Cerebrospinal fluid fistula prevention and treatment following frontal sinus fractures: a review of initial management and outcomes

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Frontal sinus fractures are heterogeneous, and management of these fractures is often modified based on injury pattern and institutional experience. The optimal initial treatment of frontal sinus fractures is controversial. Treatment strategies are aimed at correcting cosmetic deformity, as well as at preventing delayed complications, including CSF fistulas, mucocele formation, and infection. Existing treatment options include observation, reconstruction, obliteration, cranialization, or a combination thereof. Modalities for treatment encompass both open surgical approaches and endoscopic techniques. In the absence of Class I data, the authors review the existing literature related to treatment strategies of frontal sinus fractures, particularly as they relate to CSF fistulas, to provide recommendations based on the best available evidence.

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Key Words • trauma • cranialization • frontal sinus • cerebrospinal fluid • endoscopic • obliteration • outflow

Frontal sinus fractures result after 5%–12% of all severe facial traumas.13 Understanding of this injury begins with realizing its mechanism; the force needed to produce this type of fracture is significant, ranging from 800 to 1600 pounds.13 Intracranial injury is frequently present, but in a large number of cases, injury is limited to the skull alone. Frontal sinus fractures are classically grouped into 1 of 3 categories based on fracture pattern: involvement of the 1) anterior table only, 2) posterior table only, or 3) both the anterior and posterior tables. Further categorization relates to the presence or absence of nasofrontal tract obstruction. This obstruction can be caused by the initial injury or as a consequence of subsequent operative intervention.13 Nasofrontal tract obstruction leads to mucociliary stasis, which predisposes the patient to mucocele formation, headache, and infection.

A major comorbidity that can arise from frontal sinus fractures is the presence of a CSF fistula. In fact, 80% of all CSF fistulas are directly related to cranial fractures following head injuries.30 While it has been reported that there is resolution of these fistulas with nonoperative management in as many as 66% of cases within 1 month, any communication between the nasal sinus contents, the external environment, and the intracranial/intracranial compartment represents a risk for the development of life-threatening infection.7,30

Diagnosis

The diagnostic workup for patients with significant facial trauma includes a myriad of imaging techniques that vary depending on the mechanism of injury and clinical suspicion. For patients injured as a result of severe blunt trauma that experience an alteration in consciousness, a noncontrast head CT scan is the imaging modality of choice. This technique provides an excellent investigation of the brain parenchyma to evaluate for the presence of intracranial hemorrhage and contusion. Additionally, these high-resolution examinations allow for quality inspection of the bone structures of the face and frontal sinus. Postprocessing 3D reconstruction can be performed by either the surgeon or radiologist, to further aid in diagnosis or surgical planning. If a CSF leak is suspected in the setting of rhinorrhea or otorrhea, a fluid sample can be sent for β-2 transferrin analysis.30 In cases of suspected persistent occult CSF fistulas, radionuclide cisternography, CT myelography, MR phase-contrast cisternography and 3D CISS sequences, and intrathecal administration of fluorescein can aid in diagnosis.1,13,21,26
Management Strategies

Ultimately, with frontal sinus fractures, the goal of initial management is to correct the cosmetic deformity while anticipating and preventing the development of immediate and late-term morbidities related to infection and CSF fistulas. It is also the responsibility of the treating surgeon to avoid unnecessary interventions when they have no proven benefit. The risk of morbidity related to any procedure to treat frontal sinus fractures must be weighed against the anticipated morbidity of declining or delaying intervention.

