Preconquest Peruvian Neurosurgeons: A Study of Inca and Pre-Columbian Trephination and the Art of Medicine in Ancient Peru

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TREPHINATION AND CRANIOTOMY performed by abrasion, scraping, crosscut sawing, and drilling are the oldest known surgical techniques used by primitive peoples. As a result of archaeological findings, the human skull is the most frequently studied part of the excavated body, leading to the creation of a new aspect of anthropology known as “cultural osteology.” Found in ancient tombs, the human remains, mummies, skeletons, and their belongings, including war instruments, pottery, clothing, jewels, and surgical instruments, constitute the richest source of insight into the lives and pragmatic activities of ancient cultures. This study summarizes thousands of years of pre-Columbian history and medical evolution, specifically in the early and primitive practice of trephination, as precursors of neurosurgery. Comparative osteology studies have demonstrated that using primitive stone or metal instruments, the sirkaks (Inca surgeons) achieved an average survival rate of 50 to 70% of their craniectomy patients, with little incidence of infection or other complications. Despite their rudimentary knowledge of disease and pathology, a considerable knowledge of anatomy and natural medicine provided them with hemostatic agents, antiseptics, and other medical drugs, such as quinine for fever and malaria, as well as gold, silver, and other products to perform cranioplasties. Living in a world of continuous hand-to-hand combat, they also developed aggressive and defensive weapons that necessitated refinement of surgical techniques to save soldiers from battle wounds to their poorly protected crania. (Neurosurgery 47:940-950, 2000)

Key words: Inca, Peru, Pre-Columbian neurosurgery, Trephination

It has often been said that the two oldest living professions are prostitution and neurosurgery. I would assume that the ancient warrior realized very early on that it was easiest to annihilate, or at least slow down, his opponent with a blow to the head. Therefore, the concept of head injury remains as ancient as the powers of solicitation of the opposite sex.

(James T. Goodrich [12])

It is quite an experience for a neurosurgeon to examine some of the 15,000 skulls and sitting mummies that have been preserved and recovered from pre-Columbian Andean civilizations and are stored in the National Museum of Anthropology and Archaeology in Peru. Other surprises are reserved for those who visit the Gold Museum (Museo del Oro), also in Lima, with its incredible collection of jewels, pre-Columbian weapons, and metal instruments used in neurosurgical procedures by ancient Andean civilizations. These include T-shaped tumis, obsidian lances for trephination, scalpels, bone elevators, retractors, forceps, chisels and needles, bandages, and several other instruments. They are crafted of gold, silver, copper, or alloys of these metals; gold, silver, coconut, calabash, mate, or gourd plates used for cranioplasties also may be found. A meticulous examination of these operated skulls and cranioplasties demonstrates clear signs of healing and recovery in 70% of them, which forces us to pay tribute to these ancestors of our specialty and to their ability. Thousands of years ago, they demonstrated a keen knowledge of anatomy, preserving the sagittal sinuses in their approaches, treating traumatic wounds and cranial fractures, and implanting prosthetic material with a minimum of infection or osteomyelitis (22), considering the means at their disposal. It is astonishing to reflect on the enormous achievements of pre-Inca “neurosurgery” and realize that our Paleolithic ancestors, such as Sinanthropus or Homo erectus pekinensis, probably perforated the cranium only to extract and eat the human brain (5)!
HISTORICAL BACKGROUND

The Andean area, where Peru is located, has one of the roughest and most difficult terrains on earth. Thousands of years of effort were required by the first Peruvian inhabitants to tame the Andean Cordillera. The Andean culture comprised the territories of Ecuador, Peru, Bolivia, and parts of Chile and Argentina; the area is divided by altitude and climate into three regions: the coast, the Sierra, and the Amazon jungle (Fig. 1). Archaeologists have dated the first evidence of humans in the Andes to the time after the last glacial period (the Wisconsin period), approximately 10,000 BC (17, 18). Archaeologists have gradually uncovered a Peruvian pre-Columbian history of astonishing and highly advanced societies that, despite formidable geographic difficulties and frequent natural disasters, prevailed over these awesome odds until a few centuries ago. During the Hispanic colonization period, war and disease caused the extinction of this culture.

