Evolution of craniotomy as a debridement technique for penetrating craniocerebral injuries

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A craniotomy debridement technique was recommended for penetrating craniocerebral injuries as early as 1940, in World War II. However, with due consideration for the bacterial contamination of penetrating injuries, the safety of this technique was questionable. The technique has been recommended in each succeeding war, but no data substantiating the safety or eventual sequelae have been available. Analysis of the data from the large Head Injury Registry of Vietnam casualties indicates that, in properly selected cases, debridement by craniotomy technique can be safe and efficacious.

KEY WORDS □9 craniotomy □9 head injury □9 craniectomy □9 penetrating wound □9 cranioplasty □9 craniocerebral trauma □9 missile wound

During this decade, a century will have evolved since the inception of neurological surgery as a specialty. Fulton noted, in his biography of Cushing, the specialty's responsibility in the management of penetrating missile wounds of the cranium sustained in combat (p 256):7

"All branches of surgery have tended to advance during periods of war, and neurosurgeons (French) first appeared during and just after the War of 1870 when they had occasion to see large numbers of gunshot wounds of the head."

Historical Review

Cushing's first combat neurosurgical assignment was in World War I with the British expeditionary forces near Paris, in 1915. During this time, he developed the concept of locating a neurosurgical team as near to the front as feasible for earlier care of craniocerebral injuries. Colonel Harvey Cushing, MC, USA, was later delegated the responsibility of organizing the neurosurgical efforts of the American Expeditionary Forces. As a result of his personal instructions to all surgeons responsible for treatment of wounds of the head, the mortality associated with the surgical treatment of penetrating craniocerebral injuries was reduced from a forbidding 58% to a more acceptable 28%. Cushing taught meticulous debridement of the scalp using radial tripod or "Isle of Man" incisions, and skull debridement by a circumscribing craniectomy en bloc, accomplished by connecting four or more burr holes by means of a Montenovesi bone-cutting rongeur. The dural penetration was then extended minimally, and the cortex debrided using suction and irrigation to remove bone and metal fragments and necrotic tissue. Hemostasis was gained by tissue implantation of muscle stamps. A tight dural closure after complete debridement was considered imperative. Antiseptic irrigation (Dakin's dichloramine-T in oil) was used. Electrocautery and antibiotics were not yet available.5-6

The principles taught by Dr. Cushing formed the basic tenets of the surgical management of penetrating craniocerebral injuries until they were challenged by second and third generation neurosurgeons serving in World War II (1939–1945). Cushing's tripod scar incision surrendered to the lazy "S" and horseshoe flap designs, and his en bloc skull debridement technique was seriously challenged as the neurosurgeons of that era began to practice direct centrifugal craniectomy debridement. Matson described the change as follows (p 142):12
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"During WWI, block resection of an area of bone surrounding the cranial wound was carried out by drilling four or more burr holes and connecting them with a saw or rongeur. ... In WWII, this technique was no longer necessary or desirable. A more effective approach was found to be quicker, easier, and just as effective."

However, Sir Hugh Cairns of England suggested a more serious deviation from the debridement craniectomy approach, as he wrote (p 36): 8

"Another variety of case which calls for special treatment is the small, clean penetrating head wound associated with persistent neurological signs — for an example, the parietal wound with contralateral hemiplegia. Such cases are probably best dealt with by an osteoplastic flap which has the wound in its center, a type of operation which was strongly advocated by the French in 1940 for the majority of brain wounds. In the variety of cases which we are now considering, the osteoplastic flap is the best means of securing a really adequate exposure of the brain wound and thorough removal of the intracerebral clot which is usually present, sometimes as a result of delayed hemorrhage (late apoplexy). Risks of spreading sepsis of the bone flap are small in such cases, for the wounds of which I am speaking now are usually clean and the methods of preventing infection by means of bacteriostatic substances are becoming increasingly effective."