Treatment options include observation, reconstruction, obliteration, cranialization, or a combination thereof. The optimal management of frontal sinus fractures is controversial and varies between providers and institutions. The need for complex surgical procedures involving obliteration or cranialization is based on the extent of involvement of the anterior wall, posterior wall, and nasofrontal tract injury, in addition to the presence of a CSF fistula. Commonly, if posterior table involvement is present, especially with any CSF fistula suspected to be related to the fracture, aggressive surgical intervention is commonplace. This aggressive intervention involves obliteration and cranialization of the frontal sinus. In the obliteration portion, all of the sinus contents and mucosa are removed via a bifrontal craniotomy with a combination of a high-speed drill and bipolar electrocautery. Frequently, an alternative substance is used to replace the space that is created. Frontal sinus obliteration can be performed using Gelfoam, bone chips, adipose tissue (autograft), temporalis fascia, pericranium, bioglass, polytetrafluoroethylene/carbon fiber, calcium sulfate, methylmethacrylate, oxidized cellulose, hydroxyapatite, or lyophilized cartilage. The cranialization aspect of the procedure specifically relates to the elimination of the entire posterior wall, and the brain contents are allowed to fill the sinus space. Typically, a vascularized pedicled pericranial flap is procured and sutured to the inferior anterior skull base, forming a watertight seal between the brain and remnant of the frontal sinus. Alternative techniques include the use of allograft dural substitute material. Depending on surgeon preference, along with the possible need for intracranial pressure monitoring related to traumatic brain injury, CSF diversion is employed at the time of initial operation or subsequently at the development of CSF fistulas. This can be performed using either a ventriculostomy, a lumbar drain, or serial lumbar CSF taps. These techniques are not universally used at the time of initial operation, but sometimes are employed when the assessment of the integrity of repair dictates an additional maneuver to improve the chances of success. There is no study comparing one method of CSF diversion to another or assessing whether its routine use prevents delayed CSF leakage. If a CSF fistula develops in the acute postoperative period, either as evidenced by otorrhea or rhinorrhea, then CSF diversion is used for a period of several days in an attempt to remove any pressure from the operative bed. This maneuver allows tissues to heal and prevents further CSF leakage. Reoperation always exists as a treatment option, but the potential morbidity associated with reoperation should be taken into consideration.

Because frontal sinus fractures encompass such a heterogeneous injury pattern, prospective, randomized trials regarding the optimal management of frontal sinus fractures do not exist and we rely on the reports from the vast experience of several high-volume centers. In this paper, we review the major patient series reporting on the management of frontal sinus fractures, with an emphasis on the concurrent treatment or avoidance of CSF fistulas.

Methods

This literature review was exempt from Institutional Review Board approval. Data for this review were identified by searches of MEDLINE, Google Scholar, and PubMed for references from relevant articles using the search terms “frontal sinus” and “fracture.” Only articles published in English between 1970 and 2011 were included. Only studies with adequate descriptions of patient injury and management characteristics were included. For example, to be included in this review, a study must have at least described the frontal sinus fracture pattern, specific treatment rendered, and outcome.

Results

Thirteen studies were identified as meeting search criteria and were applicable for review (Fig. 1). There were no prospective, randomized trials identified; all data available were either Class II or Class III evidence. Patient series were reported of variable sizes (range 26–857 patients). Patient management consisted of the expected spectrum, ranging from observation to cranialization and obliteration of the frontal sinus. Antibiotic administration was inconsistently reported and variably prescribed. The timing of surgery, when undertaken, was also variable and inconsistently reported, with most series reporting an average time interval between 3 days and several weeks.

In a large series reported by Rodriguez et al., 857 patients with frontal sinus fractures were managed using either observation or surgery. Their treatment algorithm evaluated each injury based on whether there was nasofrontal tract obstruction, a fracture of the frontal sinus floor, and/or a fracture to the medial wall of the anterior table. Of the 857 patients, 504 were treated with surgery and 353 were observed. Obliteration, cranialization, fat obliteration, and osteoneogenesis, in varying combinations, were the 4 surgical techniques performed on the operative patients. The exact approach used was decided upon by evaluating the fracture type, degree of posterior table fracture, extent of nasofrontal tract injury, neurologic status, and presence or absence of a CSF fistula. In patients with nasofrontal tract obstruction, obliteration and cranialization had complication rates of approximately 9%. Importantly, in patients managed nonoperatively (those without evidence of nasofrontal tract obstruction), only 1 patient developed a complication. This 26-year experience provides some of the most authoritative data that following a management algorithm with nasofrontal tract outflow at its epicenter allows for excellent outcomes. These investigators concluded that frontal sinus fractures without evidence of nasofrontal outflow obstruction can be managed safely with observation alone.
Fig. 1. Schematic representing the treatment modalities of patients with frontal sinus fractures.
In another study, Liu et al.14 treated 132 patients with cases of CSF rhinorrhea (the majority of which were related to trauma) surgically, via either an endoscopic endonasal approach or a craniotomy. These authors had excellent success using an algorithm of endoscopic endonasal surgery for repair of sphenoid or ethmoid bone defects, and craniotomy for frontal sinus fractures, multiple fractures of the skull base, or when cranial nerve injury was present. After the initial operation, 124 of the patients experienced durable resolution of their CSF fistulas at an average follow-up duration of 10 months. For 8 patients with persistent or recurrent CSF fistulas, revision surgery was successful in 6 patients and the remaining 2 CSF fistulas resolved spontaneously. It should also be noted that the authors used prophylactic antibiotics in every patient, and there were no cases of serious infection.