The first discovery of Stone Age instruments of ancient Peru was made in 1948 by Rafael Larco Hoyle and Junius Bird, in Cupiniquo, north of Trujillo, where the Paijanese culture developed; the “puntas of Paijan” were used to spear big fish. Through carbon-14 testing, the skeletons found in the tombs have been demonstrated to be 8250 years old. They are located from Chiclayo to the area north of Ica (17, 18).

Other archaeological studies on the coastal desert, from Lambayeque to south of Paracas, have revealed a true “American Egypt” regarding the important findings of ancient tombs and their historical contents. These artifacts often are discovered after they have been looted by gangs of huaqueros, or grave robbers, stimulated by intense demand from the international antiquities market.

The Incas’ Tahuantinsuyo Empire was in place when the Spaniards arrived. Hundreds of years previously, the Peruvian land had been overrun by primitive peoples who were constantly at war with each other and were among a succession of civilized cultures dating back as far as 2000 BC. The most accomplished among them were the Chavin-Sechin (900 to 200 BC), the Huari-Tiahuanaco (750 BC to AD 1000), and the Moche-Chimu culture (200 BC to AD 1400) (17, 18).

One of the greatest achievements of these latter cultures was their artistic genius. They crafted exquisite ornaments in gold, silver, and precious stones, as well as pottery during several stylistic periods, most notably in the Moche culture, with stunningly lifelike portrait vases and a variety of everyday scenes created through naturalistic ceramics. Their art tells us more than is known about earlier cultures; these “visual aids” compensate for the lack of a written language and reveal their daily native life, including their erotic life. Their mummies, incredible textiles, military weapons, surgical instruments, and architecture, united by the incoming Inca Empire, earned these territories around the Imperial City of Cuzco the epithet “umbilicus of the Universe” just before the Spanish conquest. This area was equivalent to France, Belgium, Holland, Luxembourg, Italy, and Switzerland combined, measuring approximately 980,000 km².

In 1490, the Chimú kingdom was defeated by the Inca dynasty, led by the great warrior Tupac Yupanqui, the son and heir of the Inca ruler Pachacutec Inca Yupanqui. Pachacutec was considered a sort of Andean Alexander the Great. He and his son Topa managed to subjugate all their rivals from Ecuador to Chile. However, their empire fell less than 100 years later to the rapacious warriors of Spain, after Francisco Pizarro arrived in Tumbes with 179 conquistadors.

Like the Aztecs in Mexico, the Incas came late on the historical scene of Peru, and even their legends do not predate AD 1200. Like the European civilization, the Incas recounted...
their history in terms of the reign of their kings. The first was Manco Capac, considered to be the founder of the Inca Empire, in AD 1200, followed by Sinchi Roca, Lloque Yupanqui, Mayta Capac, Capac Yupanqui, Inca Roca, Yahuar Huacac, Viracocha Inca (the famous white god), Pachacutec Inca Yupanqui (1438–1471), Tupac Inca Yupanqui (1471–1493), Huayna Capac (1493–1525), Huáscar (1525–1532), and his brother Atahualpa (1532–1533). Atahualpa was executed by Pizarro in Cajamarca; he was strangled with a tourniquet, died at the stake, and was then quartered after the Incas had prepaid with gold objects filling many rooms to ransom and rescue him! Pizarro had planned to burn him alive, but Atahualpa claimed that fire would destroy his soul and Pizarro agreed to a different type of execution. Today, studying their history, we are forced to ask ourselves who were the true savages at the time. Atahualpa was the “cement” that assured the cohesion of the Inca Empire. This cement was dissolved after his death, and the lack of leadership led to the rapid decline and disappearance of the Incas for (17, 18).