Ascroft further supported this as he reported a minimum risk of osteomyelitis after debridement, and advised "returning large displaced plates with good vascular connections into position." 21

Before this time, a craniotomy flap technique had not been considered feasible, even for facio-orbitocranial penetrating wounds which were approached directly via the missile tract. Meirowsky, reporting the Korean War experience (1950-1953), stressed the classical teachings of Cushing and advised the use of craniotomy only in the management of facio-orbitocranial penetrating wounds. 13

In the Vietnam conflict (1965-1971), craniotomy flap techniques were recommended for the debridement of facio-orbitalcranial penetrating injuries. 10 Later, a craniotomy flap technique was reported as an elective alternative for vault penetrations. 8,11 The following paragraph is from the January, 1969, medical section of the Commander-in-Chief of the Pacific Command Proceedings (p 26): 8

"Craniotomy should be considered when the cerebral exposure required is large and the area of bone defect is small with a view toward avoiding a cranioplasty, or reducing the magnitude of the cranioplasty procedure at a later date. Cranietomy of the involved bone should, nevertheless, be carried out in all cases of bone penetration. Some surgeons have expressed the opinion that, in view of the gross contamination of penetrating cranio-cerebral war wounds, cranietomy should not be attempted but only craniectomy used to gain intracranial access. Statistics showing the infection rate with cranietomy increased above the infection rate with cranietomy are not presently available and this matter must be left to the judgement of the individual surgeon. If craniotomy is utilized, the probable increased resistance to infection provided by the vascular supply to the bone plate afforded by the myovascular pedicle of osteoplastic craniotomy as contrasted to the avascular free bone flap craniotomy should be considered."

At the combat neurosurgery seminar held during the 1970 annual meeting of the American Association of Neurological Surgeons, the Navy Neurosurgeons reported using the craniotomy technique with small "target craniectomy" debridement of the immediate area of penetration. No significant sequelae or overt problems were reported. 14 However, Hagan, in reporting on complications of penetrating brain wounds, stated (p 136): 8

"The recent Navy practice of performing a formal horseshoe-type scalp flap with the missile wound in the center has resulted in frequent early wound complications because the entrance wound usually has become necrotic and infected. The underlying devascularized bone flap, obtained by use of a craniotome, must then be discarded during the secondary debridement of the contaminated wound."

The other complications reported by Hagan were specifically documented with statistics and case reports, but only this anecdotal comment was assigned to the craniotomy technique. 8 Most of the cases from the evacuation hospital in Japan reported by Hagan are included in this present follow-up study, and we fail to document the problem to which he alluded.

In his review of Navy neurosurgery in Vietnam, Rish 16 reported that the surgical technique of osteoplastic craniotomy with debridement of the penetration by craniectomy in the center or along one border of the bone flap was frequently used to gain better exposure and to avoid large skull defects. 16 This progress in technique was made feasible by the availability of air-powered turbine instrumentation. The development of an air-powered craniotome permitted rapid reflection of a craniotomy flap, resulting in better intracranial exposure for cortical debridement while precluding significant skull defects that would require subsequent cranioplasty. 16,16

To evaluate the safety and efficacy of this technique, we researched the data base of a large population, The Head Injury Registry, which had been compiled by military surgeons in Vietnam (1967-1970). Registry forms delineating the initial neurological status, details of injury, surgical treatment, and acute course were sent to the National Institutes of Health for processing and storage. From this roster, a study population of 1130 cases was developed, and their complete composite medical records were assembled by the Medical Follow-up Agency of the National Research Council. The composite records from the combat zone, and military and Veteran's Administration Hospitals, were reviewed by a team of neurologists and neurosurgeons, and the pertinent data were abstracted and stored on magnetic tape. This exten-
TABLE 1
Morbidity and mortality data in 774 cases of head wound debridement in Vietnam

<table>
<thead>
<tr>
<th>Factor</th>
<th>Craniectomy</th>
<th>Craniotomy</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. Percent</td>
<td>No. Percent</td>
<td></td>
</tr>
<tr>
<td>total cases</td>
<td>711</td>
<td>63</td>
</tr>
<tr>
<td>morbidity (postop craniocerebral infection)</td>
<td>51</td>
<td>2</td>
</tr>
<tr>
<td>scalp</td>
<td>25</td>
<td>0</td>
</tr>
<tr>
<td>skull</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>epi- or subdural cerebritis</td>
<td>11</td>
<td>0</td>
</tr>
<tr>
<td>brain abscess</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>mortality (craniocerebral)</td>
<td>19</td>
<td>1</td>
</tr>
<tr>
<td>cranioplasty (secondary)</td>
<td>393</td>
<td>7</td>
</tr>
</tbody>
</table>

*Listed as the most significant location or extent of infection present in each case.

