also thought that cranial bone fragments might serve as protective talismans. He wrote that human cranial bones possessed special curative powers for epilepsy. Shavings, powders, and cinders of human cranial bones all were recomposed special curative powers for epilepsy. Shavings, as protective talismans. He wrote that human cranial bones chievous spirits would have a means of escape. If one could create an opening, these physicians reasoned, the mischievous spirits would have a means of escape.

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Taxil also thought that cranial bone fragments might serve as protective talismans. He wrote that human cranial bones possessed special curative powers for epilepsy. Shavings, powders, and cinders of human cranial bones all were recommended. They could be applied to the coronal suture, taken as potions and pills, or worn or carried in small pouches. At the time, flasks labeled Ossa Wormiana graced the shelves of pharmacies, and they were filled with suture bones for treating epilepsy. To complete the picture, Taxil even commented on the incidence of epilepsy in the young. In his opinion, it was more common in children than in adults.

Taxil’s notions regarding epilepsy and children provided indirect historical support for Broca’s theory that Neolithic trepanation was probably performed to treat seizure disorders in children. Broca, however, recognized that Taxil was using the term “epilepsy” too 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.

Broca was careful to point out that true epilepsy is relatively rare before age 10. He therefore concluded that this condition was not likely to have motivated surgery on children in the Stone Age. If young children did have epilepsy, trepanning would not have helped them—and the same can be said regarding trepanning the crania of adults (12, 19, 24). Similarly, he dismissed seizures caused by meningitis. If a child or adult had this disease, they would not have survived it, whether trepanned or not.

This process of elimination left children with “simple” convulsions, like those commonly produced during teething or by a rapid fever spike. From Broca’s perspective, these children were ideal candidates for the procedure because such conditions are benign and typically resolve on their own. Trepanning children who experienced simple convulsions, who would have gotten better anyway, would have provided the needed illusion of success. A belief in the effectiveness of the procedure, even if erroneous, was essential for it to prosper and spread.

Broca thus combined his medical and historical knowledge with what he thought he 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 whether it was routinely performed on children, both men thought a specific medical condition resulted in a procedure to cure individuals of serious problems. From Broca’s perspective, Neolithic people used trepanation to provide an exit for the demons that caused childhood convulsions; for Prunières, it represented a logical way to alleviate the consequences of depressed fractures.

RECEPTION OF THE THEORY

Broca provided a theory of trepanation that addressed why trepanation was performed, who was trepanned, when it was done, and how it fit into the culture of the time. One of the most interesting aspects of his theory was his proposal that “surgical trepanation” was passed on through false-positives. To many of his contemporaries, especially those in anthropology, Broca’s synthetic hypothesis represented a reasonable first step toward understanding the data.

Broca, however, also had his share of critics. Many thought that the overall theory had merit but some of its details did not. One such person was a woman named Buckland (27), who hoped to stimulate comparable anthropological work on English soil. She went to Paris and interviewed Broca just before he died. Although she was impressed by his knowledge, descriptions, and logic, which linked trepanation to mystical beliefs, she doubted his contention that craniotomies were routinely performed on children. She knew the procedures would have killed more than a few children, but no children’s crania had yet been identified by French skull collectors. When she politely asked Broca about this, he responded that the softer, thinner bones of a child, especially those specimens with cranial defects, would not have survived the ravages of time. Broca, of course, knew that he would have been able to make a much stronger case if he actually had such specimens.

Another critic of Broca’s theory, albeit a few years after Broca died in 1880, was Victor Horsley, the so-called “father of neurological surgery” (35, 43). At the time, Horsley (43), Macwen (45–47), and Godlee (3, 4) were giving neurosurgery its modern look, basing it on cortical localization, aseptic procedures, and experimentation. In the mid-1880s, which was when he was first beginning to operate on patients with cortical epilepsy, Horsley took the opportunity to examine the Broca skull collection in Paris. He took photos and walked away convinced that the openings were regularly placed over the so-called “motor cortex.” To Horsley (36), this meant that
the operation must have been performed as a way to treat posttraumatic epilepsy caused by cranial fractures above the motor cortex, not internal maladies (see Ref. 32).

In 1929, Lambert Horsley (64), a general surgeon, challenged Horsley’s assertion regarding locus of the openings. (The motor cortex was thought to be much larger when Horsley first presented his theory than in Rogers’ day.) He thought that, in terms of his general orientation, Broca was probably closer to the truth than Horsley. He joined with those anthropologists who maintained that demonology, religion, culture, and the primitive mind had to be brought into the equation.

