

Historical article

Cranial Surgery in Ancient Peru

Stephanie Rifkinson-Mann, M.D.

Division of Pediatric Neurosurgery, Department of Neurosurgery, New York University Medical Center, New York, New York

Trephination is the oldest known surgical technique. Peru has been recognized as a major source of ancient trephined skulls, many of which date back 2300 years. This presentation reviews from a neurosurgical perspective many of the archaeological studies performed on these skulls. Comparative osteology has shown that almost 70% of patients survived the procedure. The various instruments, hemostatic agents, anesthetics, surgical techniques, and cranioplasties used are reconstructed from the anthropological literature. The possible reasons for the use of trephination are discussed. Analysis of the data leads to the conclusion that, despite their rudimentary knowledge of disease, the ancient Incas must have had some knowledge of anatomy and proper surgical procedure. (*Neurosurgery* (23:411-416, 1988))

Key words: Inca, Peru, Trephination

As Ernest Sachs noted, "It is rather extraordinary that neurosurgery, one of the most recent specialties, should have had its beginnings in the neolithic period, long before any written records existed" (51). The oldest known operation is trephining, which was carried out by many cultures in several parts of the world (1, 3, 25, 31, 44, 54). The practice of trephination among the ancient Incas is of special interest to neurosurgeons because 2000 trephined Peruvian skulls in museums are the best evidence that cranial surgery was performed over 2300 years ago (2, 18, 25, 66). The oldest American trephined skulls, dating back to 500 BC, were found in Peru near the imperial city of Cuzco and were studied by Paul Broca and others (5-10, 24, 33-35, 37-39, 49, 53, 61, 62).

Studies have analyzed cranial bone grossly and microscopically. Incisional borders have been examined and bone thicknesses compared. The degree of skull maturation has been determined by the condition of teeth and of cranial sutures to give data on patient populations. Signs of trauma, osteitis, osteoma, and bone repair have been recorded (8-10, 16, 55-58, 61, 62, 70). Healing after surgery has been seen at the margin of the trephination and is based on a closing diploë, smooth incisional borders, and the presence of osteophytes (27, 70). Signs of bone repair have been interpreted to mean that these operations were done on live patients who survived years after the procedure (8-10, 24, 34, 38, 39, 42, 48, 61, 62, 66) (Fig. 1). Survival rates were calculated by studying the number of healed openings in trephined skulls. Over 70% show evidence of healing (Table 1) (24, 48, 62). Some investigators ascribe the substantial survival rate to the sturdiness of the people, writing that their "resistance . . . was simply amazing, some of them having survived five successive trephinings and a dozen or more skull injuries which in others might have been fatal" (38, 51).

Of the 2000 Peruvian skulls in museums, 250 specimens with trephinings were studied extensively (18, 61, 62). Of these skulls, 171 (68%) were from male and 42 (17%) were from female patients; 37 (15%) were of undetermined sex.

Gilbert Horrax noted that signs of trauma in so many male skulls suggested that surgery was undertaken for the wounds of soldiers hurt in hand-to-hand combat (15, 18, 22, 23). Wilder Penfield suggested that trephination was performed for subdural hematomas (26). Sir Victor Horsley thought that the procedure was carried out for depressed fractures and that they cured focal epilepsies caused by these injuries (22, 23). Most of the trephinings were performed on the left side, perhaps because trauma inflicted by a right-handed adversary would fall on that side (27, 31).

The possible military importance of trephination has been suggested by the frequency with which trephined skulls have been found in the burial grounds of Incan fortresses as opposed to the relative paucity of such skulls in the coastal areas known to be inhabited by pacific communities (11, 36, 29). It has been estimated that 28% to 46% of the trephinings were performed to treat traumatic injuries (15, 28, 29, 39, 42); however, several investigators have concluded that such estimates are too high (12, 29, 30). Margins of fractures or other perforations may have been removed at the time of operation, thereby eliminating obvious signs of trauma for which the operation may have been performed, or complete cicatrization of bony margins may have occurred.

