A Survey of Possible Etiologic Agents in Postoperative Craniotomy Infections*

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Major operative procedures performed routinely by neurosurgeons today were not even considered a century ago, for the sepsis that invariably complicated such efforts made elective surgical attack on most intracranial space-occupying lesions unthinkable. The contributions of Pasteur and Koch in discovering that infection was caused by microorganisms and the efforts of Lister to reduce contamination of surgical wounds were of great importance in the later development of this and every other branch of surgery.

Because of this risk of sepsis, cranial surgery made no significant advances from the 16th until the late 19th century. Lister himself was probably the first surgeon to utilize his new techniques in intracranial operations. The well-documented case operated upon by Godlee in 1884 was the first occasion on which a brain tumor was correctly localized by clinical neurological findings and removed. This patient died a month later of postoperative meningitis.

By the beginning of the twentieth century, intracranial operations had become more frequent. The operative experience of von Eiselsberg and Ranzi was reported in 1913; in 168 cases of intracranial tumors there were 61 postoperative deaths, 20 of which were caused by sepsis. Tooth's review of 265 cranial operations done in London prior to 1913 included 99 postoperative deaths of which 31 were caused by infection. Harvey Cushing seems to have had an astonishingly low rate of infection in "clean" surgical cases. In 1915 he reported 1 case of postoperative infection in 149 operations for brain tumors. In 1916, he denied any further trouble with sepsis in 300 intracranial operations. A year later, reviewing 29 patients with operations for acoustic neuromas, he stated that there was no postoperative sepsis and vehemently added, "An infected wound or meningitis following a clean cranial operation is practically inexcusable at the present day."

Cushing in 1931 presented the results of 113 operations on 74 patients with cerebellar astrocytomas. There were 2 fatal cases of postoperative meningitis, both of which occurred in reoperations for recurrent tumors. In the meningioma series of 522 operations on 281 patients, there were only 2 cases of meningitis complicating craniotomy and 3 draining sinuses, caused in 2 instances by retained cottonoid paddles. Cushing's disciples have all acknowledged his meticulous methods beginning with preparations of the scalp, careful operative technique and postoperative care of the wound, and herein may lie in part the reason for his low rate of operative infections.

Cairns in 1939 reported a series of 968 intracranial operations in 846 patients in which there were 23 fatal septic complications and 3 delayed cases of osteomyelitis of the bone flap. He believed that an increased risk of sepsis occurred with the reopening of an operative wound. Cairns' interest in prevention of sepsis continued and in 1944 he began to apply a mixture of penicillin and sulfamethazine topically in all operative wounds. With this added tactic, there was a diminished rate of sepsis following posterior fossa operations from the previous level of 8.5% to 2.5%, and after supratentorial procedures the infection rate fell from 3.3% to 0.8%.

Woodhall et al., using ultraviolet radiation of the operating room during craniotomy, had only 13 infections (1.05%) with a single fatality in 1,228 cases. Penfield, after adopting a similar technique, brought the sepsis rate for all neurosurgical procedures
TABLE 1
Infections complicating 'clean' intracranial operations at the Massachusetts General Hospital, 1952-1963

<table>
<thead>
<tr>
<th>Procedures</th>
<th>No. of Operations</th>
<th>Infections</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extrudal procedures</td>
<td>218</td>
<td>3 (1.4%)</td>
</tr>
<tr>
<td>Supratentorial intradural procedures</td>
<td>1,633</td>
<td>103 (6.3%)</td>
</tr>
<tr>
<td>Infratentorial intradural procedures</td>
<td>297</td>
<td>16 (5.4%)</td>
</tr>
<tr>
<td>Total</td>
<td>2,148</td>
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</tr>
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| From 1.1% to 0.4%. Odom continued the study of wound infection in cases done under ultraviolet radiation (0.4%) and in the period 1941-1962 reported only 16 infections and a single fatality in 2,342 craniotomies. In 122 cases of acoustic neuroma, reviewed by Pool and Pava, sepsis occurred in 7 (5.7%). Mullan's series of 100 consecutive operations for brain tumor reported in 1962 had 3 instances of postoperative infection. Green et al. also had a 3% postoperative sepsis rate in 100 consecutive craniotomies. Thornton et al. reported an incidence of 5.8% postoperative infections caused by staphylococcus aureus after intracranial operations.

It is apparent that the risk of infection following intracranial operations has remained significant and that a thorough analysis of this problem is long overdue. In this study, we have undertaken an assessment of the etiologic agents that are likely to cause sepsis after craniotomy. The varieties of infection that can occur, their manifestations, and their proper treatment have already been dealt with.

Study of 2,148 Craniotomy Cases
In the period 1952 to 1963, a total of 2,258 clean intracranial operations were performed at the Massachusetts General Hospital. In this study, 67 of these were not included because the patients survived less than twenty-four hours after operation; 43 more were deleted because clinical records were incomplete or missing. Of the remaining 2,148 cases, sepsis occurred in 122 (5.7%). Further subdivision of this group in Table 1 showed that sepsis complicated only 3 (1.4%) of 218 extradural operations; 103 (6.3%) of 1,633 supratentorial intradural operations, and 16 (5.4%) of 297 operations in the posterior cranial fossa. In this study, patients in whom burr holes alone were done have not been included, for sepsis in these is a minimal risk; only craniotomy or craniectomy cases have been studied. Compound fractures, intracranial abscesses, and missile wounds, all examples of cases with massive preoperative bacterial contamination, have also been omitted from these studies of infection following "clean" intracranial operations.

Under the heading of infections we have included only cases in which the diagnoses of abscess, meningitis, or osteomyelitis caused by pathogenic bacteria have been established beyond doubt. Complications, such as fever of unknown origin and the infrequent aseptic meningitic reactions described by Finlayson and Penfield have not been counted although, of course, it is likely that some of these may be caused by bacterial infection that is brought under control by the patient. Individual operative techniques have varied with the surgeon, some, for example, preferring a free bone flap to one hinged on temporal muscle, some using the two-layer silk suture method of scalp closure, and others preferring through-and-through sutures of stainless steel wire. In this survey, there was no indication that particular operative techniques such as these influenced the likelihood of later sepsis.

Fig. 1 shows the yearly incidences of postoperative craniotomy infections for the twelve-year period 1952-1963. There was considerable yearly variation, from an incidence of 3.3% in 1962 and 1963 to 9.5% in 1956, but the random distribution of this graph demonstrates that there has been no increasing or decreasing tendency for such infections to occur. The present rate of sepsis seems to have stabilized at approximately 3 to 4 per cent, the same level as the years 1953-1954. Similarly, the proportion of infections caused by staphylococcus aureus, as shown by the broken line in Fig. 1, has not changed appreciably. The effects of certain changes in operating techniques have not

* The author is indebted to Charles C Thomas, publisher, for permission to reproduce Figs. 1 and 2 from Postoperative Craniotomy Infections.