Rogers made his comments a decade after Sir William Osler, one of the most respected men of medicine at the turn of the century, gave his Silliman Lectures at Yale University. In 1913, Osler favored a modified version of Broca’s view when he stated:

“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 (55, p 8).

Osler did not, however, contend that the operation was performed exclusively or even largely on children. Many others adopted a modified pro-Broca orientation that deleted the parts regarding children. To quote from an article written in 1939:

“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 (74, p 167).

Clearly, Broca’s general theory had become more palatable once the age requirement was dropped.

POSTSCRIPT

The modified Broca theory is still alive and well (new evidence for extensive childhood trepanation still has not emerged). But also very much alive is the fracture theory first favored in general form by Prunières and then overlaid by Horsley, who tried to tie trepanation to cranial fractures above the motor cortex and the likelihood of Jacksonian epilepsy. Today, however, the best evidence for the fracture theory comes from the warring tribes that inhabited Peru, not from Neolithic Europe (35, 37, 50, 57, 63, 67, 73).

Many questions remain regarding the origins of trepanation, especially in Neolithic times. For example, why were the openings not filled in more over time, especially because reasonably long-term survival would allow progenitor bone cells to migrate into the margins of the wound to rebuild the bone inward? Did the surgery emerge in one place and then spread to different cultures? And, of course, why were craniotomies first performed?

The study of tribes that still practiced “surgical trepanation” into the 20th century provides some suggestions (1, 40, 42, 49, 54, 62). Among natives of the South Pacific Islands, it was performed to treat fractures, epilepsy, insanity, and headache, as well as for preventive reasons. It also was performed for headache with or without cranial fractures in Kenya and Tanganyika, where the operation was fairly commonplace. In terms of the “big picture,” the commonality seems to be that the operation was performed for any of a number of medical conditions, especially seizures and headache. There is little evidence to suggest that trepanning was routinely performed for nonmedical reasons, such as for a rite of passage or for social status.

In closing, it is worth remembering that speculation regarding how our distant ancestors thought about illness, injury, surgery, and the brain may persist for a myriad of reasons. One reason is that they may have some indirect support, and another is that certain ideas are just plain intriguing. A third reason has to do with the great names associated with these ideas, and a fourth is the Zeitgeist these people, their findings, and their ideas helped create. To these four considerations we can add yet another possibility, one which was not lost on Broca and the other surgeons and anthropologists who first examined these mutilated skulls and cranial fragments. It is the realization that our Neolithic ancestors, like the pre-Columbian Peruvians, actually may have performed seemingly dangerous and invasive surgery with unprecedented and surprising success.

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REFERENCES


**COMMENTS**

Paul Broca is a name well known to all neurosurgeons; most of us learned about “Broca’s area” very early on. However, most are not aware of his multifaceted contributions to the medical and scientific literature. Not only a skilled neurologist and surgeon, he also contributed considerable research to the anthropology literature. I have had in my own library for some 20 years his five-volume work on Mémoires D’Anthropologie (1871–1888), which includes a majority of Broca’s writings. After reading this article I pulled those volumes off the shelf and went through them for several hours, astonished on how wide and varied his research efforts were. As the authors so clearly point out, Broca always went to the source for his data and his work on trepanation. His attempts to explain why it was done were accomplished by looking and studying the recently exhumed skulls. As a result of these studies, Broca branched out even further and developed some of the earliest studies on cranionetrics and cranioscopic instruments. As a result of these efforts, he provided some of the earliest studies developed on cerebral localization, cerebral anatomy, and stereotaxy. He was a truly gifted man and one who comes to life in this article on early trepanation.

**James T. Goodrich**  
Bronx, New York

This fascinating historical article combines both an excellent history of trepanation of the cranium with the contributions of Paul Broca in the area of anthropology and medical history. These aspects of his career and his intellect are certainly less well known than his description of the Neuroanatomy of Speech. It is exciting to see yet another dimension of this outstanding pioneer in neurology.

**Edward R. Laws, Jr.**  
Charlottesville, Virginia

This is a nice article on the contribution of Paul Broca to interpretation of Neolithic and pre-Columbian skull openings. It is very interesting to discover this aspect of Paul Broca’s talents, which is not well known. Reading this article, I discovered that Paul Broca founded la Société d’Anthropologie and was a real expert in this field. It is amazing to note that the interest of a neurologist toward ancient skull openings occurred just before the first neurosurgical trepanations. This gives the impression that current neurosurgeons are at the end of a long line of people who have questioned themselves regarding the cranium and the brain.

**Bernard George**  
Paris, France

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*By the Seashore, Martinique*, by Paul Gauguin, 1887. Courtesy, Ny Carlsberg Glyptotek, Copenhagen.