Frontal Sinus Cranialization Using the Pericranial Flap: An Added Layer of Protection

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Objectives: Extensive fractures involving the anterior and posterior tables of the frontal sinus are treated by frontal sinus cranialization. During this procedure, the disrupted posterior wall of the frontal sinus is removed, the sinus mucosa is drilled away, and the brain and dura are permitted to rest against the repaired anterior wall and sinus floor. Conventionally, the area originally occupied by the frontal sinus is left as dead space or filled with free adipose tissue. We describe a method of cranialization using a pericranial flap and report our experience with this technique. Study Design: Retrospective study. Methods: The medical records of patients who underwent frontal sinus cranialization using the pericranial flap at our institution were reviewed. Demographics, indications for cranialization, complications, and perioperative outcomes were examined. Results: A total of 19 patients underwent (bilateral) frontal sinus cranialization with the pericranial flap between 2000 and 2005. Indications included extensive frontal sinus fractures involving the posterior table (78.9%), mucocele (10.5%), arteriovenous malformation (5.3%), and frontal bone osteomyelitis (5.3%). There were no intraoperative complications. A postoperative cerebrospinal fluid leak occurred in one patient with extensive skull base injuries. This was repaired endoscopically. Follow-up ranged from 9 to 55 months. Conclusions: The pericranial flap is easily harvested and versatile. Using this vascularized tissue during cranialization affords added protection by providing an extra barrier between the intracranial cavity and the frontal bone and sinonasal tract. This technique is inexpensive, safe, and effective and should be considered when cranialization of the frontal sinus is performed.

Key Words: Pericranial flap, frontal sinus cranialization, frontal sinus fractures.


INTRODUCTION

Management of extensive fractures of the frontal sinus remains controversial.1–4 These generally occur in cases of head trauma resulting from extensive force, and patients routinely present with multisystem injuries that are often life-threatening. In the patient with extensive disruption of the posterior table of the frontal sinus who has a reasonable prognosis for recovery, ablation of the frontal sinus(es) by cranialization has been recommended.

Cranialization of the frontal sinus was first described in 1978 by Donald and Bernstein.5 The original description consisted of removing the posterior wall of the frontal sinus, meticulous removal of the frontal sinus mucosa, and allowing the frontal lobe dura mater to come to rest against the anterior table and floor of the frontal sinus. Goals of this procedure are the extirpation of all sinus mucosa and the complete separation of the intracranial cavity from the sinonasal tract below. Conventionally, the area originally occupied by the frontal sinus is left as dead space or filled with free adipose tissue.5–7

Pericranial (PC) flaps based on the supraorbital and supratrochlear vasculature have previously been used with significant success for separation of intracranial and extracranial spaces after major reconstructive efforts in the head, neck, and anterior skull base.6,9 More recently, reports advocating the use of the PC flap for advanced frontal sinus operations have surfaced, although these descriptions have focused almost exclusively on the use of the PC flap in obliteration of the frontal sinus.10–13 Although frontal sinus obliteration also requires the removal of sinus mucosa and separation from the nasal vault, protection of the exposed intracranial contents is a critical issue encountered only during cranialization.

We hypothesized that the use of the PC flap in frontal sinus cranialization would enhance the safety and efficacy of this procedure. The purpose of this study was to describe our experience with the PC flap in cranialization of the frontal sinus.
MATERIALS AND METHODS

Patients who underwent bilateral cranialization of the frontal sinus using the PC flap technique at our institution were identified through a search of the institutional database by Current Procedural Terminology code for the years 2000 to 2005. Patient charts were retrospectively reviewed for demographics, indications for cranialization, details of the surgical procedure, intraoperative and postoperative complications, and surgical outcomes.

