The experimental significance of retained intracranial bone fragments

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The relationship of retained intracerebral sterile bone, unsterile bone, and combined scalp and hair to the development of intracranial abscess was studied in the dog. Sterile bone and unsterile bone were associated with abscess development in 7% of the cases. Scalp-and-fur and scalp-fur-and-bone were associated with abscess formation in 69% of the cases. The study suggests that clusters of retained bone fragments may point to potential areas of contamination by skin and hair that justify reexploration, but that isolated bone fragment may be left in place.

Penetrating cranial cerebral wounds are relatively rare in civilian practice but represent a common surgical problem to the military neurosurgeon in or near a geographic zone of hostilities.

The operative principles outlined by Cushing following experience gained in France in World War I, more clearly set down by Matson after wide experience in the European Theatre in World War II, and subsequently amplified by Meirowsky and others following the Korean conflict, are the norms by which craniocerebral wounds are managed. Briefly, these include thorough debridement of the site of entry through the scalp, enlargement of the skull perforation sufficient to facilitate adequate cerebral debridement, resection of devitalized central nervous system tissue, removal of indriven bone, scalp, hair, dirt, and accessible fragments of missile, and after attainment of complete hemostasis and a secure dural closure, approximation of the scalp in two layers. Except for the employment of antibiotics, postoperative management does not differ greatly from that subsequent to elective surgery.

Less than adequate debridement of such wounds is associated with a significantly higher incidence of cerebral abscess formation than is noted in corresponding cases more aggressively handled. Retained foreign bodies, especially bone fragments propelled inward by the inflicting missile, have been shown by most observers to be associated with a higher incidence of wound abscess formation. Indeed, Meirowsky noted that approximately 50% of cranial wound abscesses developing subsequent to primary debridement were associated with retained bone fragments.

Such observations prompted the establishment of a policy of reexploration of all individuals in whom postoperative skull x-rays revealed one or more retained bone fragments overlooked at the time of initial surgery. If skull fragments per se promote tissue reaction leading to abscess formation in the majority of situations, then the risks of reexploration are certainly justified. How-
ever, after observing the results of a limited clinical survey involving individuals harboring bone fragments who did not develop infections, the authors questioned the validity of this concept, and as a consequence carried out a detailed laboratory study of the effects of retained bone fragments on cerebral tissue.

Method

Sixty-one mongrel dogs ranging from 5 to 20 kg were used. During surgery all were maintained under Fluothane anesthesia. Four categories of animals were considered.

Group 1

In the first group consisting of 21 animals, the scalp was shaved, cleansed with Phisohex and Betadine solution, and a midline incision was carried from the external occipital protuberance to terminate at the region of the glabella. The subcutaneous tissue was incised and the scalp retracted laterally by means of a self-retaining retractor. The temporalis muscle which approximates the midline in the dog was reflected laterally in a subperiosteal fashion. A 2 cm craniectomy was established 2 cm from the midline bilaterally and near the coronal suture. The underlying dura was incised in a cruciate fashion, and a stab wound made to a depth of approximately 2 cm in a ventromedial direction. The ventricular system was not entered. Small fragments of bone averaging 2 to 3 mm in diameter were then rongeured from the edges of the craniectomy site and implanted deep in the stab wound on the left side. On the right side a small bolus of bone dust was implanted at a corresponding depth. The dura was left open, and the craniectomy site was covered with a small pledget of Gelfoam. The temporalis muscle on each side was reapproximated at the midline and securely fastened with a single layer of running 3–0 silk suture. Finally, the scalp was closed in a single layer using 3–0 running silk suture.

Group 2

The identical procedure was carried out in another 27 animals with the exception that nonsterile technique was employed, and the bone fragments and dust bolus were contaminated in the fur of the animal’s back.

Group 3

In 11 animals operated on under sterile technique, a small section of the animal’s scalp taken from the edge of the incision and averaging 2 to 3 mm plus a small bolus of contaminated fur averaging 2 to 3 mm in diameter were inserted in the depths of each of the two cerebral stab wounds.

Group 4

A final category consisting of two animals involved the insertion of combined contaminated fragments of bone, scalp, and fur in sizes comparable to those employed in the previous work.

All animals were maintained for varying periods of time ranging from 5 days to 1 year. Antibiotics were employed only if an animal developed an elevated temperature with evidence of debilitation within the first 2 to 4 days after surgery. Beginning 1 week after surgery, any animal demonstrating such findings was sacrificed and the brain examined. The scalp sutures were removed from all animals within 10 days of surgery.

All animals were eventually sacrificed and the cerebrum removed and examined. Coronal sections were made under sterile technique at the level of the lesions and these were cultured.

Results

The course of the control animals and those in the two main categories (bone contamination only, and fur, scalp, and bone contamination) is summarized in Table 1. It becomes apparent from review of Table 1 that contaminating bone, be it sterile or nonsterile, is associated with infection in a relatively low frequency (4% to 8%), whereas the addition of fur and scalp to the lesion appear to markedly increase the frequency of abscess formation (69%).

