1. (Amy) **Discuss the physiology of the nasofrontal duct.**

Development of the frontal sinus begins between the ages of two and four when the anterior ethmoid cells expand into the frontal bone. The frontal sinuses are radiographically evident by ages five to eight and reach full adult size between ages twelve and eighteen. The anatomy of the frontal sinus is highly variable. They are funnel-shaped sinuses and communicate with the middle meatus via an hourglass-like narrowing called the nasofrontal duct. Mucus in the frontal sinus flows up the medial wall, laterally across the roof, medially along the floor, and down the nasofrontal duct into the middle meatus. The nasofrontal duct often does not consist of bony walls of its own, and its borders are defined by the bony walls of neighboring structures. Because it is not always a true duct, it is thus frequently referred to as the frontal recess.

In approximately 15% of the population, a true duct nasofrontal duct exists. These ducts are located in the posterior-medial portion of the frontal sinus floor and vary in length from several millimeters to 2-3 centimeters. They travel anterior-inferiorly and empty into the anterior middle meatus. Longer ducts are more susceptible to injury in facial trauma. In most patients (up to 85%), the 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 orbit, and medially by the middle turbinate. When the ethmoid bulla reaches the skull base, it forms the posterior boundary of the frontal recess. When it does not reach the skull base, the suprabullar recess communicates directly with the frontal recess and the anterior ethmoid artery defines the posterior margin. The patency of the frontal recess depends upon several factors, including the superior articulation of the uncinate process, the agger nasi cell, the presence or absence of frontal cells, the presence of supraorbital cells, and the ethmoid bulla.

2. (Amy) **How would you assess the viability of the nasofrontal duct in frontal sinus fracture?**

Nasofrontal duct injuries are difficult to diagnose both preoperatively and intraoperatively. The CT scan is essential to definitively outline a frontal sinus fracture. However, fractures or injuries to the nasofrontal ostia or ductal drainage system are still difficult to visualize on a CT scan. The scan can 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 frontal recess. However, fractures involving the floor of the sinus, fractures of the nasoethmoid complex, inferiorly located fractures of the posterior wall, or depressed fractures of the posterior table frequently signify injury to the frontal sinus drainage system and must be further evaluated. Fractures that are medial to the midorbital ridge or involve the superior orbital rim are also more likely to involve the frontal recess.

Clinically, there are no pathognomonic signs or symptoms that indicate frontonasal duct fracture. The persistence of a fluid level in the sinus more than 7-10 days following the injury indicates a physiologic and possibly anatomic obstruction and is highly suggestive of injury to the frontonasal duct. Obstruction to outflow may indicate disruption of the duct or functional obstruction resulting from a clot or mucosal edema. Intraoperatively, patency of the nasofrontal duct may be confirmed by demonstrating drainage of saline or methylene blue dye into the nose via the trephination.

3. (Dara) **List the acute and late complications following frontal sinus fracture? What is the most common late complication and how would you manage it? Could it have been avoided?** *Laryngoscope 1988;98:516 and Plast Reconstr Surg. 1988;82:781-791.*

Early complications usually occur within 6 months and include frontal sinusitis, most commonly resulting from retained foreign bodies or bony chips; wound infections, meningitis; and, CSF leak (rates as high as 10% in some studies).
Late complications may occur up to a decade after injury and include chronic frontal headaches, forehead depression, mucocele, mucopyocele, delayed CSF leak, or brain abscess, which is caused by spread of infection from the frontal sinus intracranially through foramina of Breschet.

Chronic frontal headache is the most common late complication (reported by almost one third of the patients in Wilson’s study). In most studies, rates of chronic headache are actually slightly higher in treated groups when compared with non-treated groups. Grossman postulates that it is possible that headaches resulting from frontal sinus fracture are caused by injury to the supraorbital nerve, and the frequency of this complication emphasizes the need to carefully preserve the nerve during fracture repair.

