Rationale for Management of Frontal Sinus Fractures

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ABSTRACT
The optimal treatment of frontal sinus fractures remains controversial. Multiple treatment options and algorithms have been proposed by multiple specialties throughout the years; however, the optimal method of frontal sinus repair has yet to be discovered. Overwhelming complications such as meningitis, encephalitis or brain abscess are quite uncommon nowadays. Nevertheless, late development of invasive mucoceles is not a rarity and therefore long-term follow-up is mandatory.

Keywords: frontal sinus fractures, frontonasal duct, posttraumatic mucocele

DEVELOPMENT AND REGIONAL ANATOMY
The frontal sinus is generally absent at birth, at one year the anterior ethmoid cells begin to invade the frontal bone and its growth is complete at approximately 15 years of age. It is irregularly shaped and scalloped at its margins (the asymmetry is the rule rather the exception). The anterior table is thicker than the posterior one and more resistant to injury. The size and shape of the sinus varies among individuals and on right and left sides in the same individual, the anterior wall of the sinus being stronger than the posterior wall (1).

It requires greater force to fracture than any other facial bone (2). The frontal sinus has several critical anatomic relationships as: sinus floor-orbital roof/anterior ethmoid air cells, posterior table – anterior cranial fossa, anterior table – frontal contour. It drains via a small outflow tract into the ethmoid sinus/nasal cavity, tract which is hour-glass shaped with the true ostium at the narrowest portion; the infundibulum is above and the frontal recess is below. The majority of frontal sinus fractures are the result of high velocity impacts such as motor vehicle accidents, assaults and sport injuries. These are relatively uncommon fractures (5-15% of all maxillofacial ones) with a preponderance of male patients, aged 20-30 (3-5).

PHYSIOPATHOLOGY
Frontal sinus contains pseudostratified ciliated respiratory epithelium covered
by a layer of mucin. The cilia beat at the rate of about 250 cycles per minute, directing flow of mucin from the medial to the lateral aspect of the frontal sinus. The quantity of mucin drainage is about 5 g/cm. Some authors state that: frontal sinus drainage is impaired when the nasofrontal duct becomes damaged or obstructed. The mucus can subsequently build up behind the obstructed duct. A mucocele may develop and act as an expanding tumor. Additionally an anaerobic environment may develop, increasing the risk of frontal sinusitis involving the intracranial contents. As such, assessment of the patency and subsequent management of the nasofrontal duct are important decision making elements in the management of frontal sinus injuries. Therefore, for all frontal sinus injuries, immediate postoperative films and serial postoperative CT is indicated for an extended period of follow-up time. This should be performed immediately postoperatively after the first year and every year for up to 20 years. Mucoceles have been diagnosed decades after surgery by various investigators. The latest reviews are pointing that: drainage of the frontal sinus is variable. A true FND exists in only 15% of the population, varying from a few millimeters to 1 cm in length. In the rest of the 85%, the frontal sinus drains directly into the anterosuperior portion of the middle meatus via an ostium without a true duct or occasionally by a communication through the ethmoids, and therefore the role of FND in trauma appears to be overstated, with a failure rate of stenting of almost 30% due to subsequent scar formation and stenosis (6-9).

1. Linear fractures
   a. Transverse
   b. Vertical
2. Comminuted fractures
   a. INVOLVING both tables
   b. Accompanied by nasoethmoidal complex fractures
   • Type 3 – Posterior Table Fractures
   • Type 4 – Very severe comminuted fractures of the whole frontal area, involving the orbit, the nasal base and the ethmoid – “Through-and-Through” Frontal Sinus Fracture

The most common fractures involve the combination of the anterior and posterior tables with or without frontal recess involvement (about 2/3), isolated anterior wall fractures account approximately 1/3 and isolated posterior table fractures are rare (<1%).

A focused exam of the frontal sinus should include evaluation for any contour deformity and/or frontal lacerations and neurosensory deficits. Conscious patients should be questioned for the presence of clear nasal drainage or salty posterior nasal drainage that might be indicative of CSF leak. Examination of deep wounds should be performed under sterile technique, as these can be through and through injuries. The prognosis for such severe injuries is significantly worse and more aggressive management is indicated. A high resolution CT scan with axial, coronal, sagittal and 3-D reconstruction is the gold standard for diagnosis (10-12).

