Preservation of bone flaps in patients with postcraniotomy infections

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Object. Management of postcraniotomy wound infections has traditionally consisted of operative debridement and removal of devitalized bone flaps followed by delayed cranioplasty. The authors report the highly favorable results of a prospective study in which postcraniotomy wound infections were managed with surgical debridement to preserve the bone flaps and avoid cranioplasty.

Methods. Since 1990, 13 patients with postcraniotomy wound infections have been prospectively treated with open surgical debridement and replacement of the bone flap. All patients received a full course of systemic antibiotic agents based on the determination of the bacterial culture and antibiotic sensitivity. Notable risk factors for infection included prior craniotomies, radiotherapy, and skull base procedures. The mean long-term follow-up period was 35 ± 20 months. In all five patients who underwent craniotomies without complications, bone flap preservation was possible with full resolution of the infection and without the need for additional surgery. Among the eight patients with risk factors, bone preservation was possible in six patients, although two required minor wound revisions (without bone flap removal). Both patients who underwent craniofacial procedures required an additional procedure in which the bone flap was removed for recurrent infection (one after 2 months and the other after 29 months).

Conclusions. In patients with uncomplicated postcraniotomy infections, simple operative debridement is sufficient and it is not necessary to discard the bone flaps and perform cranioplasties. Even patients with risk factors such as prior surgery or radiotherapy can usually be treated using this strategy. Patients who undergo craniofacial surgeries involving the nasal sinuses are at higher risk and may require bone flap removal.

KEY WORDS • craniotomy • bone flap • postoperative infection • complication

The standard of care for the management of postcraniotomy wound infections consists of operative debridement and removal of the devitalized bone flap followed by delayed cranioplasty performed several months later. This strategy, although successful in treating most infections, adversely affects patient satisfaction by necessitating an additional surgical procedure for cranioplasty, as well as leaving a cosmetic deformity and lack of brain protection before cranioplasty can be performed. Methods to address this difficulty such as the suction–irrigation treatment of craniotomy infections are laborious and are associated with a failure rate of 40%. We have instituted a surgical debridement strategy to treat postcraniotomy wound infections that allows preservation of bone flaps to obviate the need for an additional operation for cranioplasty. We report highly favorable results with long-term follow-up evaluations after using this strategy in a prospective cohort of consecutive patients with postcraniotomy infections. The favorable results invite a reexamination of the common practice of discarding bone flaps in patients undergoing operative debridement.

Clinical Material and Methods

Patient Population

Of the 1200 craniotomies performed by the senior author (J.N.B.) since 1990, 13 patients experienced postoperative epidural or subgaleal bone flap infections without intradural involvement, which were manifested by purulent wound drainage (infection rate 1.1%). All 13 patients were treated prospectively with open debridement and bone flap preservation.

The patients ranged in age from 18 to 73 years (mean 36 years) and included seven men and six women (Table 1). Free flap craniotomies were performed for malignant tumors in five patients, benign tumors in six patients, cavernous malformation in one patient, and osteopetrosis in one patient. The time from the initial craniotomy to operative debridement ranged from 8 to 108 days (mean 45 days). Notable risk factors included prior multiple craniotomies, radiotherapy, chemotherapy, and the use of a skull base approach. The overwhelming majority of patients were infected with skin organisms, mostly by one of the staphyl-
### TABLE 1
Summary of 13 patients with postcraniotomy infections that were managed with operative debridement and bone flap preservation*