Because the most common presentation of serious long-term complications is frontal headache, any complaints of frontal pressure, pain, or headache in a patient with a history of frontal sinus fracture should lead to an aggressive workup. CT scanning provides the most accurate diagnostic information when evaluating a patient for complications.


Management of Anterior Table Fractures

I. Linear, Minimally Displaced or Non-displaced: conservative measures (low risk of mucosal entrapment and cosmetic deformity), observation

II. Depressed Fractures “Trap Door”: explore, remove mucosa from fractured edges (may consider cutting burs), reduce fracture, may place interosseous wires

III. Comminuted or Unstable fractures: explore, inspect posterior wall and nasofrontal recess, remove mucosa from fractured edges, reduce fracture, thin plate fixation for support

a. if < 1 cm of total frontal bone fragments are missing may consider skin covering only
b. if > 1 cm fragments are missing may need to reconstruct:
   i. Bone grafts (iliac, rib, or split calvarial)
   ii. Titanium Mesh- fewer complications and provide excellent forehead cosmesis
   iii. Methyl methacrylate
   iv. Hydroxyapatite cement- has been used both to obliterate the sinus and recreate the anterior table but experience is limited

If frontonasal recess is involved: traditionally obliteration or cranialization of frontal sinus is performed. However, some physicians have managed these patients expectantly, following this approach with serial CT scans. Patients who failed to reaerate their sinuses were treated with endoscopic frontal sinus procedures; in limited trials, favorable results were obtained. For unilateral frontonasal recess injuries in which the contralateral duct has been demonstrated to work, some clinicians advocate the Lothrop procedure: removal of the intersinus septum and the use of mucosal flaps to allow drainage through the contralateral frontal sinus. This procedure can be performed endoscopically.

5. (David) Educate the group on endoscopic repair of isolated anterior table frontal sinus fractures. Arch Facial Plast Surg. 2003;5:514-21

Notes:

Paper examined feasibility of endoscopic brow lift technique in cadaver model for repair of isolated anterior table fx
Fx treated either by closed reduction with internal fixation, CRIF plus hydroxyapatite recontouring, or HA recontouring alone

2/5 of specimens that underwent CRIF had incomplete reductions with comminution of fragment
However, study appears to show that from cosmetic standpoint, isolated anterior table fractures may be treated by recontouring alone

Advantages:

More accurate visualization, as well as visualization around corners
Minimal external incisions, reduced soft tissue dissection
Reduced hospital stay, Improved teaching

Disadvantages:

Moderate learning curve
Narrow field of view, poor depth perception
Current lack of dedicated instrumentation
Surgeon cannot operate bimanually without an assistant
6. **(Kathy)** A 25-year-old man sustains a fracture of the frontal sinus in a motor vehicle collision. CT scans reveal an anterior table fracture that involves the nasofrontal duct. Discuss the options. *Laryngoscope* 2002;112:784-90.

Pure anterior wall fractures that do not extend into the nasofrontal ducts are repaired for cosmetic purposes only. They should be explored if they are significantly depressed, since even in the absence of acute deformity they are likely to lead to deformities when the swelling resolves.

Smallest plates are generally used, and absorbable plates may work well in this area as well because there are little or no force demands on the repair. Use of an endoscope may allow repair of selected anterior wall fractures with minimal incisions. When anterior table fractures involve the nasofrontal duct, but the posterior table is intact, judgment allows more than one option.

Frontal sinus obliteration is always acceptable, but it is also reasonable to allow the sinus to function and observe what happens. If the sinus becomes obstructed and acute or chronic sinusitis develops, the sinus can then 1) be opened endoscopically; or 2) obliteration can be carried out at a later date.

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**Endoscopic Management of the Frontal Recess in Frontal Sinus Fracture: A Shift in the Paradigm?**

(*Laryngoscope* 2002;112:784-90)

Prospective cohort of 14 patients with anterior table frontal sinus fractures with frontal outflow tract involvement documented by CT scan was examined between 1999 and 2001.