Another similar modern series, reported by Scholsem et al.,22 further documents the effectiveness of a standardized treatment algorithm in the management of CSF fistulas associated with anterior skull base fracture. In 209 patients with anterior cranial base fractures complicated by a CSF fistula, the majority of patients were initially treated nonoperatively for 1 week to allow for the possibility of spontaneous healing. Then, if CSF fistulas persisted, a combined extradural and intradural closure of the tear was performed via craniotomy (in 109 patients). These investigators achieved a greater than 90% success rate following the initial procedure. However, there was no comparative analysis provided with those patients managed conservatively or endoscopically. Highlighting treatment heterogeneity, patients in this series were not administered antibiotics postoperatively, and CSF diversion was performed in the form of a daily lumbar CSF tap (30 ml/day) for 5 days postoperatively.

With frontal sinus fractures, operative nuances exist, in addition to differences in management algorithms that should be recognized. In a series reported by Gerbino et al.,7 158 patients were treated based on the location of the fracture, presence of CSF fistulas, and degree of bone displacement. Thirty-nine of the patients were observed, and the remainder underwent relatively urgent treatment (within 12–24 hours after injury) with open reduction/internal fixation and pericranial flap cranialization via a bifrontal craniotomy, nasofrontal tract cannulation, or a combination of the two. For those patients with drainage tubes, the tubes were left in place between 30 and 40 days. The CSF fistulas were eliminated using the pericranial flap technique in the 39 patients that had preoperative leakage. The success of this experience provides evidence for the argument that it is effective to preserve sinus function by reestablishing the patency of the nasofrontal tract when posterior table involvement is not present.

The concept of sinus preservation is further highlighted by a patient series reported by Bell et al.,7 in which a protocol was used to manage a variety of frontal sinus fractures. In a series of 50 surgical patients, if posterior table involvement was present, these patients were treated using either an obliteration or cranialization procedure. If the posterior table was intact and the nasofrontal tract was not, then only an obliteration procedure was performed with repair of the anterior table. Otherwise, cranialization and obliteration operations were reserved only for cases of persistent CSF fistulas. Data from additional smaller patient series are consistent with these general principles; that is, disruption of the posterior table, CSF fistulas, and nasofrontal tract obstruction all indicate a need for obliteration and cranialization.5,8,10–12,20,24,27

**Illustrative Cases**

**Case 1**

This 63-year-old man presented to the emergency department after falling 15 feet off of a ladder. He had a loss of consciousness for an unknown period of time and obvious external signs of head injury, so a head CT scan was performed. He was found to have extensive facial fractures in addition to frontal sinus fractures. There was no obvious otorrhea or rhinorrhea. Imaging revealed a left frontal bone fracture extending through both the inner and outer tables of the frontal sinus (Fig. 2). There was evidence of nasofrontal tract obstruction. The patient underwent a bifrontal craniotomy for frontal sinus obliteration and cranialization, with the use of abdominal fat and a pericranial graft (Fig. 3). Postoperatively he recovered well. At 3-month follow-up he has no signs or symptoms of infection and his wound is healed with an excellent cosmetic result. He has no evidence of CSF leak or mucocele formation. Long-term follow-up is scheduled to monitor for delayed complications of his injury. This case highlights the need for sinus obliteration and cranialization when there is nasofrontal tract obstruction and significant posterior table disruption.