FRacture CLASSIFICATION

Although there is no universally accepted classification of the frontal sinus injuries, they are characterized by location, extent of injury, involvement of the nasofrontal duct and concurrent injury of the dura.

Gonty’s Classification of Frontal Sinus Fractures
• Type 1 – fractures of the anterior wall
  1. Isolated to anterior table
  2. Accompanied by supraorbital rim fractures
  3. Accompanied by nasoethmoidal complex fractures
• Type 2 – Anterior and Posterior Table Fractures

Rationale FOR MANAGEMENT OF Frontal Sinus Fractures

Due to its unique anatomical position and physiological function, the sinus is usually assessed and managed as a separate entity within the overall fracture pattern. Adverse outcomes such as acute and chronic sinusitis, mucocele, mucopyocele, osteomyelitis, meningitis, and cerebral abscess have all been reported after treated and untreated frontal sinus fractures. Historically, the risk of infection after damage to the frontal sinus was believed to be caused principally by disruption of the drainage of the sinus, leading to retained secretions that become infected or to the formation of a mucocele, or both. A mucocele is a collection
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of mucus within the sinus that gradually enlarges and destroys the bony walls; it is an expansile lesion. A minority of frontal sinus mucoceles are the result of trauma. Infection in a mucocele results in a mucopyocele. Localized osteomyelitis and intracranial complications such as meningitis and epidural or subdural abscesses have also been attributed to the frontal sinus. Because these complications can occur many years after the initial injury, recent authors state that the actual risk of complications after apparent disturbance of frontal sinus drainage is unclear; in their view, the more likely cause of intracranial infection after trauma to the anterior skull base is untreated dural tears that are in communication with the nasal cavity and the frontal and ethmoid sinuses, rather than infection related purely to the frontal sinus (13-15).

The goal of frontal sinus fracture management is to create a safe sinus, restore facial contour and avoid short and long term complications:

Early complications – occur within the first 6 months after injury:

- Frontal sinusitis
- Meningitis
- Intracranial abscess
- Empyema
- Cavernous sinus thrombosis
- Concomitant neurologic injuries secondary to penetrating trauma or displacement of the frontal bone into the neurocranium.
- CSF leak and fistulae
- Diplopia to blindness
- Limitation of extraocular motions
- Damage of the supraorbital or supratrochlear nerves.

Late complications – occur 6 months or more after the initial injury:

- Mucocele/ mucopyocele formation
- Late frontal sinusitis
- Brain abscess secondary to frontal sinus infection
- Frontal contour defects

Treatment of frontal sinus fractures is complex and sometimes controversial. Appropriate treatment decisions can be made by assessing 5 anatomic parameters, these include the presence of:

- An anterior table fracture (A)
- A posterior table fracture (B)
- A nasofrontal recess fracture (C)
- A dural tear (CSF leak) (D)
- Fracture comminution

Treatment options would include:

- Observation
- Open reduction internal fixation (ORIF)
- Obliteration
- Cranialization
- Ablation

FRACTURES OF THE ANTERIOR WALL OF THE FRONTAL SINUS

Cosmesis is the only consideration in fractures of the anterior wall of the frontal sinus. Treatment is indicated only for those patients with displaced fractures resulting in cosmetic deformity that is of concern to the patient. Undisplaced fractures of the anterior wall require no surgical intervention. Minimally displaced fractures with no evidence clinical deformity may also be managed conservatively. The anterior wall should be reduced and fixed in the anatomical position to restore normal forehead contour, using split calvarial bone graft or titanium mesh.

Reduction. The anterior table of the frontal sinus is normally convex. Compressive forces on the frontal bone deform the convexity into a concavity. This may or may not result in fracture comminution. Mobilization of the depressed bone fragments may require significant effort to overcome compressive forces between bone fragments. Any redundant or injured mucosa at the periphery of the fracture or on isolated bone fragments should be removed. If removal of anterior table bone fragments is required, the defect should be used to inspect the frontal recess and assure that it is not injured. Traumatic distortion of fracture segments may make it difficult to realign them. While every effort should be made to maintain the integrity of each bone fragment, it may be necessary to trim the edge of a fragment to allow for fracture reduction.

