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Original Article

Surgical management of traumatic frontal sinus fractures: Case series from a single institution and literature review

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Abstract

Background: Neurosurgeons are frequently involved in the management of patients with traumatic frontal sinus injury; however, management options and operative techniques can vary significantly. In this study, the authors review the current literature and retrospectively review the clinical series at a single tertiary referral center.

Methods: After Institutional Review Board approval, the medical records and computed tomographic (CT) imaging of patients whose traumatic frontal sinus fractures were treated surgically at the University of Utah were retrospectively reviewed. Demographic information, mechanism of injury, associated injuries, operative technique, and pattern of injury on CT were analyzed.

Results: Between 2000 and 2012, 33 patients underwent successful cranialization of the frontal sinus following traumatic injury. The material used to obliterate the sinus varied. No patients required immediate or delayed reoperation. Nasofrontal outflow tract obstruction, the importance of which has been emphasized in the plastic surgery literature, was apparent on either initial or retrospective review of the available CT imaging in 96%.

Conclusions: In this series, we successfully surgically treated 33 patients with frontal sinus fractures. The presence of cerebrospinal fluid leak, nasofrontal outflow tract injury, associated depressed skull fractures, and subsequent formation of communicating pathways and infection must be considered when constructing a treatment plan. The goals of treatment should be: (i) surgical repair of the defect and elimination of the conduit from the intracranial space to the outside and (ii) elimination of any cerebrospinal fluid pressure gradient that may develop across the surgical repair. We present a treatment algorithm focusing on the presence of nasofrontal outflow tract injury/obstruction, cosmetic deformity, and cerebrospinal fluid leak.

Key Words: Cranialization, frontal sinus, nasofrontal outflow tract, pericranial flap, trauma

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INTRODUCTION

In trauma patients, frontal sinus fractures are common and account for 5–15% of all facial fractures. The most common cause of frontal sinus fractures is high-velocity blunt force trauma.[8,21,23-25,34] The management of frontal sinus fractures varies among specialties. Neurosurgical complications may present acutely or may have a delayed presentation. In the acute period, the main concern is cerebrospinal fluid (CSF) leakage, with risk of subsequent seeding of infection and progression to meningitis or cerebritis. Delayed complications include brain abscess and mucocele formation. Mucocele formation, which may result from obstruction of the frontal sinus egress or direct trauma to the frontal sinus mucosa, may progress to a mucopyocele.[13]

Risk factors for postinjury complications have been analyzed in the plastic surgery literature. A large emphasis is placed on the presence or absence of nasofrontal outflow tract (NFOT) obstruction to determine whether surgical management should be undertaken [Figure 1]. Although Rodriguez *et al.*[22] proposed a treatment algorithm based on their extensive series, treatment decisions are ultimately based on a multitude of factors, including fracture type, degree of posterior table fracture, nasofrontal duct injury, neurological status and concomitant head trauma, and the presence of CSF leak.[4,8,15,17,24,25,28,34,35]

We review the current literature and present a series of patients who underwent surgical repair for frontal sinus fractures from a single institution, propose a treatment algorithm to aid in the surgical management and treatment of these patients, and discuss techniques of cranialization of the frontal sinus, which involves complete removal of the posterior wall of the frontal sinus flush to the anterior skull base, complete removal of frontal sinus mucosa, and plugging of the nasofrontal ducts.

