As is frequently the case, art objects often depict the life in a particular civilization, thus giving a visual record of a people where the people themselves have disappeared. Peru is one of the areas of the world where art depicts the life of the people while the people themselves are present in the form of mummies to confirm much of what is seen in art. A number of ceramic vessels have been found depicting one man working on the skull of another with a knife. That such actions were possibly surgical was documented in 1865 when Squier was given a skull with a trephined opening made during life. Continued documentation of such operations has been reported in the literature, but the best studies are in Spanish. This paper is a study of the material existing in the Regional Museum of Ica, Ica, Peru, and a review of selected authors' interpretations of these operations.

Materials and Methods. The material used was from 288 individuals of a known cultural association and cemetery, from the Regional Museum of Ica, Ica, Peru. The skulls were examined visually and, where deemed necessary, by x-ray as well.

Results. Thirty-nine of the 288 skulls showed recent fractures due to trauma and five of these had visible evidence of additional long-healed fractures untreated surgically. Six skulls without fractures had evidence of some type of bone disease unrelated to trauma.

Twenty-four skulls had been trephined or treated surgically by cutting or scraping. Thirteen of these skulls showed clear evidence that the surgery was due to fracture and one that it was due to disease. Ten skulls had evidence of surgery with no clear evidence remaining for the cause of the surgery.

Table 1 gives the cultural distribution of the material, the pathology when evident, and the surgical treatment. The Paracas culture had six out of eight individuals with an obvious reason for the skull surgery. The Nazca culture had only four out of nine individuals with reasons for the surgery. While the number of skulls was similar to the early Paracas and Nazca cultures, the frequency of surgical operations was reduced in the later Huari and Ica cultures, and among the Inca skulls in this collection no surgery was seen.

The surgical techniques used are listed in Table 2. The circular cutting technique illustrated in Figure 1 was the most common technique used in the earliest cultural group (Paracas). This technique was also used by the later Huari and Ica cultures. The operation had a 50% survival rate, but one survivor had developed osteitis and died before healing occurred. The scraping technique seen in Figure 2 was used in...
Table 1
Cultural Material Used and Its Pathology and Treatment

<table>
<thead>
<tr>
<th>Culture</th>
<th>No.</th>
<th>Total</th>
<th>Surgically Treated</th>
<th>Disease</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paracas</td>
<td>60</td>
<td>10</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Nazca</td>
<td>41</td>
<td>7</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Huari</td>
<td>67</td>
<td>9</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Ica</td>
<td>66</td>
<td>6</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Inca</td>
<td>54</td>
<td>7</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Totals</td>
<td>288</td>
<td>39</td>
<td>13</td>
<td>6</td>
</tr>
</tbody>
</table>

The Paracas culture with no deaths in two individuals who had been treated. It was more commonly seen in the Nazca culture, where again survival (four out of five) was good, and was noted later in the Ica culture. The nine operations performed using the scraping technique had an overall survival rate of 78%, and this was deemed to be the best technique. There was one case of post-operative osteitis in this group and the individual died before the wound healed. There was also some type of bone disease treated by multiple scraping over an undetermined period of time (Fig 3). The crosscut sawing surgical technique shown in Figure 4 was most common in the Nazca culture, but there was only one survivor out of the four individuals examined, and this survivor of the surgery developed osteitis and died. The same is true of the Huari survivor illustrated in Figure 5. The original trephination for a fracture is on top of the head. Apparently, osteitis developed and a second operation was performed at the left temporal area, probably related with a large pocket of pus. This second operation resulted in almost instantaneous death, as no sign of healing is seen and a large fragment of bone apparently came out with the operation plug, producing a hemorrhage from the middle meningeal artery.

The drilling technique was seen in only two individuals from the Huari culture (Fig 6) and both of these individuals died during or shortly after surgery.

The most common bones trephined were parietals, frontal, occipital, and temporal in that order. The frontal bone operations generally removed less bone, but resulted in the poorest survival. Survival might have been related to the amount of bone removed, but using the circular cut technique, survival occurred with the removal of a 3-inch diameter plug of bone (Fig 7), so size is obviously not the only factor.