Summary of Cases

In order to provide for a more comparable study of craniotomy versus craniectomy as initial debridement techniques, the special situation of wounds involving the air sinuses and/or facio-orbitocranial penetration was excluded from the study group. Of the remaining 774 cases, 63 (8.1%) had been debrided by craniotomy. To establish the comparability of the two populations, the following factors were evaluated: topographical distribution of injury, level of consciousness at the time of initial examination, anatomical and radiographic extent of injury, and the extent of surgical debridement. Comparability was demonstrated by all of the above criteria, with the single exception that the craniotomy debridement group actually includes a significantly higher percentage of major surgical debridements (greater than 3 cm in depth and diameter) than the craniectomy population (82% as compared with 74%). Despite this demonstrated comparability, a clinical bias was involved, wherein the surgeon, in considering factors such as gross contamination of wounds or extended time delay from injury to definitive debridement, may have assigned higher risk cases to the craniectomy population. The data and conclusions of this analysis reflect the sound surgical judgment of the combat neurosurgeons who compiled the Vietnam Head Injury Registry.

Postoperative complications were documented to critically evaluate the debridement techniques. Table 1 displays the morbidity and mortality data from this registry review study. No statistically significant differences were demonstrated that reflect an increased risk associated with craniotomy. The craniotomy population was further subdivided into those patients with osteoplastic myovascular pedicle flaps (44 cases), and those with free bone flaps (19 cases). No statistically significant differences in morbidity were found between these two groups, but the numbers are small. Analysis of the morbidity factors revealed several areas where the complication rate was higher following craniectomy. However, in view of the clinical bias discussed above, any critique of this technique is precluded.

There was no significant difference in the mortality rates resulting from craniocerebral injury between the craniotomy and craniectomy groups. The single death in the craniotomy group was due to extensive craniocerebral injury and not related to a septic complication.

Illustrative Case Report

This 21-year-old soldier (Case 2451) sustained grenade fragment injuries to the right parietal area. He was rendered immediately unconscious and hemiparetic. He arrived aboard the hospital ship USS Repose for definitive care within 2 hours of injury.

Examination. On arrival, he was noted to be responding appropriately to his environment and was in stable general condition, but he demonstrated a spastic left hemiplegia. A penetrating wound of the right parietal scalp was evident, and radiographs revealed a metallic fragment in the midline of the parietal area. The area of skull penetration was small. After weighing all clinical and radiographic features, it was elected to debride the wound using a craniotomy flap exposure.

Operation. The penetrating scalp wound was debrided, and then a broad-based horseshoe-shaped parietal scalp flap was reflected with the debrided entry wound centered in the base and with the superior limb reaching the midline. Exposure of the peri- cranium and skull revealed the entry wound to be small, and a burr hole was placed inferior to the penetration site. Using an air-driven craniotome, an oval 10 × 12 cm skull flap was removed. The small, penetrating wound in the center of the flap was debrided to a diameter of 1.5 cm. The stellate penetration in the dura was debrided and opened widely. The cortical debridement extended along the full depth of the missile track to the falx, removing all bone and metallic fragments, hemorrhage, and contused tissue. The exposure gained via the craniotomy flap allowed...
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full inspection of the missile track, the overlying superior parietal cortical surface, and down the falx to the depth of the injury. The dura was then tightly closed primarily, the skull flap returned and secured with stainless steel wires, and the pericranium and scalp reapproximated anatomically.

Postoperative Course. The postoperative course was uncomplicated. The final residual skull defect was minimal (less than 2 cm), and no cranioplasty was necessary.

This case is an example of the safety and efficacy of the craniotomy flap technique approach to a penetrating injury, which resulted in better cortical exposure for debridement and avoided a large, postoperative skull defect and secondary cranioplasty.

Conclusions

1. This study supports Cairns' proposal that certain penetrating craniocerebral wounds can be safely and efficaciously debrided by craniotomy.
2. The exposure gained by craniotomy allows for better cortical debridement and management of associated intracranial problems.
3. Significant skull defects requiring delayed cranioplasty are usually avoided in craniotomy debridement.
4. This substantiation of the safety and feasibility of craniotomy as a debridement technique for selected cases should not be construed to relieve the neurosurgeon of the critical responsibility of sound, discrete surgical judgment; considering in each case such significant factors as: time delay from wounding to definitive treatment, gross contamination, large areas of comminuted nonviable bone fragments, and minimal extent of intracerebral trajectory.

References


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