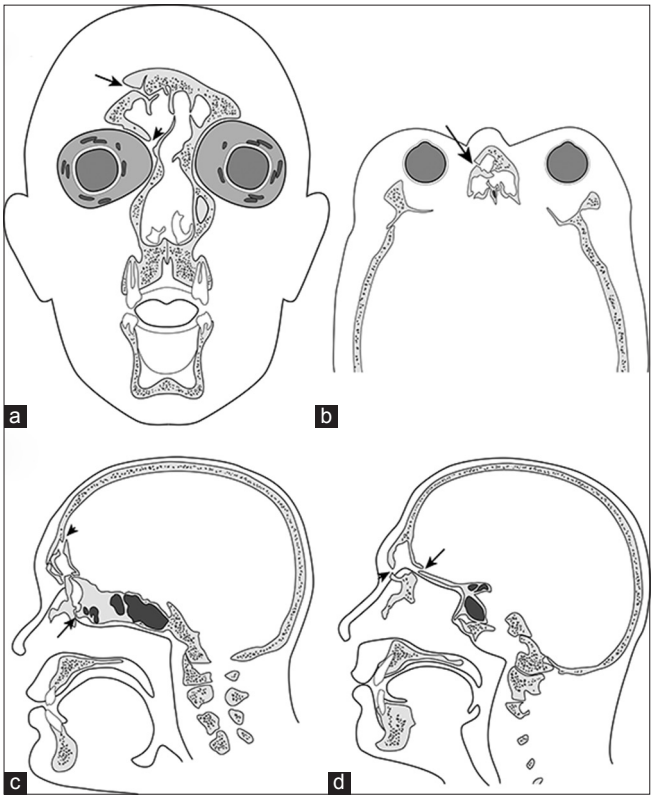

Figure 1: (a) Coronal illustration demonstrating a mildly displaced comminuted fracture of the right frontal sinus. The fracture involves the superior frontal sinus (arrow), and the displaced fracture fragment mildly narrows the egress of the right frontal sinus (arrowhead). (b) Axial drawing illustrating the typical nasofrontoethmoidal complex fracture involving the frontoethmoidal recess (arrow). (c) Sagittal drawing depicting displaced comminuted fractures of the frontal and anterior ethmoid sinuses (arrowhead), obstructing the drainage pathway of the frontal sinus (arrow). (d) Sagittal illustration showing a complex fracture of the frontal sinus involving the inner (arrow) and outer (arrowhead) tables.The type of injury increases the risk for cerebrospinal fluid leak and intracranial infection

MATERIALS AND METHODS

After receiving Institutional Review Board approval, we queried our neurosurgical operative database to identify adult patients who had undergone surgical repair for frontal sinus fractures from 2000 to 2012. Patients who underwent frontal sinus repair secondary to nontraumatic injuries and patients treated nonsurgically were excluded from the series.

Hospital charts were reviewed to evaluate patient demographics, mechanism of injury, presence of CSF leak, number of days until operative intervention, and associated injuries. Imaging studies and radiology reports were reviewed and retrospectively reexamined to evaluate for NFOT obstruction. Operative reports were used to determine the presence of CSF leak, type of operative intervention performed, and material used to cranialize the sinus.

RESULTS

We identified 33 patients who underwent operative repair of frontal sinus fractures during the study period [Table 1].

Table 1: Mechanism of injury for 33 patients treated surgically for frontal sinus fractures

Mechanism of injury	Number of patients (%)
Assault, accidental blunt force trauma	13 (39)
Motor vehicle accident	7 (21)
Motorcycle accident	4 (12)
All-terrain vehicle accident	3 (9)
Self-inflicted gun shot wound	2 (6)
Fall from height	2 (6)
Plane crash	1 (3)
High-speed bicycle crash	1 (3)

Of the patients in this series, 31/33 (94%) were male, and the mean age was 33.9 ± 11 years (range 15–62 years). Thirty-one patients were admitted as trauma patients; two patients presented as outpatients several years after their injury.

The most common mechanism of injury was blunt force trauma [Table 1]. Fourteen (42%) patients were injured in accidents involving motorized vehicles. Thirteen (39%) patients were assaulted or suffered accidental direct blunt force trauma to the head and face. The remaining six patients were injured by a variety of mechanisms.

Eight (24%) patients had a CSF leak at their initial presentation, which manifested as persistent CSF rhinorrhea diagnosed upon history and physical with provocative testing. The initial radiology reports (available for 28 patients) indicated that 1 patient (3%) had NFOT obstruction; however, retrospective review of the available computed tomography (CT) images indicated that 27/28 (96%) demonstrated NFOT obstruction. Twenty-six of the patients had radiographic evidence of fractures through the anterior and posterior tables of the frontal sinus; one patient had a nasoethmoidal fracture with NFOT obstruction; and one patient underwent evacuation of an acute right frontal epidural hematoma with subsequent violation and cranialization of the ipsilateral frontal sinus. The average time to surgery was 4.6 ± 7.8 days after presentation. This time-to-surgery statistic excludes three patients from our series: Two of the patients were undergoing revision surgery after presenting 5 and 15 years after their initial traumatic injury, and one patient was transferred from an outside institution after a 25-day hospitalization period for the acute traumatic event.

All 33 patients underwent cranialization of the frontal sinus after the injury. Of the 26 (78%) patients with radiographic evidence of frontal sinus fractures, 15 had greater than full-width displacement through the sinus and 11 had less than full-width displacement.