The gross and histologic features of lesions contaminated with bone alone (Figs. 1 left and 2) characteristically develops into a small solid lesion with centrally located bone, peripheral to which is seen a band of gliosis blending more peripherally with normal brain. Lesions harboring the additional contaminants of fur and scalp, with or without bone (Figs. 1 right and 3), characteristically mature into a classic abscess, with cen-
Retained intracranial bone fragments

TABLE 1
Summary of results

<table>
<thead>
<tr>
<th>Results</th>
<th>Sterile Bone</th>
<th>Contaminated Bone</th>
<th>Fur and Scalp With and Without Bone</th>
</tr>
</thead>
<tbody>
<tr>
<td>total cases</td>
<td>22</td>
<td>27</td>
<td>13</td>
</tr>
<tr>
<td>number infected</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>% infected</td>
<td>8%</td>
<td>4%</td>
<td>69%</td>
</tr>
<tr>
<td>average time for infection</td>
<td>15</td>
<td>18</td>
<td>8</td>
</tr>
<tr>
<td>range of observation (mos)</td>
<td>1–12</td>
<td>1–12</td>
<td>1–12</td>
</tr>
</tbody>
</table>

Thus, there was a striking difference in the tissue response to retained bone as compared to bone plus fur and skin.

Discussion

The use of animal experimentation to predict human responses carries with it the phylogenetically related error of variation in species response. This fact is appreciated, and indeed the dog nervous system may in fact be less vulnerable to infecting agents than that of the human; if so, this study has questionable value. However, a reasonable degree of correlation will be assumed.

If retained fragments are in fact associated with an increased incidence of cerebral abscess formation, the mechanism by which this occurs is probably due to one of the following processes: 1) the fragments per se promote inflammatory response through a chemical mechanism, thus creating a sterile abscess; 2) the fragments carry bacteria into the depths of the cortex and, like other contaminated foreign bodies within a wound, act as a nidus for infection; 3) the fragments themselves have nothing to do with the development of the infection but, rather radiologically outline a region of the wound which has not been surgically approached in the initial debridement and thus harbors the usual contaminants of a penetrating head wound including bone, hair, particles of scalp, external debris, missile fragments, and devitalized brain.

If one assumes the first postulate, namely, that the fragments per se initiate sterile abscess formation, the lesions too should be sterile and the incidence of abscess formation would be expected to be higher than that noted in this study. If, as suggested in the second possible mechanism, the abscesses are presumed to be caused by bacteria indriven with the bone, then here too the

Fig. 1. Left: Coronal section at the level of retained bone fragments but without abscess formation. Right: Coronal section at the level of a cerebral abscess presumably related to a retained cluster of bone fragments and debris.

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incidence of abscess formation might be expected to be considerably higher than the 4% observed and certainly higher than the 8% noted in the sterile bone category. The fact that retained bone fragments, whether sterile or contaminated, were not associated with abscess formation in most instances casts doubt on the validity of the previously unquestioned policy of vigorous removal of all bone fragments.

The fact that bone is not the offending agent in the development of wound abscesses in general is suggested by the results in the category of lesions containing bone, fur, and scalp, or in the category of fur and scalp alone without bone, where abscesses develop an impressive 69% of the time. This distinct difference in reaction rate appears to be attributable to the scalp and fur rather than bone, since they are the two factors not included in the previous category where the infection rate was less than 10%. The impres-
be assumed that this represents an area overlooked at surgery, and, if the statistics observed in animals can be extrapolated to human beings, an abscess will develop approximately in about 65% of such cases. Their presence, therefore, is a measure of the thoroughness of debridement.\textsuperscript{12,15} If, however, following thorough debridement a skull x-ray reveals one or more small, scattered, nonclustered bone fragments, the central tract still quite possibly has been well debrided and the fragments seen may lie peripherally in relatively uncontaminated brain, a condition which we feel does not require further surgical debridement.\textsuperscript{5}

If all retained fragments do not carry the significance generally attributed, how then did this concept develop? Information related to craniocerebral wounds in one phase of the Korean conflict suggested that 50% of infected penetrating head wounds harbored bone fragments.\textsuperscript{2,14} Although this may be so, the converse is not necessarily true, that is, that most wounds harboring retained bone fragments are associated with wound abscesses. The indriven debris, soft tissue, and other nonradiopaque material are responsible for most wound abscesses, with bone fragments playing a minimal role.

If one considers the advantage of reexploration, namely, the prevention of abscess formation in approximately 6% of the cases, and compares this to such risks of reexploration as extension of previous neurological deficit, the higher infection rate known to occur in reoperated surgical sites, and the mortality rate related to intracranial surgery and anesthesia, the question arises as to whether it is prudent to subject all to risks while only a small minority benefit. One might, rather, maintain a period of close observation directing attention to the possible development of a space-occupying mass (abscess) that can then be evacuated.

\textbf{Fig. 3.} Sections through abscess showing central necrotic debris surrounded concentrically by an area of acute chronic inflammatory cells, moderate gliosis, and peripherally by an area of edematous parenchyma. \textit{Left:} H. \& E., $\times 2.5$. \textit{Right:} H. \& E., $\times 25$. 

\begin{figure}
\centering
\includegraphics[width=\textwidth]{fig3}
\caption{Sections through abscess showing central necrotic debris surrounded concentrically by an area of acute chronic inflammatory cells, moderate gliosis, and peripherally by an area of edematous parenchyma. \textit{Left:} H. \& E., $\times 2.5$. \textit{Right:} H. \& E., $\times 25$.}
\end{figure}
Fig. 4. Schematic diagram of penetrating cerebral wound, showing central cluster of bone fragments (A) with contaminants and peripheral isolated fragments that often are not contaminated (B).

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References

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