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs), Sex</th>
<th>Operation</th>
<th>Pathological Findings</th>
<th>Days to Revision</th>
<th>Infecting Organism</th>
<th>Risk Factors</th>
<th>2nd Wound Revision</th>
<th>Follow Up (mos)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>38, F</td>
<td>frontotemporal craniotomy</td>
<td>infundibular eosinophilic granuloma</td>
<td>31</td>
<td>few small Gram-positive rods</td>
<td>none</td>
<td>no</td>
<td>34</td>
</tr>
<tr>
<td>2</td>
<td>18, M</td>
<td>suboccipital craniotomy</td>
<td>pineal region mixed germ cell tumor</td>
<td>108</td>
<td><em>Propionibacterium acnes</em></td>
<td>chemo</td>
<td>no</td>
<td>32</td>
</tr>
<tr>
<td>3</td>
<td>27, F</td>
<td>frontotemporal craniotomy</td>
<td>cavernous malformation</td>
<td>28</td>
<td><em>coagulase-negative Staphylococcus</em></td>
<td>none</td>
<td>no</td>
<td>9</td>
</tr>
<tr>
<td>4</td>
<td>23, M</td>
<td>bilateral craniotomies or craniectomies, skull vault decompensation</td>
<td>cortical sclerosis (Engelmann disease)</td>
<td>37</td>
<td><em>S. epidermidis</em></td>
<td>none</td>
<td>no</td>
<td>53</td>
</tr>
<tr>
<td>5</td>
<td>33, F</td>
<td>frontotemporal craniotomy &amp; transcallosal approach</td>
<td>subependymoma</td>
<td>51</td>
<td>no growth found in culture</td>
<td>none</td>
<td>no</td>
<td>30</td>
</tr>
<tr>
<td>6</td>
<td>31, M</td>
<td>frontal craniotomy</td>
<td>convexity meningioma</td>
<td>11</td>
<td><em>Enterobacter aerogenes</em></td>
<td>RT, PMC, CSF leak</td>
<td>no</td>
<td>30</td>
</tr>
<tr>
<td>7</td>
<td>25, F</td>
<td>frontal craniotomy</td>
<td>recurrent hemorrhagic GBM</td>
<td>102</td>
<td><em>S. epidermidis</em></td>
<td>RT, PMC, CSF leak</td>
<td>no</td>
<td>8</td>
</tr>
<tr>
<td>8</td>
<td>41, M</td>
<td>frontoparietal craniotomy</td>
<td>recurrent anaplastic oligodendroglioma</td>
<td>33</td>
<td><em>Propionibacterium acnes</em></td>
<td>RT, PMC, chemo†</td>
<td>no</td>
<td>23</td>
</tr>
<tr>
<td>9</td>
<td>46, F</td>
<td>transpetrosal presigmoid approach</td>
<td>petroclival meningioma</td>
<td>27</td>
<td><em>E. aerogenes &amp; Proteus mirabilis</em></td>
<td>CSF leak</td>
<td>no</td>
<td>60</td>
</tr>
<tr>
<td>10</td>
<td>32, M</td>
<td>frontotemporal craniotomy</td>
<td>recurrent optic glioma</td>
<td>44</td>
<td><em>Propionibacterium acnes</em></td>
<td>RT,† PMC</td>
<td>yes</td>
<td>24</td>
</tr>
<tr>
<td>11</td>
<td>45, F</td>
<td>bifrontal craniotomy &amp; anterior cranial base osteotomy</td>
<td>squamous cell carcinoma of ethmoid sinus</td>
<td>8</td>
<td><em>Klebsiella pneumonia</em></td>
<td>PMC, skull base surgery</td>
<td>yes</td>
<td>50</td>
</tr>
<tr>
<td>12</td>
<td>73, F</td>
<td>bifrontal craniotomy</td>
<td>recurrent skull base meningioma</td>
<td>12</td>
<td><em>S. aureus</em></td>
<td>RT, skull base surgery</td>
<td>yes</td>
<td>77</td>
</tr>
<tr>
<td>13</td>
<td>30, M</td>
<td>biparietal craniotomy</td>
<td>PNET of posterior corpus callosum</td>
<td>93</td>
<td><em>Propionibacterium acnes</em></td>
<td>RT</td>
<td>yes</td>
<td>23</td>
</tr>
</tbody>
</table>

* chemo = perioperative chemotherapy; CSF = cerebrospinal fluid; GBM = glioblastoma multiforme; PMC = prior multiple craniotomies; PNET = primitive neuroectodermal tumor; RT = perioperative radiotherapy.

† History of chemotherapy or radiotherapy.

Among the 13 patients who underwent open debridement of the bone flap, the bone flap was preserved in 12 patients (Table 1). Due to the nature of the senior author's surgical practice, the majority of infections were noncontiguous and occurred in patients who had undergone skull base procedures. In one patient no organism was isolated.

## Results

### Treatment Methods

- **Operative Debridement**: Among the 13 patients who underwent open debridement of the bone flap, the bone flap was preserved in 12 patients (Table 1). Due to the nature of the senior author's surgical practice, the majority of infections were noncontiguous and occurred in patients who had undergone skull base procedures. In one patient no organism was isolated.

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allergic reaction to vicryl sutures, in another patient (Case 13) who had previously undergone radiation treatment for a primitive neuroectodermal tumor.

In the two patients in whom bone flap removal was ultimately necessary because of recurrent infection (Cases 11 and 12), this occurred after 2 months in one patient, but not until a lengthy delay of 29 months in the other. These two patients shared several risk factors for poor wound healing, the most notable being that they had undergone craniofacial procedures through an anterior skull base osteotomy for anterior skull base tumors involving communication with the nasal sinuses. Additionally, one patient had undergone previous tumor resection and the other had completed postoperative radiotherapy.