Many trephined skulls show no gross abnormality. There is no evidence that pre-Columbian Peruvian trephination was performed to obtain bony amulets to be used as charms (12, 17, 21, 34, 37, 41, 52). Operation may have been performed to cure cerebral disease. One cause of illness was thought to be disaffection in the spirit world. The patient may have violated a taboo. The spirits revenged by introducing into the body a demon, which had to be let out (13, 14, 20, 64, 65). Sir William Osler wrote, "[Trephination] 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" (44).

Another cause of cerebral disorder was thought to arise from the loss of the ethereal image of man. Once separated from the body, illness followed. If there was no way for the

TABLE 1
Survival Rate after Trephination^a

	No. (%)
Skulls with signs of healing	
Completely healed	119 (55.6%)
Partially healed	35 (16.4%)
	154 (71.0%)
Skulls with no signs of healing	60 (28.0%)
Total of skulls studied	214 (100.0%)

^a After Weiss P: *Osteologia cultural: Practicas cefalicas*. An Fac Med (Lima) 1958.



FIG. 1. Pre-Columbian skull from Cuzco, Peru, showing triple trephination followed by a period of healing. (From Muñiz MA, McGee WJ: *Primitive trephining in Peru*. MA, 16th Ann Rep Am Bur Ethnol for 1894-5, pp 3-72, 1897.)

spirit to return, the patient died (64). Horrax suggested that the afflicted may have suffered paralysis, cerebral palsy, severe depression, or mental retardation and that trephination would have been used to allow the spirit to return, thereby curing the disease (11, 22).

There is no indication that any anesthetic beyond a mild intoxicant was used, perhaps potentiated by herbal preparations of datura, yuca, or coca (18, 24, 26, 63, 65, 67) (Fig. 2). Sachs wrote that "the common practice of chewing the leaves of *Erythoxylon coca* . . . may have been used for its anesthetic effect" (51). The most painful aspect, the scalp and periosteal incision, would have already occurred in cases of trauma (26). The operation may have been performed while the patient was in coma or shock (27).

Walker (65), Asenjo (4), Wilkins (68), and others have noted that the operation itself followed a definite sequence (24, 32, 43, 67-69, 71) (Fig. 3). The patient may have been in a sitting position or semireclining to reduce blood pooling and to increase the field of vision (4). The high frequency of parietal craniectomies may have been due to the accessibility of the area to the operator, who may have held the head fixed with his left arm or between his knees and then operated with his right hand (26, 40) (Fig. 4). From the study of mummies with scalp scars, the incisions seem to have been linear (4).

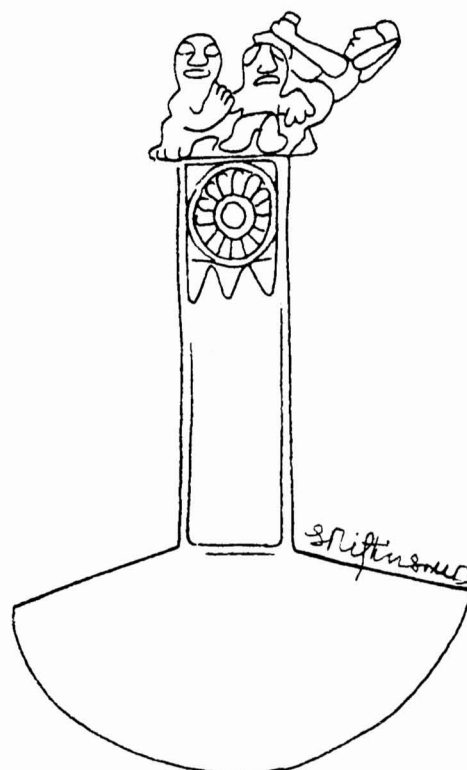


FIG. 2. Sketch of a tumi with a sculptured handle shows a crying patient being restrained by one person while a surgeon performs a trephination. (After A. Asenjo: *Neurosurgical Techniques*, 1963; courtesy of Charles C Thomas, Publisher, Springfield, IL.)