7 patients were included in a modified treatment algorithm, in which open reduction of bony fracture was performed without osteoplastic obliteration of the frontal sinus.

Serial CT scans were obtained at 8 weeks after injury. Patients with persistent frontal sinus obstruction after medical treatment underwent an extended endoscopic frontal sinusotomy or a modified endoscopic Lothrop procedure.

Post-operatively, 5 patients had spontaneous frontal sinus ventilation.

2 patients, both of whom had naso-orbito-ethmoid fractures, had persistent frontal sinus obstruction clinically and radiographically. These patients were successfully managed with an endoscopic frontal sinus procedure.

**Conclusion:** A select group of patients with frontal sinus and outflow tract fracture may be managed with open repair of the anterior table fracture without obliteration. In these cases, suspected frontal outflow tract obstruction can be managed expectantly. Failed frontal sinus ventilation may require FESS to reestablish mucociliary clearance.

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7. **(Caroline)** You are called to the trauma bay to evaluate a 30-year-old female with a frontal sinus fracture. A CT scan shows a comminuted fracture of the anterior table and a linear non-displaced fracture of the posterior table. There is no evidence of CSF leak. How would you manage this patient?

A linear non-displaced fracture of the posterior table if isolated is controversial. Many authors would choose to observe while others would explore and possibly obliterate. However, the presence of a concomitant comminuted anterior table fracture necessitates exploration and internal fixation for both cosmetic and functional reasons. The nasofrontal duct should also be explored to ensure patency and if the defect is severe enough, bone grafting may be necessary (i.e. iliac or rib). Obliteration would then be performed. If the posterior table fracture was significantly displaced or comminuted, most authors would advocate cranialization.

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Although rarely encountered, there remain indications for obliteration and reconstruction of the frontal sinus, including traumatic disruption of the frontal nasal drainage apparatus and significantly displaced posterior table fracture, advanced suppuration with epidural abscess or meningitis, loss of significant portions of the anterior table of the frontal sinus, and failure of endoscopic approaches to satisfactorily communicate the frontal sinus and the nasal cavity. Autologous tissues used include fat, muscle, pericranial flaps, or cancellous bone. The failure of synthetic materials to become vascularized and fully integrate with native tissues results in their high percentage of infection and extrusion.

*Laryngoscope* 2002;112:32-6. **Frontal sinus obliteration with hydroxyapatite cement.**

The technique the authors describe represents a modification of the pericranial flap transposition used for anterior cranial base reconstruction. A foreshortened pericranial flap is harvested and placed across the floor of the frontal sinus and into the introitus of the nasofrontal ducts to aid in partitioning the frontal from the lower sinuses. The use of this watertight, immunologically competent barrier further reduces the probability of retrograde infection. Hydroxyapatite in the liquid phase is contoured to both completely fill the three-dimensional defects in the frontal sinus and reestablish an acceptable forehead contour. This method eliminates the need for a second operative site with potential donor site morbidities.

*Otolaryngol Head Neck Surg.* 2001;124:304-7. **Frontal sinus obliteration with the pericranial flap.**

Frontal sinus obliteration is often accomplished by autologous grafts such as fat, muscle, or bone. These avascular grafts carry an increased risk of resorption and infection as well as donor site morbidity. Vascular regional flaps may be used to
obliterate small sinuses with less morbidity. The scalp is the soft tissue covering of the cranium. It consists of 5 layers: skin, subcutaneous tissue, aponeurosis and muscle, loose areolar tissue, and pericranium. The pericranial flap is a composite flap consisting of the pericranium and the overlying loose areolar tissue. Hydroxyapatite cement has recently become more popular for sinus obliteration because of its ease of use and lack of donor site morbidity. Placement of hydroxyapatite cement in acutely infected sinuses is not advisable. In addition, hydroxyapatite cement, like cancellous bone, may pose problems with cases requiring revision surgery. As the pericranial flap is well vascularized, it reduces the risk of infection in an often-contaminated surgical field. The pericranial flap has minimal donor site morbidity and requires no additional surgical incisions. The pericranial flap can be used successfully in cases with comminuted frontonasal sinus fractures, as it does not rely on the bony sinus wall for its blood supply.

