FRONTAL SINUS FRACTURES

Fractures involving the frontal region represent some of the least common injuries that affect the facial skeleton. The incidence is 5 - 15% of all facial fractures. However, because the frontal area makes up part of the brain case, the fatal potential of these injuries is much greater than with other facial fractures. The majority of these fractures are caused by automobile accidents and assaults.

Anatomy

The frontal sinus is a pyramidal, air-filled cavity which lies between the lamina of the frontal bone. The size and shape of this sinus varies among individuals and between the two sides. The anterior wall is generally considered the strongest of the two tables. The posterior wall is much thinner and weaker and separates the sinus from the dura of the frontal lobe in the anterior cranial fossa. The eyebrows and the buttress of the supraorbital rim demarcate the lower anterior border of the frontal sinus. The sinus floor consists of membranous bone which is the thinnest of the sinus boundaries and the most vulnerable to injury. The floor also forms 2/3 of the medial orbital roof. There is usually a thin septum arising from the midline of the sinus floor which partially or totally separates the two sides of the sinus.

The arterial blood supply of the frontal sinus is primarily diploic branches of the supraorbital artery which arise from the ophthalmic artery and from branches of the anterior ethmoid artery. Superficial venous drainage is by the angular and facial veins. The deep venous drainage is through the ophthalmic vein to the cavernous sinus. In addition, there are veins present in the mucosa of the frontal sinus which communicate with the dura and the diploe of the cranium. The perforations in the bone containing these veins are known as Breschet's canals, and blood may
flow in a retrograde fashion into the anterior cranial fossa because of the lack of valves in these veins. Spread of infection through these veins can then lead to development of a subdural or brain abscess. Sensory innervation is provided by the ophthalmic division of the trigeminal nerve.

The frontal sinus begins as an evagination of the anterior-superior portion of the middle meatus known as the frontal recess. This is first recognizable during the end of the third month of fetal life. A furrow develops in the frontal recess around the fifth month which progresses to form a larger pit or several smaller ones from which the sinuses develop. The sinuses may develop as a large direct extension of this area (no true duct) or may push upward maintaining communication with the nasal cavity by a formed nasofrontal duct.

Between the ages of 1 and 2 years, this developing sinus begins to grow between the anterior and posterior tables of the frontal bone. By age 3, it extends several millimeters above the frontonasal suture line. The frontal sinus becomes recognizable radiographically by age 7, but is not clinically significant until age 10. It usually reaches adult size by age 18, and may continue to grow slowly throughout adulthood.

The drainage pattern of the frontal sinus is variable. In 15% of the population, a true nasofrontal duct exists. These ducts are located in the posterior-medial portion of the floor of the sinus. They vary in length from a few millimeters to 2-3 centimeters and are lined with respiratory mucosa. Longer ducts are more susceptible to traumatic disruption. These ducts travel in an anterior-inferior direction to empty into the anterior end of the middle meatus. More commonly (85%), the frontal sinus drains directly into the middle meatus via an ostium without a true nasofrontal duct.

The primary purpose of the frontal sinus is to serve as a mechanical barrier to protect the brain from trauma. The frontal sinuses are positioned more anteriorly than the other paranasal sinuses and are situated to absorb anterior cranial facial trauma.

Evaluation

For purposes of initial evaluation, frontal sinus fractures should be regarded as head injuries. The majority of these patients are victims of automobile accidents with multiple injuries requiring a multispecialty team approach and complete evaluation. The standard trauma protocol must be followed with emphasis on ensuring an adequate airway, breathing, circulation, CNS status, and C-spine. Any other life-threatening injuries take precedence over the sinus fracture. Injuries to the thorax, abdomen, and extremities are not uncommonly associated with injury to the head and face and must not be overlooked. Appropriate consultations must be obtained and treatment must be prioritized appropriately.

In any patient sustaining significant maxillofacial injury, the cervical spine should be suspect and should be evaluated both radiographically as well as clinically prior to other studies or examinations requiring hyperflexion or other manipulation in the head and neck. The c-spine should be stabilized in a cervical collar until a cross-table lateral radiograph is obtained and demonstrates that all seven cervical vertebrae are normal.
A thorough neurologic examination is extremely important. Significant intracranial injury occurs more commonly with injury to the frontal sinus (12-17% of the time) that with injury to the mandible or midface due to the proximity of the frontal sinus to the brain and the great forces required to cause a frontal sinus fracture. Neurosurgical consultation should be obtained promptly if abnormal neurologic studies or brain CT changes are observed. Changes in mental status as well as nausea or vomiting are suggestive of intracranial injury. It is important to search for cerebrospinal fluid leakage from the nose or directly from lacerations and exposed bone which could signify dural displacement coupled with a posterior table fracture. A traumatic CSF fistula of the frontal sinus is a life threatening process deserving urgent attention.