Fixation. Bone fragments should then be repositioned and fixed with internal fixation hardware. Stability can generally be achieved with thin titanium plates. This will minimize the risk of visibility/palpability of the implants. The number of plates will be dictated by the stability of the reduction. Alternatively, one long curved plate might be used to secure several fracture segments.
FRAC TURES OF THE POSTERIOR WALL OF THE FRONTAL SINUS

Involvement of the posterior wall is relatively common, about 80% of the frontal sinus fractures include disruption of the posterior wall. Significant complications of intracranial sepsis have been demonstrated in cases in which posterior sinus wall fractures were treated conservatively. This incidence is associated with leaving a dural tear in communication with the nasal cavity via the frontal sinus. In this case, a craniotomy is mandatory, because adequate dural exploration and repair cannot be reliably performed through the sinus itself. This procedure is frequently performed with the neurosurgery team.

CASE PRESENTATION

A 34-year-old man sustained a left frontal anterior and posterior wall fracture after an accidental blow to the head with the back of an axe (Figure 1). Immediately after the injury, the patient noticed discomfort in upper gaze, temporary decrease in visual acuity and esthetic deformity at the frontal area. At the initial examination, there was mild superior palpebral edema, ecchymosis, and slight limitation of supraduction of the right eye and associated pain and diplopia in downward gaze, complete anesthesia in the left V1 nerve territory.

A preoperative computed tomography scan showed an extensive fracture of the superior orbit rim, anterior and posterior wall of the frontal sinus. At surgery, the frontal bone was approached coronal, with a dissection carried in a subperiosteal plane. After subperiosteal dissection to expose the supraorbital rim and the frontal bone (Figure 2, Figure 3).

The fractured bone fragment was repositioned in an anatomical position, and they were secured using titanium plates positioned over the bony defect (Figure 4). The mucosal remains of the frontal sinus were carefully removed, and the sinus cranialization was performed in order to exclude the frontal sinus. No stenting of the frontonasal duct was performed.

The follow-up was extended to 24 months after the titanium plate was implanted, and the clinical assessment demonstrated good biocompatibility, good overall support of the bone fragments without the relapse of the fracture line, and no signs of local inflammatory reaction.

Stenting of the Frontonasal Duct (FND)

Patency of the FND has been considered to be important in preventing infection of the frontal sinus and the development of a mucocoele.
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cele. This certainly is the case when one considers acute and chronic frontal sinusitis. However the role of the FND in trauma appears to have been overstated. There is no reliable evidence for the use of stenting in re-establishing adequate sinus drainage.

Obliteration of the Sinus

Obliteration of the frontal sinus with autologous materials such as fat, muscle or bone or with synthetic materials such as hydroxyapatite has been described. Fat appears to be the most popular choice for attempts to obliterate the frontal sinus, but failure rates of up to 25% have been reported. Free fat grafts can be expected to undergo a significant rate of necrosis, because any non-vascularized graft is dependent on the vascularity of the recipient site to survive, so in some authors opinion the current approach to injuries to the floor of the frontal sinus is to do nothing, that is in keeping with the current method of treatment of nasoethmoidal fractures.

Southampton protocol for the treatment of fractures of the frontal sinus:

- **Anterior wall fracture**
  - Undisplaced – no treatment
  - Displaced with cosmetic deformity: open reduction with internal fixation; autologous bone graft or titanium mesh

- **Posterior wall fractures**
  - Undisplaced – no treatment
  - Displaced: craniotomy, cranialization of the sinus, and dural repair with isolation of the anterior cranial fossa with pericranial flap

- **Floor fractures**
  - No treatment

CONCLUSIONS

The management of frontal sinus injuries continues to challenge craniomaxillofacial trauma surgeons because of the low incidence of injury and the absence of good data supporting clinical decision making. Orbital involvement may result in ophthalmoplegia, diplopia, enophthalmos, proptosis, hypoglobus, and partial or complete loss of vision. Morbidity and mortality are often dependent on the anatomic characteristics of the fracture, concomitant injuries, and comorbidities. Management of frontal sinus fractures is so controversial that the indications, timing, method of repair, and surveillance remain disputable among several surgical specialties. Four basic principles have to be accomplished: reestablish the frontal bony contour to its premorbid state, restore normal sinus mucosa with a patent drainage system if possible, obliterate the sinus cavity if the normal mucosa or drainage system cannot be reestablished, and create a permanent barrier between the intracranial and extracranial systems to prevent life threatening infectious complications. By following these four basic principles,
frontal sinus fracture management will be safe and effective as long as extended surveillance is part of the protocol.

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