**Case 2**

This 52-year-old man was involved in a motor vehicle collision and was ejected from his vehicle. He was brought to the emergency department by paramedics with an obvious, open injury to his frontal sinus and multiple facial fractures (Fig. 4). He was comatose upon arrival...
and his neurological examination was unreliable because of the administration of medications given to facilitate transport. Imaging revealed a complex fracture of the right frontal sinus. Additionally, he had a right frontal lobe contusion. He was quickly taken to the operating room to explore his globe, cranial nerves, and frontal sinus fracture and to decompress his frontal lobe. A bicoronal incision was made and allowed for the creation of a bifrontal craniectomy, through which a partial frontal lobectomy was performed in addition to debridement of the retropulsed, fractured bone. His lacerations were then debrided and closed and a contralateral, frontal approach ventriculostomy was performed (Fig. 5). Postoperatively, he developed a CSF fistula out of his right eye that resolved with further aggressive ventriculostomy drainage. He was able to tolerate weaning and removal of the ventriculostomy with no further evidence of CSF leak. As his condition stabilized over the course of several weeks, he was taken to the operating room again for cranioplasty, along with cranialization and obliteration of his remaining frontal sinus. This case highlights the indication for a planned, staged procedure, with immediate wound debridement and CSF fistula avoidance paramount in the acute setting for a critical, unstable patient with multisystem trauma.

Discussion

Mismanaged frontal sinus fractures can lead to serious and long-lasting sequelae. Complications can be fatal and include wound infection, brain abscess, meningitis, recurrent sinusitis, osteomyelitis, mucocele, CSF fistulas, cosmetic deformity, headache, and cranial nerve injury.8–11,19,22,24,25 An evidenced-based approach to the management algorithm for these fractures is imperative for optimal patient outcome.

In this review of the available literature, the mechanism of injury had a distribution that was similar in all studies, with motor vehicle accidents being the most common. Other inciting agents that were similar among the studies include falls, assaults, occupational injuries, sports injuries, and gun shot wounds.8,10,24 Computed tomography scans were nearly universally obtained in all patients to evaluate the extent of injury. All frontal sinus fractures should prompt investigation of suspected brain injury (if not already undertaken), given the proximity of the sinus to the brain.
the brain parenchyma and the mechanism of injury. Penetrating injuries through the posterior table are implied to be contaminated and violate the dura; this should be factored into operative planning. Additionally, with penetrating lesions or with grossly comminuted fractures, imaging of the cerebrovasculature for injury should be undertaken. Because the anterior skull-base bone and penetrating objects produce significant CT artifact, we routinely perform dual-energy CT angiograms to improve the visualization of the cerebral blood vessels in these instances, similar to techniques previously described.15,38 This method provides a rapid, noninvasive evaluation that improves the resolution and accuracy of diagnosis in these traumatic lesions (Massachusetts General Hospital institutional experience; not yet published).

An accurate initial diagnosis is the key factor in the successful management of patients with frontal sinus fractures.13,28 The goals of preoperative imaging are to determine 1) if anterior table, posterior table, or both are involved; 2) whether there is any significant displacement; 3) if there is nasofrontal tract obstruction; 4) whether there is significant brain or cerebrovascular injury; and 5) if the dura could have been violated. The best imaging technique available to visualize the nasofrontal outflow tract is a high-resolution, thin-slice CT scan.13 Three-dimensional reconstruction can be performed on a variety of software platforms to gain a better understanding of the patient’s anatomy. Even with the best noninvasive imaging, errors can occur. Discrepancies with imaging have been discovered at the time of surgery with direct visualization.18