The material that was used to pack the sinus and obliterate the nasofrontal duct varied among the 25 patients [Table 2] for whom the information was available. The most commonly used material was temporalis muscle harvested prior to the craniotomy (8/25; 32%) or temporalis muscle in combination with bone chips (4/25, 16%). Bone graft was used in 4/25 (16%) patients and harvested pericranial flap in 4/25 (16%). The material that was used to overlay the cranialized sinus was recorded in 28 patients; it was most commonly a pericranial flap with an attached vascular pedicle (24/28, 86%) of the patients [Table 3]. Other grafting materials used were tensor fascia lata in 3/28 (11%) and pericranial graft and AlloDerm in 1/28 (4%).

Table 2: Materials used to pack the sinus in 33 patients who had surgery for frontal sinus fracture

Material	Number of patients (%)
Temporalis muscle	8 (24)
Temporalis muscle with bone chips	4 (12)
Bone graft	4 (12)
Pericranium	4 (12)
Tensor fascia lata	2 (6)
Galeal flap with bone graft	1 (3)
Pericranium with fat	1 (3)
Fat	1 (3)
No material recorded	8 (24)

Table 3: Materials used for sinus overlay in 33 patients who had surgery for frontal sinus fracture

Material	Number of patients (%)
Pericranial flap with vascular pedicle	24 (73)
Tensor fascia lata	3 (9)
Pericranial flap with AlloDerm	1 (3)
No material recorded	5 (15)

Overall, 22/33 (67%) patients had associated intracranial injuries classified radiographically as either intraparenchymal hemorrhage, cerebral contusion, traumatic subarachnoid hemorrhage, epidural hematoma, or subdural hematoma. No patient required immediate reoperation or had delayed abscess or mucocele formation requiring surgery.

Illustrative cases

Case 1

A 17-year-old male presented with multiple stab wounds and extensive facial trauma. A facial CT three-dimensional surface rendering showed the extent of the facial trauma and injury pattern [Figure 2a]; the initial head CT [Figure 2b] showed evidence of bilateral subdural hematomas and right frontal pneumocephalus with an associated fracture through the frontal sinus. CT of the facial bones [Figure 2c] showed not only a fracture through the anterior and posterior tables, but also evidence of NFOT obstruction. The fracture was displaced less than the full width of the frontal sinus. Approximately 5 days after his initial presentation, he underwent a bifrontal craniotomy and cranialization of the frontal sinus with placement of pericranial graft. Postoperative head CT [Figure 2d] shows interval cranialization of the frontal sinus and repair of the fracture.

Case 2

A 25-year-old male suffered a self-inflicted gunshot wound to the face. The bullet had caused massive orbital, facial trauma, including a right frontal sinus

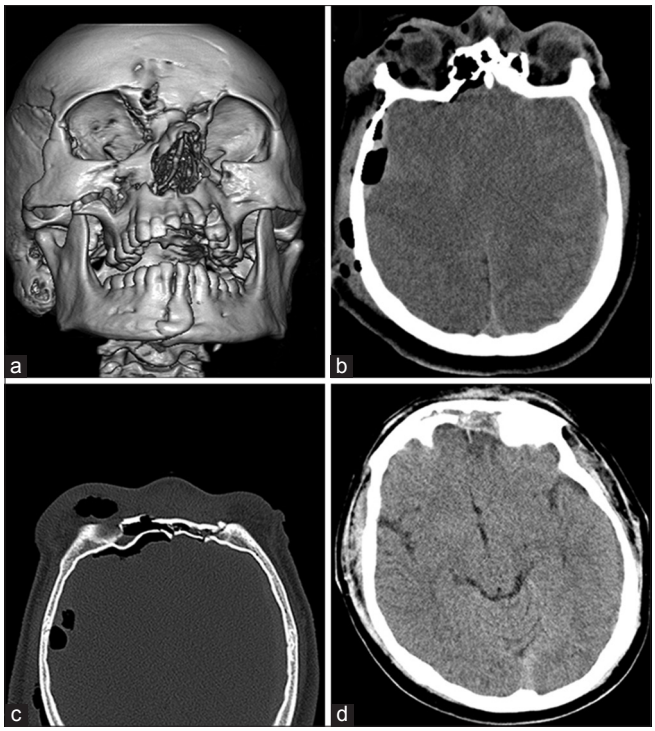

Figure 2: Case 1. (a) Three-dimensional recontruction showing the injury pattern and extensive facial trauma suffered by this 17-year-old male. (b) Axial head computed tomography (CT) scan demonstrating bilateral subdural hematomas with associated cerebral edema and moderate amount of pneumocephalus. (c) Axial CT scan of the facial bones displaying a comminuted fracture through the frontal sinus with disruption of the anterior and posterior tables. The degree of displacement is less than full width. There is associated nasofrontal outflow tract obstruction and moderate right frontal pneumocephalus. (d) Postoperative axial head CT scan demonstrating interval resolution of the subdural fluid collections as well as successful cranialization of the frontal sinus