It is notable that many patients were successfully treated with bone flap preservation, despite their risk factors. Of the eight patients with one or more risk factors, four were treated without any further procedures, whereas two (Cases 10 and 13) required minor wound revisions with bone flap preservation and another two (Cases 11 and 12) ultimately underwent an additional surgical procedure and bone flap removal for recurrent infections. Of five patients who had received radiotherapy, two were treated without an additional surgical procedure, two required minor wound revisions, and only one ultimately required bone flap removal. A history of craniotomy for recurrent tumor was relevant in four patients, including one who required a minor second wound revision and one in whom the bone flap was discarded only after an infection developed 29 months later. Of two patients with a history of chemotherapy, neither required wound revision. Three patients underwent skull base surgeries: one patient in whom a presigmoid approach had been made to a petrous apex meningioma and the clinical course was uncomplicated (Case 9), and two patients who underwent craniofacial surgery, in whom ultimately bone preservation was not possible (Cases 11 and 12).

Nearly all patients had infections secondary to skin organisms, with staphylococcus and Propionibacterium acnes being the most common. One patient had experienced an initial Gram-negative bacillary infection due to K. pneumoniae; this was the patient whose bone flap was removed after a 29-month delay (Case 11) because of an infection caused by K. pneumoniae and Pseudomonas aeruginosa. Two other patients had infections due to E. aerogenes, including one with a mixed E. aerogenes–Proteus mirabilis infection, most likely due to involvement of the mastoid sinus following a transpetrosal approach (Case 9).

### Discussion

Since 1990, we have had a postcraniotomy infection rate of 1.1%, which compares favorably with average rates reported in large series, which range from less than 1% to as high as 11% in patients with recurrent malignant gliomas. We have prospecively managed all postcraniotomy wound infections with operative debridement and preservation of bone flaps. Although this series is relatively small, it spans more than a decade and demonstrates that simple operative debridement is sufficient in patients with uncomplicated postcraniotomy infections, making it unnecessary to discard bone flaps and perform cranioplasty. Even patients with risk factors such as prior surgery, skull base procedures, chemotherapy, or radiotherapy can be successfully treated using this strategy in most cases. Patients with craniofacial surgeries involving the nasal sinuses, however, are at higher risk and might be best treated with bone flap removal and delayed cranioplasty.

The methods used for surgical debridement and delivery of systemic antibiotic agents to facilitate bone flap preservation are straightforward. Aggressive operative debridement with elevation of the bone flap and antibiotic irrigation to remove all dead tissue, debris, suture, and foreign material is desirable. The bone flap is vigorously scrubbed before replating it in place. Additionally it is reasonable to avoid leaving an excess of bulky hemostatic agents. FloSeal or Avitene are reasonable choices; they can be irrigated away after hemostasis has been achieved. Finally a full course of specific systemic antibiotics is indicated, based on determination of the bacterial cultures and antibiotic sensitivities.

Traditionally, the management of postoperative infections has consisted of operative debridement and removal of devitalized bone flaps followed by delayed cranioplasty. A management strategy that preserves the bone flap has the obvious advantage of avoiding the cost and inconvenience of an additional operative procedure for cranioplasty and the ensuing decreased patient satisfaction from the sizeable cosmetic defect and lack of brain protection during the several months before cranioplasty can be safely performed. Previously Chou and colleagues reported having modest success with the suction–irrigation method of wound management. In their report of 25 patients success was achieved in 60%, although the follow-up period was not lengthy. This laborious and inconvenient method necessitated daily antibiotic irrigation through subgaleal drains over a 5-day period. The lack of success was likely due to insufficient operative debridement because the bone flaps were not reelevated. Additionally, the use of drains for an extended period of time may have contributed to the risk of reinfection. Based on our results, we conclude that additional irrigation is superfluous following vigorous surgical debridement. Other reports justify the rationale for bone flap preservation by describing anecdotal successes follow-