Early ophthalmologic consultation should be obtained in the emergency department for any fractures of the frontal sinus when they concomitantly involve the orbit and should be considered in every case of frontal sinus fractures. It is important to document visual acuity, pupillary function, and ocular mobility and to inspect the anterior chamber for blood (hyphema) and the fundus for gross disruption. In one study by Holt, of 787 patients with facial fractures who were evaluated by an ophthalmologist in the emergency department, 89% of those with frontal sinus fractures had associated eye injuries!

A general head and neck examination should be performed promptly, carefully palpating and exploring locally all wounds and lacerations. Note any crepitance, bony step-offs, point tenderness, soft tissue swelling, rhinorrhea, epistaxis, or abrasions and contusions around the neck. The extent of soft tissue injury overlying the sinus can be misleading and may not reflect the degree of injury to the sinus. Soft tissue swelling is often seen over the frontal region and may not allow for the diagnosis of a depressed fracture on palpation.

**Radiography**

Computed tomography has become the imaging study of choice for evaluating fractures of the frontal sinus. It provides superior detail of simple and complex comminuted fractures of the anterior and posterior tables of the frontal sinuses, as well as other facial and cranial bones. Subtle and obvious bony displacements and fragments, as well as foreign bodies are readily detected. CT scans also provide simultaneous information regarding facial, orbital, and intracranial soft tissue injury. Both axial and coronal views with 1.5 mm cuts should be obtained.

CT scans may not clearly define fractures or injuries to the nasofrontal ostia or ductal drainage system. It will, however, provide enough detail to make fairly accurate predictions of nasofrontal duct involvement. Isolated fractures of the anterior table of the frontal sinus and transverse linear fractures through the anterior and posterior table above the floor of the sinus are not usually associated with damage to the nasofrontal duct. However, CT evidence for fractures involving the floor of the sinus, the nasoethmoid complex, inferiorly located fractures of the posterior wall, or depressed fractures of the posterior table almost always signify injury to the frontal sinus drainage system and must be evaluated further.

CT scanning can also be helpful in anticipating possible dural disruptions. Findings on CT that usually signify torn dura include: a wide gap in the posterior wall or any marked displacement of
fragments; a fracture passing across both sinuses; a large projecting fragment posteriorly; a fracture that widens as it progresses inferiorly; or tilting of the crista galli.

Management

Treatment of frontal sinus fractures has been controversial for years. The goals, however, remain the same: cosmetic restoration and prevention of early and late complications including acute and chronic sinusitis, mucocele formation, brain abscess, and osteomyelitis. The first step in the treatment of frontal sinus fractures is to evaluate and manage more serious life-threatening injuries. Once this has been accomplished, the following data is obtained in order to formulate a treatment plan: the specific bony tables involved, the type of fracture(s), presence or absence of nasofrontal duct involvement, and CSF leakage.

Although a treatment plan may be formed on the basis of pre-op evaluation and CT scan findings, the surgeon must be ready to modify this plan based on the findings at the time of the exploration. A risk to benefit evaluation must be made to determine the least operative intervention that will achieve the optimal result. This is particularly important to remember in dealing with frontal sinus fractures in children in order to avoid interfering with the growth centers and causing iatrogenically induced deformities.

Definitive management of facial fractures should be delayed until the patient is stable and optimum conditions exist for a good surgical result and recovery. Frontal sinus fractures do not require immediate surgical attention unless they are associated with a neurosurgical or ophthalmologic emergency. Patients not requiring operative treatment for associated injuries should be observed for head trauma for 48 hours prior to frontal sinus exploration.

Surgical Approaches

Frontal sinus trephination is most commonly used to treat acute frontal sinusitis, but it can be used for selected frontal sinus fractures. Access is gained through an incision under the medial aspect of the eyebrow and carried down to the periosteum. A chisel or drill is then used to enter the anterior floor of the frontal sinus. A depressed anterior wall fracture may be reduced using an elevator inserted through the trephination. It is possible to inspect the ipsilateral posterior table but exposure is limited. Patency of the nasofrontal duct may be assured by demonstrating drainage of methylene blue dye into the nose via the trephination.