Operative Technique

All procedures were performed using a two-team approach by otolaryngology and neurosurgery. With use of a standard bicoronal incision, a conventional skin flap is dissected anteriorly in the subgaleal plane to the level of the supraorbital orbital rims to adequately expose the frontal bone. Once the anteriorly based PC flap is designed, its borders are incised sharply using the superior temporal lines as lateral limits of dissection. The posterior edge of the flap is incised in the region of the vertex to provide adequate flap length. As displayed in Figure 1, the flap is then gently elevated from the underlying calvarium using a periosteal elevator from posterior to anterior. A frontal craniotomy extending into the superior portion of the frontal sinus is then performed, which permits exposure of the posterior table of the frontal sinus as well as the sinus interior. The dura, intracranial contents, and posterior frontal sinus table are closely examined for injury. Necrotic tissue and foreign material are debrided. With use of a drill or rongeur, the disrupted posterior wall of the frontal sinus is then completely taken down, flush with to the floor of the anterior cranial fossa. Bony septations within the sinus are also removed. Next, the mucosa of the frontal sinus is meticulously removed, and the interior of the sinus is carefully drilled (Fig. 2). The mucosa at the frontal sinus ostium is inverted and pushed inferiorly into the nasal cavity, and the superior region of the frontal sinus outflow tract (previously referred to as the nasofrontal duct) is plugged with temporoparietal fascia or muscle and secured with fibrin glue. Any defects of the anterior table of the frontal bone and the frontal lobe dura are repaired.

After the mucosa is entirely removed and the communication with the sinonasal cavity has been abolished, the PC flap is draped over the denuded frontal sinus anterior wall and floor as well as over the exposed anterior cranial fossa floor to cover any bony defects. Once the flap is tucked posteriorly under the inferior aspect of the retracted frontal lobes, we then reflect it superiorly so that it rests on the anterior frontal lobe dura mater (Fig. 3). This folding of the flap on itself provides an additional layer of flap coverage between the frontal lobe dura and the damaged anterior frontal bone. The flap is secured into place using dural tacking sutures and fibrin glue. As the frontal bone is placed back to its native position, the anterior region of the craniotomy is drilled down (approximately 3 mm) to ensure that its edges are smooth and there is no impingement on the PC flap, which enters the intracranial cavity at this site (Fig. 4). Finally, the skin wound is closed in a multilayered fashion over a closed-suction drain if desired.

RESULTS

Nineteen patients underwent frontal sinus cranialization using the PC flap technique at our institution.
during the past 5 years. Patients ranged in age from 19 to 65 years, with an average 36.4 years. Mean follow-up was over 15 (range, 9–55) months. The large majority of patients were men (84%). Cranialization was performed in the setting of significant disruption of the posterior table of the frontal sinus, which was largely caused by extensive facial trauma in our population (15 of 19 patients, 79%). The mechanism of injury was usually motor vehicle crashes (53% of trauma cases), followed by blunt force from a variety of objects (40%). In addition to posterior frontal sinus wall injuries, 13 of 15 (87%) trauma patients also had significant disruption of their anterior frontal sinus tables, which required operative management, usually in the form of reduction and internal fixation of fractures. Other indications for cranialization, shown in Table I, included large frontal sinus mucoceles (10.5%), frontal sinusitis causing osteomyelitis with posterior table erosion (5.3%), and frontal sinus involvement by a dural arteriovenous malformation (5.3%).

Operative time averaged 5.6 (range, 3–10.5) hours. Although most operative procedures were limited to cranialization of the frontal sinus and repair of anterior table fractures, several patients underwent a variety of associated procedures at the same operative setting including orbital exenteration (for ruptured globe), ethmoidectomy, reduction and fixation of additional facial fractures, and resection of a dural arteriovenous malformation (Table I). Rents in the dura mater were identified and repaired in 10 of 15 (67%) trauma patients. Postoperative length of hospital stay varied widely from 3 to 70 days, with 13.1 days as the average.

There were no intraoperative complications, and no perioperative infections were noted. Postoperative cerebrospinal fluid (CSF) rhinorrhea was encountered in one patient (representing 6.7% of trauma patients and 5.2% of the total study population), who had extensive skull base fractures. This young male patient sustained severe injuries when he was involved in a high-speed collision while riding a motorcycle without a helmet. At the time of his frontal sinus cranialization surgery, numerous anterior skull base defects were noted and covered with the PC flap. However, postoperatively, the patient developed a CSF leak that did not respond to conservative therapy, including a lumbar drain, and the patient was therefore taken back to the operating room 3 weeks later for endoscopic repair. At the second procedure, two areas suspicious for CSF leak and bony dehiscence within the lateral wall of the right sphenoid sinus were identified and successfully repaired endoscopically.