Our only means of studying these ancient, extinct Inca and pre-Inca civilizations is through the art and instruments found in archaeological sites. These findings provide a visual record: their mummies, ceramic vessels, clothes, metal instruments for medical and war purposes, jewels, and statues depict the life of the people who manufactured them. We found that more trepanations were performed in ancient Peru than in the rest of the ancient world combined, apparently for the treatment of trauma, disease, epilepsy, and headache, as well as for rituals, among other purposes (1). Archaeological skulls exhibit evidence of recovery, a low infection rate, and good results that could be compared with those of modern times, considering the conditions under which they were performed! Some of the ceramics, called huacos, depict medical achievements such as a surgeon working on a patient’s cranium with instruments (Fig. 2). Such procedures have been documented in the literature (the best studies are in Spanish) (3, 13, 19).

**MEDICAL KNOWLEDGE OF THE TIME**

Examination of several skulls reveals extensive cranietomies, which preserved the trajectory of the dural sinuses and left behind protective bone bridges, thus demonstrating anatomic knowledge of these regions (4, 9, 10, 13, 16, 22) (Fig. 3). The surgeon’s experience in inducing hemorrhages in these areas probably was transmitted to his assistants. Weiss (27) suggests the existence of centers and schools for teaching and training in Paracas and Cuzco, where archaeologists have found ruins resembling hospitals.

During the Inca period and in previous eras, the vast Tahuantinsuyo Empire reached a high level of culture under the paternal government of the monarchs. The culture was based on agricultural (agrario) socialism, admirably organized, which could be observed in all aspects of their social life. Because of wise sanitary precepts and protective measures for the people, the Tahuantinsuyo Empire detribalized into a large population.

Without populous cities or pollution-producing industries, the people were engaged in agriculture, mining, military service, herding, and fishing. They endured a rustic rural life in small villages over the altiplanos (high plateaus) and coastal valleys, where they led a healthy existence in the open air and sunlight. Relative prosperity owing to the magnificent political organization of the state meant that tuberculosis, whose cause and diffusion depend essentially on poor social conditions, was not endemic in their populations (7, 8, 17, 18). Nursing during infancy was imposed by inflexible natural law; therefore, infantile mortality caused by gastrointestinal illnesses was avoided. Tuberculosis and enteritis have always been the most powerful causes of demographic loss in some populations (17, 18).

Through empirical intuition, the aborigines knew the contagion mechanisms of exanthematic typhus (which could be demonstrated in central Europe only at the beginning of this century). They fought it with isolation measures and recognized the role of insects in its propagation; in the tribes where an epidemic occurred, a penalty was imposed, represented by a tax with reeds containing swarms of lice (Pediculus capitis and P. vestimenti). It is also evident that they understood the means by which malaria, endemic on the Peruvian coast, was spread. Houses were systematically built in the high and sandy part of the valleys, outside the cultural centers and outside of the access radius of the vector insects (7–9, 13, 17, 18).

Numerous reports in historical chronicles refer to the pharmacological wealth of the Incas, stating that la Mamma Viracocha (mother earth), one of their goddesses, (Mamacocha was the sea) would show them the plants with healing powers and those that were poisonous. They had large and selected herbolarios; they knew diseases quite well and the means to cure them with the use of herbs (9, 13, 17, 18). It is well known that
they were the first to use the cortex of cinchona bark, which contains quinine, to fight malaria. This knowledge was revealed to the world when the life of the Viceroy Luis Jeronimo de Cabrera y Bobadilla, fourth count of Chincho´n, was saved (9, 13). Their high achievements in agriculture, mining, industry, art, irrigation, architecture, ceramics and pottery, and elegant textile fashions, which are now preserved in museums after being buried for centuries, amaze observers and artists who contemplate them.