In selected cases, a frontoethmoidectomy via a Lynch incision may be used for limited access to the frontal sinus. An incision is extended from below the medial border of the eyebrow inferiorly midway between the medial canthus and nasal dorsum. This is carried down to the periosteum and the sinus is entered using a chisel or drill. This allows combined access to the ipsilateral ethmoid and frontal sinus.

The osteoplastic flap allows a direct approach through the anterior wall of the frontal sinus but preserves the anterior wall by hinging it inferiorly on the blood supply coming through the periosteum and soft tissue. The forehead contour is preserved by replacement of the bone-periosteal flap over the sinus at the completion of the procedure. This approach provides wide
exposure to the frontal sinus and can be used to explore both sides, repair anterior table fractures, obliterate the sinus with fat, or remove the posterior wall with cranialization and ablation of the sinus. This may be done via an overlying laceration, a brow incision, or a coronal incision. The coronal incision is preferred because it provides the best exposure, it allows the neurosurgeon access to perform an anterior craniotomy if findings warrant, and it hides the scar in hair-bearing skin. An exception to the use of a coronal incision would be a male patient with a predilection to male pattern baldness. In these patients, a brow incision (gull-wing) might heal with a more acceptable scar (controversial).

The frontal sinus ablation procedure (Reidel procedure) allows the overlying soft tissue to obliterate the sinus by collapsing inward to meet the posterior table after removal of the anterior table and the mucosa. This can be accomplished via a brow incision or a coronal incision. Reconstruction of the forehead defect can be performed 6-12 months later using metal plates, calvarial bone graft, or synthetic materials.

The cranialization procedure preserves forehead contour. This is done via an osteoplastic sinusotomy. The entire posterior table is removed and the brain is allowed to expand forward. For this procedure to be successful, the dura must be intact or repaired carefully and patched with fascia if indicated, all mucosa must be removed, and the nasofrontal duct must be well plugged with fat and fascia. These patients require perioperative IV antibiotics. In cases of severe head trauma, this allows the brain to decompress into the frontal sinus defect.

Treatment Options

There are several philosophies regarding the approach to frontal sinus fractures. Some authors feel that surgical intervention is necessary in almost all frontal sinus fractures to adequately evaluate the extent of injury to the nasofrontal duct and posterior walls regardless of radiographic findings. This approach has become much less popular as the diagnostic capabilities of CT scans have improved. Others feel that unless the posterior wall is severely displaced or comminuted, cerebrospinal fluid leakage is present, or the nasofrontal drainage system is likely to have been injured, close follow-up without surgical intervention is appropriate. Also, many feel that surgical intervention is appropriate for cosmetically unacceptable anterior table fractures.

ANTERIOR TABLE FRACTURES

These represent the most common fractures and the least complex of the frontal sinus fractures. These are very rarely associated with injury to the drainage system or CSF leak. Linear, nondisplaced anterior table fractures may be managed by observation and close follow-up evaluations to ensure that the sinuses remain clear and air containing. Minimally displaced anterior table fractures with no gross external deformity may be managed by observation. However, if there is any question as to the possibility of a noticeable deformity in the future, the fracture should be explored. Grossly displaced anterior table fractures require reduction and fixation in the anatomic position to restore the normal forehead contour. Titanium microplates are generally preferred over wires and other techniques. Fixation may not be necessary in minimally comminuted fractures if the bone is stable after reduction.

POSTERIOR TABLE FRACTURES
Fractures of the posterior table are frequently complicated by dural tears, with associated CSF leaks and damage to the nasofrontal ducts. Controversy exists as to the treatment of linear (nondisplaced) fractures of the posterior table. Many feel that all nondisplaced fractures of the posterior table should be explored because of the difficulty in assessing the degree of posterior wall displacement without direct inspection. However, as CT capabilities have improved, some feel that if there is no CSF leak or NFD injury these patients can still be safely observed. Neurosurgical consultation is recommended for all posterior table fractures.

Hybels and Newman evaluated the natural history of posterior fractures using a cat model. They demonstrated that mucocele formation occurred in the presence of nasofrontal duct obstruction and when mucosa was inadequately removed in an obliterated sinus. They were able to demonstrate that with adequate drainage of the sinus, mucosa did not grow into the fracture lines. They also showed that healing of the posterior wall occurred with new bone formation if the fracture line was depressed less than the width of the posterior table. Fractures with loss of bone or separation between the fragments greater than the width of the posterior table healed by fibrous tissue filling the defect. Hybels concluded that nondisplaced or minimally displaced fractures of the posterior table may be treated conservatively if there is no CSF leak or NFD injury.