**DISCUSSION**

This series, the largest in the North American literature, supports the PC flap technique as a safe and effective method for cranialization of the frontal sinus. The PC flap is a pedicled myofascial flap that consists of scalp periosteum and the overlying loose connective (areolar) tissue. The flap is well vascularized, receiving contributions from the supraorbital, supratrochlear, and superficial temporal vessels. This rich vascularity allows for versatility in design: the flap may be unilateral or bilateral, and it can be based either anteriorly or laterally. The PC flap can be harvested easily and quickly, and its use in frontal sinus surgery obviates the morbidity of another donor site because it is already within the surgical field.

Most reports describe flap elevation after a traditional bicoronal incision, although other routes of access may include pretrichial, trichophytic, through preexisting lacerations, and even the midforehead approach for shorter flaps. The method of harvesting the flap also varies by report because the initial elevation may be subperiosteal, after which the pericranium is dissected from the scalp skin, or elevation may begin in the subgaleal plane, to be followed by elevation of the pericranium from the cranial bone. We prefer to elevate the flap in the subgaleal plane through a bicoronal incision because the flap is more easily designed and dissected from

**TABLE I.**

<table>
<thead>
<tr>
<th>Associated Procedures</th>
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<tbody>
<tr>
<td>Orbital exenteration (1 of 8 pts), ORIF nonfrontal facial fractures (2 of 8)</td>
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<tr>
<td>Drainage epidural abscess and ethmoidectomy (1 of 2)</td>
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<tr>
<td>Drainage of subdural abscess</td>
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<td>Resection of dural AVM</td>
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MVC = motor vehicle collision; ORIF = open reduction, internal fixation; GSW = gunshot wound; AVM = arteriovenous malformations.
the stable platform of the calvarium as opposed to dissection from a mobile, previously elevated scalp.

A key element in advocating this flap for the cranialization procedure is that it provides an additional layer of protection for the intracranial contents by using vascularized tissue. We believe that in this particular patient population, the importance of this cannot be overstated. As demonstrated by our study and others, the large majority of individuals requiring this procedure have suffered extensive frontal trauma, which routinely results in significant injury to the anterior frontal sinus wall and forehead skin as well as to the posterior sinus wall. As a function of the cranialization procedure, the already damaged (and often contaminated) anterior table is then drilled from the inside, potentially resulting in further devitalization. In addition to providing coverage of the frontal lobes and separating the intracranial cavity from the sinonasal tract below, the PC flap also importantly reinforces these damaged anterior structures and further separates them from the intracranial contents. The recruitment of healthy vascularized tissue into this heavily traumatized area may also enhance healing. By folding the flap on itself using the technique described, a “double layer” of protection of vital neurologic structures can easily be achieved. The presence of a PC flap applied to the dura and floor of the cranialized cavity may also confer an advantage over the longer term, during which mucocele formation may occur. Believed to arise because of the incomplete exenteration of sinus mucosa, the development of a mucocele is a significant complication that may occur 10 years or more after frontal sinus cranialization. Theoretically, an extra barrier of tissue may provide the brain and neurologic structures some element of protection from an expanding mucocele.

Patients surviving extensive head trauma often have unique and devastating injuries, which makes comparison of complication rates somewhat problematic. The major complication rate of 5.2% in this series of 19 frontal sinus cranializations (6.7% for trauma patients, specifically) is consistent with other published series. The one postoperative CSF leak we encountered, however, was subsequently identified to be originating in the lateral sphenoid sinus and not the anterior skull base. This complication, therefore, does not represent a failure of the PC flap technique, which, even in this patient, did well to prevent any CSF leakage from the heavily damaged anterior cranial fossa region that was actually covered by the flap. It should be further noted that, unlike other reports, we did not encounter any perioperative infectious complications. Congruent with the findings of the study by Gerbino et al., we suspect that the reduction in postoperative infections may be attributed to the use of the PC flap during the cranialization procedure.

The ideal technique for cranialization of the frontal sinus and the role of the PC flap in this operation has yet to be established. Larger-scale efforts with long-term patient follow-up are needed to further clarify the advantages of this method. The use of the PC flap, especially in the setting of extensive frontal trauma, may reduce the risk of CSF leak and perioperative infections and augment the results of the cranialization procedure.

CONCLUSIONS

The PC flap is easily harvested and versatile. Using this vascularized tissue during cranialization affords added protection by providing an extra barrier between the intracranial cavity and the frontal bone and sinonasal tract. This technique is inexpensive, safe, and effective and should be considered when cranialization of the frontal sinus is performed.

BIBLIOGRAPHY