The Incas thus were not, as some may assert, a barbarous and brutish people, lacking a government and without social organization, immersed in profound ignorance and unable to develop industries, arts, or elementary rules of social life. On the contrary, a careful historical-sociological analysis demonstrates a cultured and creative people, wise and refined, with esthetic tendencies and an appreciation of the highest manifestations of the spirit. They had the capacity to learn medical and surgical arts and to achieve advanced methods and techniques corresponding to their elevated cultural hierarchy, which also was reflected in various aspects of their social life.

Intentional deformations of the head

Intentional deformation of the head, widely practiced when the Spaniards arrived, was banned in 1752. The main purpose of deformation was to establish differences and characteristics among different tribes and nations, chiefly among the nobility. The methods used were the cuna and the llautu. Some specimens of the former were found in Chilca on the coast, dating from 3800 BC, and were associated with suprainion trephination. The llautu involved tying ropes, padded cushions, and leather straps around the heads of young people, which over time produced plagiocephalic crania or other deformations (9) (Fig. 4).

Head trophy and head shrinking

The pre-Inca Nazca and Paracas were true headhunting cultures. They demonstrated their ferocity in war through the mundurucu and tsan-tsas: emptying the contents of the skull through the occipital bone, then shrinking and drying the skulls for trophies. They hung these trophies on their belts, as did the Amazon Jı´varos (9).

It is surprising that the Spaniards were not able to capture the highly advanced medical and surgical capabilities of the conquered aborigines. These practices abruptly and definitively collapsed at the moment of conquest, which virtually destroyed all aspects of the old civilization found in Peru. Cities of great historical importance, such as Machu-Picchu, Huayna-Picchu, and Wiñay-Huayna, were jealously hidden from the view of the conquistadors, and their ruins were not found until 1913 and 1941, respectively (7, 8, 17, 18). This phenomenon was probably produced by a violent clash between the two opposing civilizations. The conquistadors imposed their creed, habits, and principles and inhibited the dominated community. Keeping secrets was the only means of defense and a silent form of protest (7, 8, 17, 18).

THE WEAPONS

Weapons in antiquity were either offensive or defensive. We traveled to Lima specifically to observe these items in museums, to study their effect on cranial trauma, and to view the protection Peruvians used for self-defense.

![FIGURE 4. Typical plagiocephalic deformation of the head, obtained by tying straps around the head of a young person.](image-url)
Among offensive weapons (Fig. 5), we found the classic bow and arrow; the spear or lance; the cerbatana (blow pipe); the honda or maraca (slingshot to throw stones); the estolica, tiradera, or cumana (darts thrower); the lanza or spear, named chuqui, turcuna, or pica, for different sizes; the boleadora or ayllu (two or three round stones attached to a rope); the clava, maza, or huactana (a heavy, 90-cm-long club of wood or stone); the porra, which was responsible for most of the cranial trauma (a long wooden handle with a heavy, sometimes stellate, stone in the extremity, which was called macana or huicapa); the hacha, chictana, or champi (a combination of porra and axe); the chingana (a large double-edged dagger); the tuccina (a sword); and the tumi (a semilunar knife, also used, in smaller sizes, for scalp incisions by the tribal surgeons) (7–9, 13).

The defensive equipment (Fig. 6) was precarious and unsafe, because it was made of fragile material such as wood, cane, bamboo, or thin metal. The escudos (shields) were crafted of wood lined with leather. The corazas (breastplates) were worn by the nobility and were made of bronze, silver, or gold; their shine dazzled the Spaniards. The escampiles, aucanas, or cushma were breastplates made of wood or cotton to protect against enemy arrows (9). Large tumis also were used to behead or decapitate enemies or in religious and traumaturgic ceremonies. In the Museo del Oro, a gold statue with a ferocious facial expression holds a tumi in one hand and a decolated head in the other (Fig. 7).