In contrast, Donald states that nondisplaced posterior wall fractures may not heal by bony union. Additionally, dural tears often exist adjacent to these posterior wall defects which may predispose the patient to meningitis if an episode of sinusitis develops. He supports fat obliteration of the frontal sinus in all cases of posterior wall fractures.

For displaced posterior wall fractures, surgical exploration is generally agreed upon, but the optimal surgical treatment is controversial. In moderately displaced fractures of the posterior table, mucosa may become trapped in the suture line. These require surgical attention because continued growth of the mucosa may result in mucocele formation, or if sinusitis occurs, meningitis, cerebritis, or a brain abscess may occur. Also damage to the NFD is frequently associated with displaced fractures of the posterior table and should be evaluated at the time of exploration. Most authors recommend fat obliteration of the frontal sinus as treatment for displaced frontal sinus fractures. The rationale for obliteration is to provide a secure barrier between the unsterile nasal cavity and the intracranial area. Complete removal of mucosa is imperative to prevent potential mucocele formation. A bicornal craniotomy is used, providing optimum exposure for evaluation and repair of both dural and bony injuries. The dura is repaired either with a simple suture closure or using a fascial graft. Once the dura is closed, the bony fragments are reduced. In most instances, simple reduction is sufficient. If instability exists, a reduction plate is applied from the intracranial side to provide fixation. If >50% of the posterior wall is fractured, then a cranialization procedure should be performed. This is because the extensive bone debridement and dural grafts required to repair a severely comminuted fracture may not have the vascular bed to support a fat graft.

NASOFRONTAL DUCT INJURIES

A competent nasofrontal communication is necessary to the normal function of the frontal sinus. Partial obstruction of the NFD may predispose to chronic sinusitis or recurrent episodes of acute sinusitis. Complete obstruction of the NFD can lead to mucocele formation which may act as an
expanding tumor, eroding bone and exerting a mass effect on adjacent brain or orbit. If bacteria seed the mucocele, a mucopyocele will develop with the potential danger of life-threatening intracranial infections. Therefore, the surgical treatment of fractures impairing drainage of the frontal sinus requires either reconstruction of the sinus drainage system or obliteration of the sinus.

Attempts at treating unilateral obstruction to the NFD by removing the intersinus septum and allowing drainage down the contralateral side have proven unsuccessful due to the unpredictability of the drainage system and fibrous tissue ingrowth at the site of the removed septum. Catheter placement in the NFD has also been abandoned due to ductal stenosis.

Reconstruction of the NFD may be attempted for frontal sinus fractures when the pre-op assessment has shown that the posterior wall does not require surgical attention. This can be done via a frontoethmoidectomy approach with or without the use of temporary stents. Advocated of this argue that it is a lesser procedure with fewer complications than the osteoplastic flap and allows direct access to the ethmoid air cells. This can be done bilaterally if both NFD are injured.

For NFD injuries associated with posterior wall fractures, the best treatment is an osteoplastic flap approach with complete mucosal removal, fat obliteration of the sinus, and plugging of the NFD.

CONSERVATIVE TREATMENT AND FOLLOW-UP

For patients in whom operative exploration is not mandatory, conservative treatment measures include broad spectrum antibiotics (more controversy), +/- systemic decongestants, dependent drainage to aid in clearing the blood filled sinus, avoidance of nose blowing to prevent pneumocephalus, and close observation. If the patient's clinical course changes or if mental status changes develop, immediate CT scanning and surgical exploration are recommended.

Follow-up is extremely important in any patient who sustains a frontal sinus fracture. Complications may not develop for many years after the injury, and this fact must be emphasized to these patients. At any time in the patient's life when complaints of frontal sinusitis, frontal sinus pressure, visual changes, unexplained fevers, and persistent frontal headaches arise, he should be evaluated for complications and should undergo a CT scan.

Conclusions

Frontal sinus fractures are uncommon injuries representing only 5-15% of all facial fractures. Patients suspected of sustaining a frontal sinus fracture must undergo a complete evaluation in the emergency department following the trauma protocol (airway, breathing, circulation, C-spine) and must have potential life-threatening injuries addressed and treated prior to treatment of the fracture. Appropriate neurosurgical and ophthalmologic consultations should be obtained in the ER. CT scanning is the method of choice for evaluation of the fracture. The treatment of frontal sinus fractures is controversial and individual factors must be taken into account in each case. However, if any doubt exists as to the need for sinus exploration, then the sinus should probably be explored.
BIBLIOGRAPHY