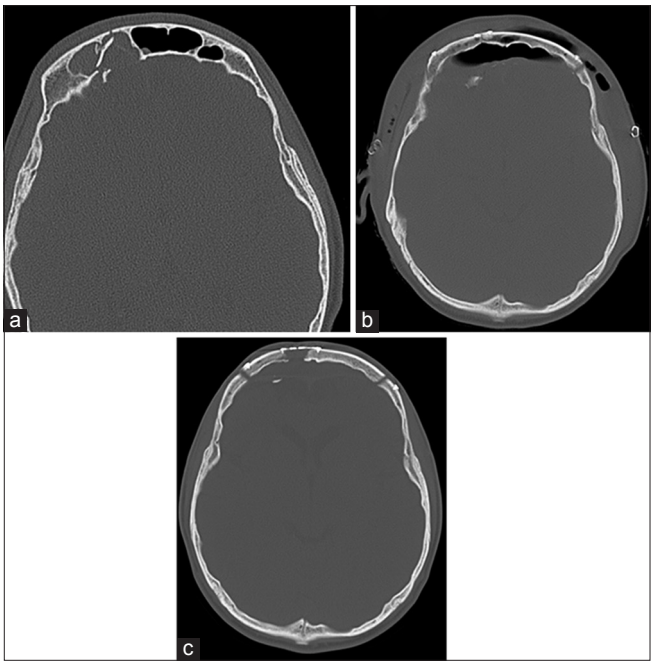

Figure 3: Case 2. (a) Axial head computed tomography (CT) scan with bone windows demonstrating right frontal sinus fracture with near-complete opacification of the frontal sinus; the fracture extended through the anterior and posterior tables and was greater than the full width of the frontal sinus. (b) Postoperative head CT showing successful cranialization of the frontal sinuses and residual pneumocephalus. (c) Follow-up head CT, approximately 1.5 months after surgical intervention, demonstrating good bony healing with significant resolution of the cerebral edema and mass effect

fracture with near-complete opacification of the frontal sinus [Figure 3a]. The fracture extended through both the anterior and posterior tables and was greater than the full width of the frontal sinus with radiographic evidence of NFOT obstruction. The patient had CSF rhinorrhea. Seven days after his presentation, he underwent a bifrontal craniotomy with cranialization of the frontal sinus and placement of a lumbar drain. Postoperative head CT [Figure 3b] showed successful cranialization of the frontal sinuses and residual pneumocephalus. The patient was evaluated 1.5 months after surgery and had no evidence of CSF leak. The follow-up head CT [Figure 3c] displayed postsurgical changes with significant resolution of the cerebral edema and mass effect.

DISCUSSION

Frontal sinus injury is common in patients who have experienced trauma. Various treatment algorithms have been proposed, but there is little neurosurgical literature to guide treatment strategies. Mismanagement of frontal sinus fractures may lead to severe infectious and structural complications.[5,33]

Blunt force trauma is commonly the primary mechanism of injury, which was also true in our series of patients.[9,18,33] This mechanism often involves impact to the cranium including the facial structures, and thus multiple specialities are involved with caring for these patients. The plastic surgery literature has placed an emphasis on evaluation of NFOT involvement as an indicator for operative intervention, citing the rate of subsequent formation of mucocele in these patients as high and potentially avoidable.[22] Although in our series, there was only one patient with NFOT obstruction reported at the time of presentation, review of the imaging by an experienced neuroradiologist showed that 27/28 (96%) of available studies demonstrated NFOT obstruction. Although this was not used as a criterion in this series, given the data of subsequent complications reported in the literature, we now specifically evaluate for NFOT obstruction in patients with frontal sinus fractures. Rodriguez *et al.*[22] reported no complications among 222 patients who lacked NFOT involvement that were treated conservatively; this suggests that careful evaluation of NFOT may be necessary to assign patients to conservative treatment.

We found that 67% of the patients in our series had concomitant intracranial injuries, a common finding in patients with frontal sinus fractures with associated NFOT injury.[22] Other studies have shown a more variable rate of intracranial injury with frontal sinus injury alone (33–77%),[9,19,26,33] likely based on variable mechanisms of injury and inclusion of patients managed without surgery.