Discussion. More trephinations have been done in ancient Peru than in all of the rest of the ancient world combined. The suggested reasons for this type of surgery are numerous—trauma, disease, epilepsy, headache, and ritual to name a few; but whatever the reason such operations, considered serious and dangerous in most parts of the world, were quite commonplace in Peru. The present study contains all of the surgical techniques known. Over half of the cases still showed evidence of the underlying disease for which the operation was performed, and the recovery and low infection rate were better than might be expected for surgery done under such conditions even in modern times.

Table 2
Surgical Techniques and Survival for at Least 6-8 Weeks

<table>
<thead>
<tr>
<th>Culture</th>
<th>Circular</th>
<th>Surgical Techniques and Survival for at Least 6-8 Weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lived</td>
<td>Died</td>
</tr>
<tr>
<td>Paracas</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Nazca</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Huari</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Ica</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Inca</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Totals</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

Discussion. More trephinations have been done in ancient Peru than in all of the rest of the ancient world combined. The suggested reasons for this type of surgery are numerous—trauma, disease, epilepsy, headache, and ritual to name a few; but whatever the reason such operations, considered serious and dangerous in most parts of the world, were quite commonplace in Peru. The present study contains all of the surgical techniques known. Over half of the cases still showed evidence of the underlying disease for which the operation was performed, and the recovery and low infection rate were better than might be expected for surgery done under such conditions even in modern times.
The amount of material in the Regional Museum of Ica examined for trephinations was about the same in all of the cultural groups; yet the earlier cultural groups (Paracas and Nazca) had the most surgery. Head lesions in these groups were also more common. The Huari culture had only half as many individuals who had undergone surgery, and the Ica culture even less than any other group. No individuals from the Inca culture or the colonial period had had surgery in this series. It is of interest that in the Paracas, Nazca, Huari, and Ica cultures, the surgery was associated at least in part with disease or fracture of the skull. Surgery of Inca skulls may be seen in the Regional Museum of Cuzco and is reported in the literature on the basis of cemetery location and skull deformity, but most earlier investigators neglect to mention the cultural groups providing the material. This major drawback of many earlier studies is a result of using material from random surface finds or obtained from grave robbers.\textsuperscript{8,9} In order to have good documentation of cultural association, material must be excavated scientifically, as a single cemetery may have a mixture of two or more cultures.

This study included material illustrative of all four techniques—circular cutting, scraping, crosscut

Fig 1—Large trephined opening illustrates the circular cutting technique (top). Type of instrument used is the obsidian blade (bottom).

Fig 2—Small irregular opening seen at center made by scraping with an obsidian blade.
Fig 3—While most skull surgery was associated with trauma, some was done for disease. This skull was scraped at different intervals over a long time period.

Fig 4—The crosscut sawing technique done in the temple region resulted in almost immediate death, possibly due to rupture of the middle meningeal artery. The bone had extensive osteitis due to a previous trephination and fractured when the cut section was pried out.

Fig 5—The crosscut opening made at center of skull was related to trauma. Unfortunately, infection developed and the patient died.

sawing, and drilling. The Paracas culture (600 BC–100 AD) used primarily the circular cutting technique, one that gave a more or less round piece of bone. Some authors have suggested that this method was used initially to collect bone discs from dead men’s skulls, to be used as talismans, and that from this practice surgery of the living developed. Such a theory is questionable, as circular cutting is concurrent with that of scraping where no disc of bone is removed. It is more logical to think of skull surgery as originating from removing splinters of bone from a wound and scraping the bone smooth as a form of debridement to promote healing. During the colonial period, this form of skull surgery was described on several occasions, but no evidence of trephining has been found in the early colonial material; the present study had no trephining in the Inca culture, although we know that it was practiced by the Incas in other localities. The crosscut technique was first seen in the Nazca culture (100 BC–800 AD), essentially a coastal
one, that followed the Paracas culture. In the last 200 years of the Nazca culture, there was evidence of close contact with the mountain culture originating around Lake Titicaca. This mountain culture eventually developed into the Huari culture, and around 800 AD their warriors overran the coast and northern mountains, forming an empire. It is possible that the Nazca skulls exhibiting the crosscut technique were from individuals of the late Nazca period, since they are from a highland location rather than a coastal one and this technique is thought to be of mountain origin as is the rare drilling technique. The Huari culture (800 AD–1200 AD) has examples only of the crosscut and drilling techniques. The Ica culture (1200 AD–1450 AD) which followed upon the dissolution of the Huari empire used only the circular and scraping techniques.