FIG. 3. The ancient Peruvian surgeon begins the trephination while assistants restrain the patient. A priest seeks supernatural intervention through incantations and prayers. (Courtesy of the Parke-Davis Division of the Warner-Lambert Co., Morris Plains, NJ 07950; reprint of "Trephining in Peru," by Robert A. Thom.)

These were made with chisels of copper, silver, gold, or a mix of these three metals; knives and obsidian lances; or tumis (straight or crescentic blades with a short central T-shaped handle) (18, 26, 61-63, 67). The cranial openings were recti- or curvilinear, V-shaped in cross section and canoe-shaped as seen from a coplanar angle. They were broad and deep toward the middle and shallow and narrow at the edges. Bone elevation was done by applying a knife or other instrument in lever-like fashion as a fulcrum over one margin, resulting in



FIG. 4. Clay huaco, discovered in 1917 by Morales Macedo, shows an ancient Peruvian surgeon sitting behind a patient and supporting the head with his left hand while performing a trephination with his right hand. (From A. Asenjo: *Neurosurgical Techniques*, 1963; courtesy of Charles C Thomas, Publisher, Springfield, IL.)

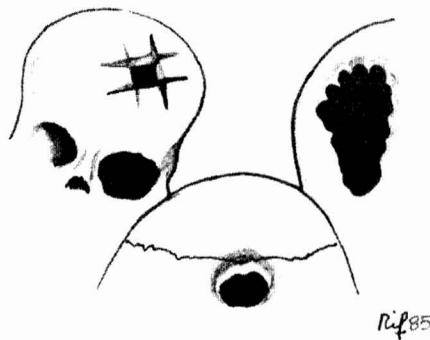


FIG. 5. Sketch depicting the major techniques of Incan trephination: left, rectangular; right, cylindrical-conical; center, circular.

the edge being splintered, crushed, or undercut (15). Rough margins were smoothed over by rasping or filing away the bone with an irregularly edged instrument. Modern neurosurgeons, repeating the procedure experimentally on postmortem adult skulls, estimated that one trephination took 30 minutes to an hour (18, 26).

Three types of Peruvian trephination have been classified according to the shape of the craniectomy: rectangular, cylindrical-conical, and circular (26, 67) (Fig. 5.). A variation of the last method, the supra-inion technique, is distinguished by its consistent location in the wormian "Inca bone" (26, 67) (Fig. 6). Taveras and Wood suggested that the term "Inca" was used to denote this bony anomaly because of its presumed frequency in Peruvian mummies (19, 47, 52, 59, 60).

Hemostasis may have been obtained by the application of extracts from the Andean *Ratania* root and *Pumachuca* shrub, rich in tannic acid (27, 50, 63). The surgeon may have applied beeswax to bone edges and compressed the scalp externally (63). Scalp margins were joined in some cases by tying the hair across both sides of the cut (65). The wound may have been sutured; metal needles and cotton thread have been found at burial sites (26, 46, 67). One 1500-year-old Peruvian skull with signs of recent trephining had a cotton bandage covering the wound (18, 24, 36, 42, 65) (Fig. 7).

Little is known about what these primitive surgeons did to

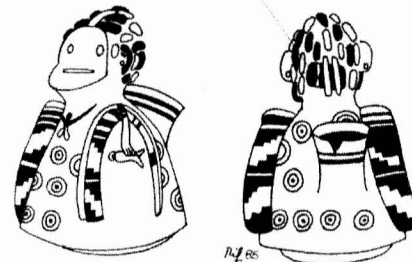


FIG. 6. Sketch of a ceramic huaco showing a rectangular occipital trephination, an example of the supra-inion technique, which is distinguished by its consistent location in the wormian "Inca bone."

prevent infection. Harvey Cushing noted that skulls had been found with gold or silver plates covering the craniectomy, but that the plates were not well tolerated (13, 67). Cranioplasties of mate, coca, gourd, coconut, calabash, or other plants also failed (4, 15). Few cases of osteomyelitis were found, however (24, 31). Sachs wrote that the operations were done rapidly because little anesthetic was used. This speed may have played a key role in decreasing infection (51).