**HEAD PROTECTION**

Examination of the cascos (helmets) was one of the main purposes of this study. Cascos were worn to protect the head; crafted of wood or thin metal, they were called umachina and nahuichina, respectively. Some were made of interwoven thin cane and were very light. Feathers, plumes, and other ornaments and emblems were attached to the front. Ribbons of different colors hung from the back. The helmets were quite fragile, which may explain the prodigious development of surgical treatment for cranioencebral trauma to correct the effect of heavy weapons, chiefly the porra, on the warriors’ poorly protected crania (9) (Figs. 8-10). Sometimes, heavy cotton turbans were used by the soldiers, which also provided little protection against blows to the head.

**CRANIAL TREPHINATION**

The suggested reasons for trephination surgery in ancient Peru are numerous. Operations apparently were performed for trauma, fractures, diseases of the cranium, scalp and cranial infections, epilepsy, headaches, mental disease, and some traumaturgic rituals (1, 4, 9, 13, 15, 16, 22) (Fig. 11). The main trephination techniques evident in archaeological skulls are associated with excavations in the territories of the Paracas, Nazca, Huari, and Ica cultures. They were less popular in the more recent Inca culture and were apparently interdicted in the Inca empire long before the Hispanic conquest (1, 4, 9, 13).

Examination of the operated skulls reveals samples of several techniques, including circular cutting, scraping, crosscut sawing, and drilling (1, 2, 4, 6, 10, 13–16, 20, 22, 24–26) (Fig. 12). The Paracas culture primarily used the circular cutting technique. The first evidence of the crosscut technique is in the Nazca culture, which followed that of the Paracas in the
area around Lake Titicaca. This mountain culture eventually developed into the Huari culture, and around AD 800 their warriors overran the coast and northern mountains and formed an empire; these skulls exhibit only the crosscut and drilling techniques (AD 800 to 1200). The Ica culture (AD 1200 to 1450) followed the dissolution of the Huari Empire and used only the circular and scraping techniques. Examination of these skulls reveals that surgical wounds rarely became infected, and some skulls indicate survival (Fig. 13). In contrast, during the 18th century, trephination of the cranium in Europe reached nearly 100% fatality and was discontinued (1).

Some authors think that antiseptics were used in these primal Peruvian cultures, namely the well-known Peru balsam, tannin, saponins, and cinnamic acid, which also was used for embalming the dead. Studies on Peruvian trephination began in 1865, when Squier (23) showed Paul Broca a skull from a tomb of Yucay that had a frontal square craniectomy. After examining it, Broca concluded that it was an intentional trepanation (5).

Lastres and Cabieses (16) made an important study of healing and survival after these primitive trephinations and advanced some interesting observations: 1) no sign of biological reaction of the cranial vault means that death was almost
immediate; 2) a discrete ring of superficial osteoporosis around the wound appears 1 to 4 weeks postoperatively; 3) destruction of necrotic bone occurs around the edge of the wound, owing to osteolysis with separation of irregular fragments and sequestrum formation; these tend to fall off and be lost during the preparation and cleaning of a skull for examination in the museum; and 4) the edge of the wound reaches an equilibrium and calcium is deposited. New bone forms radial striations, and eventually the edge consolidates (Fig. 14). These last two processes do not occur until a number of months have elapsed (1, 4, 16).