### Table 2

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Time to 2nd Revision</th>
<th>Infecting Organism</th>
<th>Removal of Bone Flap</th>
<th>Findings</th>
<th>Risk Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>42 days</td>
<td>none</td>
<td>no</td>
<td>RT-induced wound dehiscence</td>
<td>RT, PMC</td>
</tr>
<tr>
<td>11</td>
<td>29 mos</td>
<td>Pseudomonas aeruginosa/K. pneumoniae</td>
<td>yes</td>
<td>delayed wound infection</td>
<td>PMC, skull base surgery</td>
</tr>
<tr>
<td>12</td>
<td>67 days</td>
<td>S. aureus</td>
<td>yes</td>
<td>communication w/ nasal sinus</td>
<td>RT, skull base surgery</td>
</tr>
<tr>
<td>13</td>
<td>38 days</td>
<td>S. aureus</td>
<td>no</td>
<td>giant cell skin reaction</td>
<td>RT</td>
</tr>
</tbody>
</table>

Preservation of bone flaps in postcraniotomy infections

**TABLE 2**

Summary of patients requiring a second wound revision
ing bone flap debridement alone or preservation of hydroxyapatite and primary wire mesh cranioplasties at the initial surgical debridement. A variety of risk factors are known to be associated with postcraniotomy wound infections, including cerebrospinal fluid leak, prior craniotomies, radiotherapy, and craniofacial procedures involving the nasal sinuses. These factors, particularly prior radiotherapy and craniofacial procedures, are also likely to be associated with repeated infection following initial surgical debridement. The small number of patients involved in this series makes it difficult to generalize and stratify patients with significant risk factors for infection and poor wound healing; however, all patients in this series who had no risk factors had full resolution of their infection after a single operative debridement. This suggests that patients with benign pathological conditions and uncomplicated histories can be treated with bone flap preservation, including those patients who have initially undergone craniotomies for vascular malformations, aneurysms, tumors, or seizures. No patient in this series had suffered trauma and thus it is difficult to speculate on the likelihood of success when nonendogenous bacteria have potentially contaminated the wound. The nature of the referral practice analyzed in this series was heavily weighted toward neurooncology and, therefore, a sizeable percentage of patients had undergone prior craniotomies for recurrent tumors, as well as radiotherapy and chemotherapy. Interestingly, even patients with these risk factors were successfully treated with bone flap preservation. Although two of the eight patients with risk factors required subsequent wound revisions for poor wound healing, it did not appear that removal of the bone flap would have prevented a revision, because their wound healing was compromised by a giant cell dermal reaction or a radiation-induced wound dehiscence. The most obvious risk factor predictive of ultimate bone flap removal is anterior skull base lesions in patients who have undergone craniofacial procedures involving communication with the nasal sinuses. Interestingly, one of the patients in this category (Case 11) was initially treated successfully, but required an additional operation 29 months later. In such an anecdotal case it is difficult to determine if bone flap removal would have ultimately prevented this infection recurrence. The patient’s clinical history was also complicated by her having undergone previous surgery and having a Gram-negative rod infection (K. pneumoniae), a more virulent organism than most skin bacteria. The other treatment failure in a patient who underwent surgery (Case 12) was complicated by radiotherapy. Therefore, although a craniofacial procedure involving the nasal sinuses is a significant risk factor, it is possible that patients with infections whose histories are uncomplicated by radiotherapy or prior surgery may still be successfully treated with bone flap preservation. It is difficult to generalize pessimistically about all patients with skull base lesions because the one patient in this series who underwent a temporal craniotomy and a transpetrosal approach had an uncomplicated antibiotic course, despite the fact that there was communication with mastoid air cells. The success of this treatment strategy argues for a change in the standard of care for patients with uncomplicated postcraniotomy wound infections. The results reported here will benefit from verification in larger numbers of patients by other neurosurgeons. Although treatment failures and subsequent bone flap removals will be inevitable as the number of patients increases, the substantial benefits afforded by this approach justify its use for the majority of patients in whom success is likely. Risk factors such as prior surgery, radiotherapy, or skull base approaches may adversely affect outcome and, although not absolute contraindications, should be candidly evaluated and discussed with individual patients before operative debridement is undertaken.

Conclusions

We report the highly favorable results of a prospective study in which aggressive surgical debridement was performed to preserve bone flaps without cranioplasty in patients who had postcraniotomy wound infections. In these patients, simple operative debridement was sufficient and it was unnecessary to discard bone flaps and perform cranioplasties. The substantial benefits to patients of bone flap preservation include avoidance of a temporary, large, cosmetic craniotomy defect over the unprotected brain as well as an additional surgical procedure for cranioplasty. Even patients who have undergone previous surgery, radiotherapy, skull base procedures, or chemotherapy may be successfully treated using this strategy, although they carry a higher risk. The only risk factor strongly correlated to lack of success is a prior craniofacial procedure involving communication with the nasal sinuses.

References

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