It is hard to believe that the ancient surgeons did not have some understanding of anatomy, as many of their patients survived (18, 61, 63). Horsley suggested that prehistoric surgeons may have had an idea of localized brain function because many openings were made over the motor cortex, "which when irritated gives rise to movements of the opposite side of the body" (23, 51). As noted by Gurdjian, "In some



FIG. 7. A 1500-year-old Peruvian skull from the Nasca region, showing recent trephining and bandage. (Collected by A. Hrdlicka, from *Ciba Symposia* 1:176, 1939.)

specimens the midline vertex bone is undisturbed as if the operator knew of possible dangers from working in the midline vertex" (20). This understanding of vital brain regions may have been gained by experience when surgeons damaged the venous channels and caused hemorrhage and death (20, 45, 67). Perhaps such information was related to other operators or training centers in Cuzco or Paracas, where evidence of medical treatment has been found (26, 67). There is no firm evidence that trephination was performed posthumously in Peru (26), but it has been suggested that the procedure was practiced by inexperienced surgeons on patients who had died of some cause other than that directly related to the trephination itself to give the young surgeon technical experience (11, 12, 26, 38).

The trephination was practiced independently in several areas around the world implies that certain practices arise from similar human responses to ideology or need, irrespective of culture or environment (20). Possibly the people treating such cases recognized the relation between certain syndromes and lesions of the nervous system (23, 62, 63, 67). Because primitive humans explained disease in magical terms, critics have sought to discredit the knowledge of medicine that they may have possessed (18). As Asenjo noted, however, "even the most primitive peoples attributed to the brain the faculty of directing the spiritual and intellectual activity of man" (4). Therapeutic methods often become acceptable depending on their results, whether or not they are understood. Once thought to be effective, they may be used routinely, as trephination is today in the practice of modern neurosurgery.

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Reprint requests: Stephanie Rifkinson-Mann, M.D., Department of Neurosurgery, New York Medical College, Munger Pavilion, Valhalla, NY 10595.

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COMMENTS

Dr. Rifkinson-Mann presents a topic that has intrigued scientists throughout the ages. Many of the giants in medicine have written and spoken about the topic of prehistoric trephination, well referenced by the author. It is not surprising that the interpretations of the first trephinations discovered in modern times caused considerable controversy. No written records of the reasoning behind the need for trephination have been discovered; however, the evidence of ancient skulls confirms that the act was practiced in prehistoric times. Our remote ancestors simply handed down by tradition to succeeding generations their knowledge of the effects of injuries and their treatments. This is where the controversy arises: Why? Essentially three schools of thought have evolved: trephination for (a) cerebral disease, (b) religious acts or rituals, and (c) trauma. Dr. Rifkinson-Mann quite nicely presents all three schools. The author, however, leads the reader to believe that the ancient Incas must have possessed some knowledge of anatomy and proper surgical techniques. An opposing and not-to-be-overlooked opinion is provided by Dr. D. Campillo, who studied more than 3000 ancient skulls (1) and concluded that scientific knowledge was not the reason for trephination. His argument was based on the characteristics of the lesions. With trephine sites rarely exceeding 3 to 5 cm in diameter, and those only a few millimetres deep, it would be quite difficult to operate efficiently even with modern instruments. Many skulls demonstrate the presence of intracranial tumors (i.e., hyperostosis), yet these skulls are without evidence of surgical intervention. If the early surgeons had recognized the relationship between certain syndromes and lesions of the nervous system, it seems logical that they would have addressed those lesions and that evidence of surgery would be present. On the contrary, it is exceptional when evidence of these lesions coexists with a trephination (1). Furthermore, instrumentation plays a great part in any neurosurgical procedure. The rough tools used in the brain by the ancients would have certainly led to poor outcomes. Finally, not all primitive people believed the brain to be the spiritual and intellectual organ. Many believe that the soul, intelligence, and emotion were located in the heart. Some considered disease to be located in the liver (1). Thus, if there seemed to be a problem with intellect or emotion, why address the brain? Therapeutic methods logically become acceptable based on their results. Trephination could have been an innocuous procedure if the brain was not embarrassed. This practice would have allowed a significant degree of success and thus approval of the procedure. With the approval came the transmission of the technique for generations. Incompleted trephination by means of a drilling technique has also been noted (1), but why was the act begun and not completed? In these cases, a religious act or ritual was the likely reason.