SURGICAL INSTRUMENTS

From the study of mummies with scars over their scalps (Fig. 15), it is evident that incisions were performed in a linear fashion (4, 11, 13, 15, 16). Instruments found archaeologically include chisels made of copper, silver, gold, or champi (the Inca bronze) (Fig. 16). Obsidian knives, made of a silex sharp-edged volcanic crystal called escapelos or pedernales, were used for incisions and cutting bone (Fig. 17). They would disintegrate if used in a drilling fashion. The famous tumi, a metal instrument with a crescent blade and a short central T-shaped handle (Figs. 18 and 19), which today is the symbol of Peru, was used to open the scalp (but never the bone, as might be expected). Some researchers have used tumis on cadaver skulls with success (13, 21). Bone elevators, dura protectors, forceps, suturing needles, cotton bandages, and hemostatic wool tourniquets for the head also have been found. Some of this equipment has been used by present-day Peruvian neurosurgeons for demonstration of Inca-period interventions (13, 21). Cranioplasties using gold or silver may be observed at the Museo del Oro (Fig. 20). Other materials, such as mate, gourd, coconut, and calabash, have been reported to be failures (1, 5, 9, 13, 22), because some cases of osteomyelitis were found (1, 4, 13, 16, 27).
Little is known regarding anesthesia, which probably was based on herbal preparations containing coca, datura, or yuca. Alcoholic beverages such as chicha, made of fermented corn, was given to patients in large amounts, causing a soporific effect (9). Hemostasis was obtained with herbal extracts of Andean ratania root, pumachuca shrub, and preparations rich in tannic acid (9, 13, 22). Thermal needles, metal cautery, and boiling oil also were used. Metal suture needles have been found with cotton threads at burial sites (9, 13). Scalp margins were sometimes joined by tying the patient’s hair across both sides of the incision (22). Curettes made of cachalot (sperm whale) teeth have been discovered, and cotton dressings and gauze-like material have been found around operated skulls (9) (Fig. 21).

There were two kinds of tribal doctors: the churihampicamayoc, who treated the nobility, and the more popular sirkak or sangrador (the bleeder), who treated the common people and performed craniectomies during war and peace. In 1944 and 1953, two separate teams of modern neurosurgeons attempted to revive ancient Peruvian neurosurgery, using only museum archaeological surgical instruments. They used the instruments initially in cadavers and then tested their effectiveness in human patients (13, 21). As these interventions were considered historically important, we summarize them here as interesting and unusual case reports.

ILLUSTRATIVE CASES

Patient 1

On September 9, 1944, in the Hospital Mixto de Belén, in Cuzco, the seat of the old Inca Empire, two daring neurosurgeons performed the first neurosurgical operation using old archaeological instruments...
provided by the Museum and Archaeological Institute of Cuzco. The surgeons were Dr. Sérgio A. Quevedo, who was also the Chairman of Anthropology at the Museum, and Manuel Callo. They found a patient suited for the procedure, a 22-year-old woman who had experienced cranioencephalic trauma after a tree fell on her head, resulting in a depressed cranial fracture, Jacksonian epilepsy, and dysphasia. She was prepared, and the scalp was cleaned with antiseptics.

A circular compression was placed around the head to achieve hemostasis, with wool tourniquets applied in the same manner formerly used by the sirkak or Indian surgeons. The incision was performed using an archaeological tumi, which also served as a periosteal elevator. The bone was opened with an obsidian silex chisel, and the dura was protected with an Incaic dura protector. A 6-cm by 3-cm oval craniectomy was performed, and the scalp flap was retracted with another Inca instrument. A cranioplasty was performed using plastic mate-
rial, and the wound was closed with a special champi needle, after sulfa crystals were left underneath, because no other antibiotics were available. The patient was perfectly well after a 1-hour procedure and had a good recovery.

However, the patient developed a bronchopulmonary complication after the 7th postoperative day and died. The nurses reported later that she had removed ice chips from the pack that had been placed on the scalp to prevent swelling. The patient had sucked them at night, pretending they were ice cream, and she developed a pulmonary complication and infection (21, p 51).

### Patient 2

The following account was reported by Drs. Francisco Graña and Esteban D. Rocca (Fig. 22): On July 1, 1953, we decided to carry out our first trephination in a cadaver, over the frontal region; using a tumi with a radius of 3 cm for the scalp incision, followed by a cranial trephination using an obsidian silex knife and other instruments borrowed from the National Museum of Anthropology and Archaeology. We have demonstrated that the typical obsidian cannot be used in...
circular movements like a drill—it will disintegrate; it has to be used in sawing movements, until the external surface of the bone is penetrated. A rectangular craniotomy was obtained after the diploë was traversed. The opening was completed using chisels and bronze elevators. A bone plaque was thus obtained, including the compact external layer and spongy layer, leaving the internal layer intact (13, p 266).