Embryology of the frontal sinus and anatomical considerations

Frontal sinus development begins during the fourth or fifth week of gestation and continues through intrauterine growth and the postnatal period and into puberty and even early adulthood.[7] During the 13th week of development, the infundibulum expands superiorly giving rise to the frontonasal recess.[7] The frontal sinus subsequently develops during 16th week as a direct elongation of the infundibulum and frontonasal recess as a result of superior migration of the epithelium of the anterior ethmoidal cells that penetrate the inferiormost aspect of the frontal bone between the two tables.[7]

The primary pneumatization of the frontal bone occurs slowly, with its completion at the end of the first year of life.[7] At this point, the frontal sinus is a small, smooth, blind pocket, and it remains this way until 2 years of age. Secondary pneumatization begins at this point and continues until adolescence.[7] There is vertical pneumatization into the squama of the frontal bone from the anterior ethmoidal air cells. Variations may occur because of independent development of the right and left sinus, with each side undergoing separate reabsorption of bone and separation of air cells.[7] Frontal sinuses may develop asymmetrically, fail to develop, or have unilateral dominance. The location of the air cells in the vertical and lateral directions can be extreme. The ethmoid sinuses are partially constructed by the horizontal portion of the frontal bone; any fracture traversing the frontal bone could involve the ethmoidal complex leading to a higher risk of CSF leakage.

Anatomic variations in frontal sinus anatomy can complicate clinical decision-making. Although aplasia or hypoplasia may confer a protective effect against CSF leak following frontal bone or facial trauma, other congenital anomalies, such as hyperpneumatization, may predispose to additional complications. Careful review of high-resolution CT scanning can help identify aberrant anatomy and identify potential sources of additional concern; this step may be especially important for preoperative surgical planning.

As previously discussed, the presence of NFOT obstruction is paramount in determining appropriate treatment for frontal sinus fractures. The NFOT, the communication between the frontal sinus and the nasal cavity, can be variable; it can exist as an ostium directly communicating with the nasal cavity or as a duct, referred to as the nasofrontal duct. It is important to understand that blunt facial trauma can impair drainage of the frontal sinus distal to the nasal cavity; therefore, understanding the CT and gross anatomy is crucial in correctly triaging these patients. The ostium or duct may be obstructed by direct trauma or secondary swelling to the lateral anterior nasal cavity. If there is swelling, temporary obstruction may lead to a "short-term" outflow obstruction; similarly, if the pathology is more anatomic, "long-term" outflow obstruction may occur. Although thorough clinical evaluation is necessary to determine the presence of CSF leak, use of soft-tissue imaging, either CT or MRI, may be useful in identifying "distal" obstructions that may represent blockage of the NFOT, especially in patients suffering mid-face trauma.

The common embryological and anatomical relationship of the frontal sinus with the ethmoid sinus makes the interplay between these structures quite unique.[7] Given that up to one-half of patients with frontal sinus injuries have associated mid-face fractures[16] and the complex relationship between the anterior nasal bony and soft tissue structures and the frontal sinus, consideration and involvement of multiple specialists may be required to allow for comprehensive assessment of the patient and performance of complete and adequate surgical repair.

Imaging considerations and NFOT anatomy

CT imaging of the face is routine following blunt trauma, especially when there is obvious face and head involvement. Imaging should be used as an adjunct to clinical examination; however, many trauma patients are sedated, intubated, and unable to comply with provocative maneuvers to identify potential CSF leak. CT may not definitively identify violation of the NFOT because of the complex three-dimensional anatomy in this region; additionally, MRI of the face and orbits is rarely used in the acute setting and may be inferior to CT because of the need to evaluate bony structures and prominences clearly. For patients with no intracranial injury and minimal frontal sinus injury not requiring operative repair, CSF leaks may be investigated with high-resolution CT cisternography or endoscopy utilizing intrathecal fluorescein.[16]

The frontal sinus egress is via the NFOT. On CT, particularly with multiplanar reconstructions, this can be localized by following the frontal sinus via a pneumatized channel to the anterior ethmoid air cells. The nasofrontal duct can be identified as the duct-like structure that extends from the frontal sinus to the middle meatus, whose walls are formed by the bordering bony anatomic structures. The narrowest portion of the NFOT is the frontal ostium. The superior portion widens into the frontal sinus and the inferior portion expands into the frontal recess or NFOT. The frontal sinus drains through

the frontonasal opening, which is usually located in the posteromedial aspect of the floor, and the NFOT course is posterior and caudal [Figure 4]. In up to 85% of patients, the NFOT/frontal recess is not a tubular structure but an ostium that drains directly into the middle meatus. It is bordered anteriorly by the agger nasi cell, laterally by the lamina papyracea of the orbit, and medially by the middle turbinate. An ethmoid bulla or suprabullar recess may form the posterior boundary of the NFOT/frontal recess.[10,31]

Longer NFOTs are more susceptible to injury in facial trauma. Obstruction of the NFOT with comminuted fracture fragments can result in scarring and long-term complications including mucocele formation or chronic sinusitis as a result of outflow obstruction.[11,27] In this series, *post-hoc* review of the imaging by an experienced neuroradiologist showed that 27/28 (96%) of available studies demonstrated NFOT obstruction. This most likely represents an initial underdiagnosis, thus we emphasize the evaluation of the NFOT by neurosurgeons and radiologists to aid in the diagnosis.