The weaponry of the Incas of Peru frequently produced wounds of the head. The medicine men apparently learned that removing the depressed or driven bone would relieve the pressure on the brain and might even cure the patient. In these cases, trauma was the apparent basis for intervention.

Of course, survival would have depended on the degree of injury or embarrassment to the underlying brain. In these instances, the ancients could not have planned their bone flap, for the opposing warrior did this for them. If an important structure (i.e., venous sinus) were involved, the likelihood of survival was quite remote. It seems most unlikely that the ancients could have controlled this type of bleeding with a favorable outcome. A generous exploration of the underlying structures would have been needed. Few giant trephinations demonstrate postoperative survival (1).

The Incas of Peru were not the only people in the New World to practice trephination. There are isolated examples in North America as well (2). The climate of the North, however, is not suitable for preserving the remains of its early inhabitants. The unusually dry air of the plains and mountains of Peru is credited with preserving the remains of the empire of the Incas (3).

In conclusion, has the author completely answered the question of the reason for trephination? I think not. The controversy continues. The purpose of these early craniectomies can only be conjectured. This is a topic that will always spark interest—especially in the neurosurgical world.

T. Glenn Pait
Washington, District of Columbia

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This enlightening report reviews from a neurosurgical perspective the many archeological studies on ancient Peruvian trephined skulls. The review is extremely well researched and well referenced, including the important French and Spanish sources on trephination techniques used by the pre-Incan and Incan peoples who inhabited prehistoric Peru. Sweeping conclusions regarding the reasons for cranial surgery (other than trauma with fracture) are difficult to substantiate in a society about which little is known other than from descriptive pottery and recovered utensils, yet certain conclusions are believ-

able considering the archeological evaluation of a good number of skulls and certain Peruvian customs existing into the 20th century. For instance, the Peruvian Indians have been known to pack a wound with powdered coca leaves (about 9% cocaine) to make operation painless (4). Healers or surgeons of Incan Peru were also competent herbalists (2).

Paul Broca, the first to examine these skulls scientifically, argued that the ancient Peruvian trephinations had a "fanciful, ritual, or religious object" and was unwilling to believe that they were undertaken as therapeutic measures (1). Victor Horsley, after examining the skulls in the Broca Museum at Paris in 1887, concluded that the operative openings were nearly always over motor cortex, that the patients may have been suffering from jacksonian epilepsy, and that cure could have resulted (1). The fact that skull trephination has been kept a strict secret by the tribes of the Andean highlands is more favorable to Broca's supernaturalistic hypothesis. Even more fascinating is the fact that trephination has been practiced over much of the globe, apparently independently and probably relating to the observation that deranged or asocial behavior, headaches, and epilepsy have intracranial origins. There is no doubt that an intense exorcistic experience (such as trephination) can yield significant psychological improvement, and, if sustained, result in secondary improvement of physical ailments. Even recent case reports of trephination as a technique for achieving higher consciousness may be found (3). Fortunately, the prehistoric as well as modern day cranial surgeon finds that the majority of patients survive, although indications for operations will always be expected to change over the years.

James L. Stone
Chicago, Illinois

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