A second intervention on a cadaver was carried out on July 6, 1953, in an attempt to imitate the craniotomies found in the Museum. An oval craniectomy was performed in August, this time exposing the dura, with the same instruments.

On September 10, 1953, we prepared a patient who had experienced cranioencephalic trauma followed by right hemiplegia and aphasia, and in whom a subdural hematoma was diagnosed. He was given the usual preoperative medication, followed by general anesthesia with intubation. The operative technique included sterilization of the pre-Incaic instruments and placement of a rubber tourniquet over the external occipital protuberance and glabela, similar to the ones used in the pre-Columbian era, which were made of wool, thus obtaining compression of the pericranial vessels. The operative field was delimited, and the scalp incision was performed with a tumi held by its handle, using the right hand, reaching the perios- teum with a single coup, elevating the periosteal sheath with the same instrument and leaving the bone surface exposed. A round craniectomy was then performed, using a chisel-like tumi, introduced step by step, gently hammering it in. A bluish meninge was thus exposed, showing a bloody collection underneath. It was incised with the same tool, and the hematoma was drained. The next steps of the operation and total aspiration of the hematoma were terminated using regular neurosurgical instruments. The use of the pre-Columbian instruments was thus demonstrated.

We call attention to the use of the tourniquet in pre-Columbian fashion, which has allowed a perfect hemostasis during the whole procedure. The use of the tumi for the scalp incision had a surprising result, and the chisel-tumi combination was also perfect for the craniectomy (13, p 266). The original text contains several photographs and x-rays illustrating the procedure. Figure 22 shows the scalp incision. The postoperative period and follow-up of the patient are not reported in the article.

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In some instances, the emphasis on historical and cultural aspects sacrifices the contribution to neurosurgical knowledge. The case reports documenting the use of historical instruments in operations on live patients are an interesting addition to the article. However, these experiments may have gone beyond acceptable ethical limits for the profession.

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Articles concerning the practice of neurosurgery in pre-Columbian Peru always make for fascinating reading. This article adds interesting historical vignettes and excellent pictorial material. The article covers a multitude of aspects on the art of medicine practiced by these ancient cultures. In the authors' attempt to provide a summary of all aspects of pre-Columbian neurosurgical knowledge, some of the subsections are treated superficially. This article stimulates interested readers to pursue and expand their knowledge of this inspiring subject.

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One cannot but be amazed at our early "neurosurgical" colleagues who not only managed to perform trepanations with great skill but also managed to keep the majority of patients alive. When one looks at the survival data of 17th century European surgeons, for example, and compares them with results achieved by the Inca surgeons, the latter seem to have the better outcome! I have always had difficulty understanding how a patient could consent to having a hole drilled in his or her head, with minimal anesthesia and in total body restraints, and survive the ordeal. Yet survive they did, and as the authors point out, there are many examples of healed trepanations among the museum collections of Peru. Even more impressive are the skulls exhibiting successful cranioplasties made of silver and gold, which were placed with such skill that the bone healed around them. The tragedy of this early Peruvian period is the lack of written material and documented oral history; these would have provided remarkable insights into these early surgeons and their techniques. Nonetheless, a review of their work, the style of trepanation, and the use of the tumis reveals some remarkable early neurosurgical interventions. All of this was accomplished with remarkably good outcomes considering the lack of anesthesia and aseptic technique.

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This historical article is of interest primarily because of the extraordinary illustrations provided. There is much of interest, and the authors have expanded our knowledge concerning a number of aspects of neurosurgical history in South America.

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