Surgical technique

For all patients, we performed a bifrontal craniotomy with complete removal of the posterior wall of the frontal sinus culminating with diamond burr drilling flush to the anterior skull base [Figure 5]. This technique involves complete removal of the frontal sinus mucosa and allows for cauterization to any remaining mucosa eliminating any potential space for mucocele formation. For difficult cases, autologous fat graft and vascularized pericranial flap is used in conjunction with primary repair of any dural tear and possible fascia grafting. We hypothesize that there is less resorption of fat than muscle, and fat can be spread evenly over a larger area; however, for simple plugging of the nasofrontal ducts, we have not seen a clear advantage of muscle, fascia, or fat, which are all sufficient. In cases of high flow leaks, we have found that external ventricular drainage for 4–7 days assists in successful repair. In cases in which the left and right frontal sinuses are clearly separate and there is no obvious communication, a unilateral craniotomy may be attempted. We rarely use a unilateral craniotomy as this method results in less complete cranialization and the intersinus septum is generally thin and easily damaged during mucosal removal. In cases of adjacent laceration, we prefer to incorporate this into the incision; however, we do not compromise on the size of the pericranial graft and will often undermine the posterior aspect of the incision to allow for a larger graft [Figure 6]. Any lacerations or perforations of the pericranial graft are repaired primarily with 4-0 Nurolon suture. Care must be taken to replace the frontal bone flap in such a manner as to provide good cosmesis and still allow for vascularity of the flap. Pericranial flap compression by bone replacement can cause pericranial flap ischemia and could result in considerable mass effect. Despite these preferences, we are aware that multiple techniques are successfully employed in the surgical treatment of these injuries.

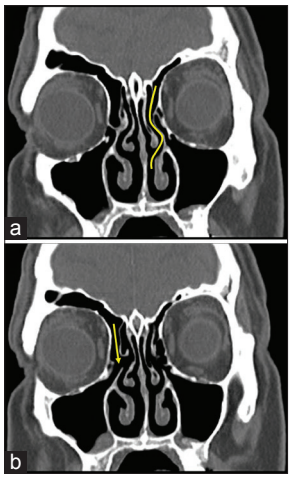

Figure 4: (a,b) Coronal CT multi-planar reconstructions demonstrating the course and trajectory of the nasofrontal duct and NFOT

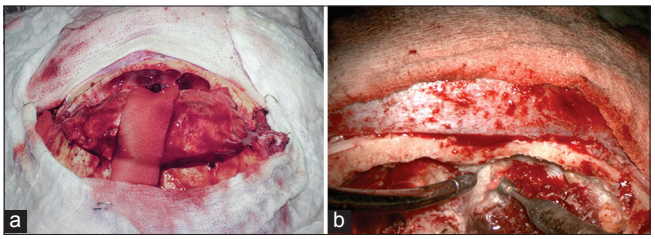

Figure 5: Photograph showing skin incision for a bicoronal skin incision and bifrontal craniotomy (a), photograph of drilling of the posterior wall of the frontal sinus using a diamond burr (b)

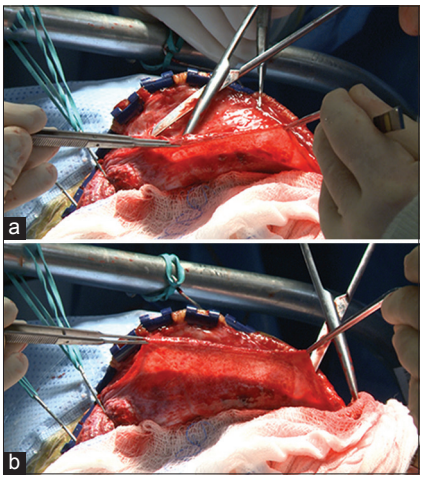

Figure 6: (a,b) Intraoperative photographs showing harvesting of pericranial graft

A treatment algorithm focusing on a combination of variables is ideal in the management for patients with frontal sinus injury; however, no straightforward progression exists because of associated intracranial

injuries and critical illness in blunt trauma patients, which can lead to delay in the surgical treatment of these patients. Manolidis *et al.*[16] proposed that injury of the anterior and posterior tables leads to frontonasal duct injury and that involvement of the nasoethmoidal complex and medial orbital rim in the fracture pattern causes frontonasal duct injury as well.[16,29,30] This association is not complete, however, and careful review of CT imaging through the bony structures in this region by an experienced neuroradiologist is pivotal in making an accurate diagnosis and aids in clinical decision-making.