Details of methodology are scant, but speculations abound as to anesthesia, suturing, use of protective plates, and other practices. One protective plate of gold over the operative site was reported by Tello, and several reports about the use of pieces of gourd are to be found in the literature. Bandages were known and one made with the equivalent of fine surgical gauze was found in place on a head wound of unknown type. Tourniquet-type cords were also reported, but whether they were used to control bleeding is not certain. Cauterization of wounds was practiced, but again its purpose is unknown. Closure of the skin flap by sutures was performed. Thus, it is possible to form some picture of operative practices, but we are left in the dark concerning the use, if any, of anesthesia and the medical treatment of the healing wound. Most evidence points to the fact that the majority of surgical wounds did not become infected and that successful recovery was probably as good as could be expected in traumatic head wounds even today. In European medicine, trephination of the skull in the 18th century had reached a point of nearly 100% fatality and was discontinued. Some writers would like us to believe that antiseptics were used in Peruvian cultures, based on the supposed use of Peru balsam, tanin, saponins, and "acide cinnamique" in embalmings of the dead. Unfortunately, studies of material from all major cultures in the Regional Museum of Ica fail to show any such materials used in embalming. At best, the occasional mummy will have a red or black face paint consisting of a heavy metal salt. Such material is not found on other parts of the body. The lack of infections is probably due to absence of virulent, wound-adapted agents. This may be due to the absence of hospitals or other institutions which serve to transfer these agents and the absence of a type of warfare that would encourage active

Fig 6—Use of the drilling technique for an unknown reason. Note hole at left was not finished.

Fig 7—This healed lesion made by the circular cutting technique had a very large plug of bone removed.
battlefield surgery with its resulting transfer of bacteria from one patient to another. It would appear that wound infection problems in Europe are fairly recent, dating from the era of the Napoleonic wars. A further area of discussion noted in the literature is the problem of judging the length of survival. The healing of trephinations can be recognized by a smoothing over of the cut surface, but the time and steps in this process are not clearly described. It has been reported that modern trephined openings in the skull have had complete closure with restoration of the cranial vault, yet other writers claim that little or no callus is formed and the wounds remain open. Furstenburg suggests that closure is stimulated by deposit of bone debris on the dura; if this is true, scraping and sawing techniques should provide enough bone debris to stimulate closure in small wounds. Lastres and Cabrieses outline the steps in healing as seen grossly on dried bone:

1. No sign of a biological reaction means almost immediate death.
2. A discrete ring of superficial osteoporosis around the wound appears from one to four weeks.
3. Destruction of necrotic bone around the edge of the wound due to osteolysis with separation of irregular fragments and sequestrum formation occurs. These tend to fall off and be lost during the preparation and cleaning of the skull for examination in the museum.
4. The edge of the wound reaches an equilibrium and calcium is deposited. New bone forms radial striations and eventually the edge consolidates. This latter reaction, together with 3, does not take place before a number of months have elapsed.

These repair processes are influenced by many factors including the condition of local tissues, topical therapy, infection, and if infection occurs, the etiological agent and often the immunological reactions. Thus it is very difficult to put a time sequence on the healing of a given lesion due to the long list of unknown factors in any given paleopathological specimen.

We would like to see a review on a cultural basis of all documented material with attention being given to all aspects of skull surgery and its sequelae. We feel that such studies might be most informative in tracing the development of this interesting operative technique among primitive peoples.

REFERENCES

1. _ROCCA E: Traumatismos Encefalocraneanos_. Lima, Imprenta Santa Maria, 1953.