In addition to imaging, diagnosis includes the determination of CSF fistula formation.28 It is important to recognize that if the nasofrontal tract is obstructed, dural lesions can be present without CSF rhinorrhea.20 In an alert patient, it is important to query for the sensation of liquid draining from the nose, or a “post-nasal drip” complaint.28 While 1 study recommended waiting 1 week after trauma to perform surgery because it allows some time for conservative treatment and possible spontaneous healing of CSF fistulas, there is an 8- to 10-fold increased risk of developing meningitis if a CSF fistula is present for more than 7–10 days.4 The time interval to treatment in the reviewed series varied widely, ranging from immediate operative repair in the case of severe brain injuries to more than a week. Most interventions were performed approximately 3 days after injury.6,13 and no patient series supported standardized urgent or emergency repair.22,23

The goals of all treatments for frontal sinus fractures in these series were to protect intracranial structures, prevent complications, and correct any cosmetic deformities. Treatment options included the following: 1) observation, 2) sinus reconstruction with preservation of sinus membrane, 3) sinus reconstruction with obliteration, and 4) sinus reconstruction with cranialization.3 Fat, muscle, and bone were the most commonly reported materials used during obliteration and cranialization procedures. One patient series in particular28 recommended using allogenic lyophilized cartilage, which has been used for frontal sinus trauma since 1987 due to its ability to ossify and resist resorption. Another observation from these series can be made, which is that correction of nasofrontal tract obstruction can be successfully performed in selected patient populations (sinus preserving) in contrast to sinus obliteration procedures.9 There are no head-to-head comparisons of these 2 techniques, nor do we anticipate that any will be performed in the future. What is generally agreed upon, though, is that the consequences of nasofrontal tract obstruction necessitate treatment. If radiographic interpretation is indeterminate and the patient undergoes a craniotomy, assessment of patency of the nasofrontal tract can be unreliable due to traumatic mucosal edema. Techniques to test intranasal drainage such as gentle probing of the outflow tract or methylene blue dye administration should be performed.8,13

Endoscopic, endonasal, and transcranial techniques are the two general surgical approaches for frontal sinus fractures.13 When managing CSF fistulas in relation to frontal sinus fractures, data support that an endonasal approach can be used only if the lesion is small and precisely localized.22,27 Due to the complex nature of these lesions, an intracranial approach is recommended in most instances to allow for adequate evaluation and exploration.14,22,27 Liu et al.14 even recommends against intranasal procedures for frontal sinus fractures with CSF fistulas, because of the potential risk of iatrogenic nasofrontal tract obstruction.

Perhaps the item of greatest variability in the management of patients with frontal sinus fractures is the use of prophylactic antibiotics. This issue is controversial because, while prophylactic antibiotics are used to prevent infections, they also present the risk of infection with opportunistic pathogens.14 They may also alter the physiological nasopharyngeal flora and eliminate the reliability of microbiological analysis of CSF samples when meningitis is suspected.22 Practice pattern varied greatly in the reviewed series: while Liu et al.14 used prophylactic antibiotics in all patients and found no cases of sinusitis were reported. Other series, such as that reported by Scholsem et al.,35 did not use antibiotic prophylaxis, and this study reported 5 cases of meningitis postoperatively. The efficacy of antibiotics is difficult to study given the heterogeneity in injury pattern, patient characteristics, and study designs.

Conclusions

There appears to be multiple instances of Class II and III evidence that frontal sinus cranialization is an effective treatment of fractures when a CSF fistula is present, and obliteration is useful for nasofrontal tract outflow involvement. There appears to be no definitive evidence regarding the timing of surgery related to complication rates. There also appears to be no evidence that a CSF fistula is prevented with one type of surgery versus another; the vast majority of patient series report an algorithm that utilizes frontal sinus cranialization in these cases. No definitive evidence supports prophylactic antibiotic use. Further prospective, randomized trials and experiences from high-volume trauma centers will prove useful in determining the most efficacious means to manage this heterogeneous entity.
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Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper. Author contributions to the study and manuscript preparation include the following: conception and design: Walcott, Coumans, Nahed. Acquisition of data: Walcott, Castro. Analysis and interpretation of data: Walcott, Castro. Drafting the article: Walcott, Castro, Nahed. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Walcott. Study supervision: Walcott, Coumans.

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