In Figure 7, we introduce a treatment algorithm combining the experience at our center and the recommendations made through our literature review. The presence of NFOT obstruction and CSF leak are the cornerstone of the treatment algorithm. Patients monitored with observation require close follow-up with clinical and radiographic surveillance for the development of fistulas and sinus tracts. Although we successfully treated all 33 patients with no immediate or delayed reoperation, lack of long-term follow-up in trauma patients makes it more difficult to assess long-term complications and outcomes.[34] CSF leak warrants initiation of antibiotic prophylaxis with central nervous system (CNS) penetration.[20] Ioannides and Freihofer[12] previously created an algorithm with emphasis on NFOT obstruction; the algorithm we have created incorporates NFOT obstruction, but, on the basis of findings in the recent literature, it also places large emphasis on CSF leak and antibiotic use. The goals of surgical treatment should be to (i) surgically repair the defect; (ii) eliminate the conduit from the intracranial space to the outside, and (iii) eliminate any CSF pressure gradient that may develop across the surgical repair.

All patients in our series underwent cranialization of the frontal sinus. The time to surgical repair depended on many factors including patient stability, patient transfer, and associated injuries. There is no specific recommendation for the timing of frontal sinus repair, however, many factors should be considered. Bellamy *et al.*[2] reported a cumulative rate of serious infection of 11%. In addition, they found external CSF drainage, local soft-tissue infection, and operative delay beyond 48 h after injury were independently associated with fourfold ($P < 0.05$) increased risk of infection.[2] Thus, earlier operative intervention may prevent the formation and morbidity of severe intracranial CNS infection.

Bellamy *et al.*[2] demonstrated that 36% of patients with surgically managed frontal sinus injuries had a preoperative CSF leak. They also found 14 cases of serious infection with involvement of the posterior table and NFOT compromise. Pollack *et al.*[20] reported a complication rate of 6% in a series of 154 patients who underwent cranialization for frontal sinus fractures. They reported 12 patients with CSF leaks (including 8 noted