In comparing frontal sinus obliteration with fat, muscle, bone, and spontaneous osteoneogenesis in an experimental model, Rohrich and coworkers concluded that the method of obliteration was not critical to the success of the procedure. Rather, they stressed the importance of permanent occlusion of the nasofrontal ducts, complete removal of all frontal sinus mucosa, and removal of the inner periosteum with a high-speed drill.

Autologous tissues have the lowest failure rates and are the best tolerated in the frontal sinus. Limitations of autologous tissues relate primarily to donor site morbidity, the need for a second surgical site, and prolonged operative time.


This article uses high-resolution thin-section coronal computerized tomography (CT) scanning for patients who have anterior cranial base fractures. It classifies them into the following four major types: I, cribriform; II, frontoethmoidal; III, lateral frontal; and IV, complex (any combination of the other three types). Fractures with a maximum bone displacement that extended farther than 1 cm in any plane were classified as "large" and those less than 1 cm as "small." It then compares 48 patients who were treated by conservative (20 patients) or surgical (28 patients) means and measures their risk of posttraumatic meningitis to try and standardize decision making concerning surgical repair of traumatic CSF fistulas. There was found to be a gradation of risk: Large cribriform (Type I) were the most likely to develop posttraumatic meningitis and small lateral frontal (Type III) were the least likely. The following variables follow a trend toward inducing a high long-term risk of posttraumatic meningitis: 1) proximity to the midline (this applies primarily to the cribriform [Type I] and, to a lesser degree, to the frontoethmoidal [Type II] fractures)(ANOVA, p = 0.015); 2) large fracture displacement (1 cm) (ANOVA, p = 0.079); and 3) prolonged rhinorrhea (lasting 8 days)(analysis of variance [ANOVA], p = 0.017). These variables seem to have a cumulative effect. Fractures with these combined criteria should be repaired surgically as soon as the posttraumatic brain edema has subsided. These fractures include large cribriform (Type I) fractures with transient rhinorrhea (lasting 5–8 days) and large frontoethmoidal (Type II) fractures with prolonged rhinorrhea (lasting 8 days).

10. (tali) How would you manage the frontal sinus mucosa during an obliteration or cranialization procedure? Support your answer with data.

Pathophysiologically damaged frontal sinus mucosa is much different from intact mucosa. The submucosa tends to be thickened, fibrotic and infiltrated with chronic inflammatory cells and the mucosa tends to encyst, thins to a single cuboidal layer and is heaped up. There are large areas of mucosa devoid of cilia and there is a tendency for the cysts to expand and secrete fluid into their lumens. These cysts can erode bone by pressure or enzymatic digestion and they are prone to infection. Mucocele formation may result from injury to mucosa, fracture of the frontonasal duct or mismanagement of a frontal sinus injury.

The goal of oblitative and cranialization procedures is to remove any frontal sinus mucosa and then destroy the outflow tract into the nasal cavity if necessary. The mucosa in the ducts is everted into the nasal cavity and the superior portions are plugged with some sort of tissue (fascia, muscle, bone chips) and usually sealed with bioadhesive (fibrin glue or tisseal). In case of obliteration, all inner cortex bone should be removed from the sinus. Mucosa in the human frontal sinus is able to invaginate into pits of inner cortex bone. Donald described these as the vascular pits of Breschet (Heckler, 1987). Failure to remove mucosa from these pits can possibly lead to entrapment and late formation of mucoceles. To achieve this, a high-speed burr is recommended.