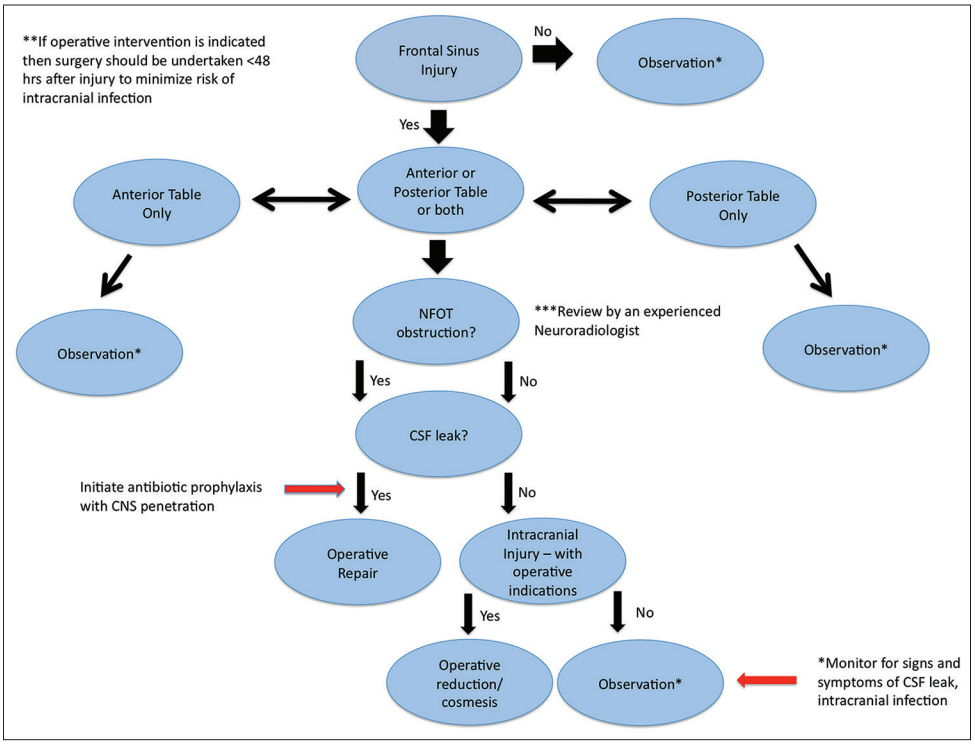

Figure 7: Treatment algorithm for patients with traumatic frontal sinus injury

on initial presentation), none of whom were started on CNS-penetrating doses of antibiotics prophylactically. One patient developed serious intracranial infection in the acute period (<48 h) prior to operative repair. It has been reported that operative delay beyond 48 h was associated with a 4.03-fold increased risk for serious infection, external CSF drainage catheter use had a 4.09-fold increased risk for serious infection, and local soft-tissue infection conferred a 5.10-fold increased risk for serious infection.[2]

There are anecdotal reports on material used to pack the sinus after stripping the mucosa, but there are no long-term studies that show greater efficacy for one particular material. The use of a pericranial flap to layer over the obliterated sinus was well described by Donath *et al*.,[6] who concluded that a pericranial flap is easy to harvest and serves as an extra barrier between the intracranial cavity and the nasofrontal duct. This was mirrored to a large extent in our study, in which 86% (24/28) of patients had placement of a pericranial flap. Ioannides and Freihofer[12] suggested that the use of autologous cancellous bone to obliterate the sinus should depend on the size of the sinus. There was wide variability in the material used to occlude the nasofrontal duct, most likely due to surgeon preference. In our series, one patient developed a CSF leak that required subsequent ventriculoperitoneal shunting; however, the type of graft that was used was unavailable.

The rate of delayed mucocele formation following frontal sinus injury has been previously studied based on anecdotal reports. Until 2004, there were 10 documented cases of delayed mucocele formation as a result of traumatic frontal sinus injury. Koudstaal *et al*.[14] reviewed three cases of delayed mucocele formation occurring 13, 22, and 35 years following injury; they also theorize that long-term follow up is necessary to adequately follow and document this complication. Although the exact incidence of posttraumatic delayed mucocele formation is unknown, the theoretical risk and previously published cases warrant consideration of this factor when treating frontal sinus injuries. Postsurgical mucocele formation, which can occur in incomplete cranialization and removal of the mucosa of the frontal sinus, is an additional consideration, but rates of this are low.[32]

Nonoperative management of frontal sinus fractures

This series focuses on the surgical management of frontal sinus fractures; however, a majority of frontal sinus fractures may be managed conservatively. The absence of CSF leak and NFOT obstruction are two major factors that could predicate conservative management; nonoperative management involves close observation for development of CSF leak and sign and symptoms of meningitis. A majority of patients with frontal sinus injury will not require surgical intervention, and most cases of CSF rhinorrhea acutely after trauma will cease spontaneously.

In this series of patients managed surgically, vaccines were not used in the acute setting. Patients returning for follow-up visits were urged to visit their primary care physicians and update their vaccinations; however, the compliance rate with measure is unknown. Currently, the CDC recommends either the pneumococcal conjugate vaccine (PCV13) or the pneumococcal polysaccharide vaccine (PPSV23) for patients with CSF leaks.[1]

Patients managed conservatively are treated with standard trauma and neurosurgical protocols for fluid resuscitation and maintenance, with 0.9% sodium chloride solution. Specifically, there is no use of fluid restriction for frontal sinus injury, unless other systemic conditions demand this course of treatment. Most patients with posttraumatic CSF rhinorrhea will have spontaneous resolution. The routine use of carbonic anhydrase inhibitors to decrease CSF production is not typical; however, given its efficacy in patients with suspected high intracranial pressure leaks, it may represent a possible therapeutic option.[3]

Limitations

This is a case series from a single institution, which may reflect the homogeneity in treatment methods and operative indications. It is a retrospective study, thus subjecting the data to recall bias and limitations based upon availability and accessibility to the medical records. There is a lack of long-term follow-up, which is common in the trauma population.[34] Despite these concerns, we believe that this study provides a meaningful framework for neurosurgical management of patients with traumatic frontal sinus injuries based upon our clinical experience and the review of the literature.

CONCLUSIONS

The management of frontal sinus fractures by neurosurgeons can be variable. In our series and review of the literature, the presence of CSF leak, NFOT injury, associated depressed skull fractures and intracranial injuries requiring operative intervention, and potential formation of communicating pathways and infection were all considerations when considering operative repair. Future studies may further define optimal repair technique and materials used obliterate the sinus based on long-term follow-up and outcomes. We have created a treatment algorithm that neurosurgeons can use; however, a multitude of factors play a role in this decision.

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