

TITLE: Frontal Sinus Fractures

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History

Frontal sinus fracture surgery was first described by Reidel in 1898, when he performed an exenteration on the frontal sinus. This was done by removing the entire anterior table of the frontal sinus. The defect was covered with skin, which left a poor cosmetic defect. Killian also performed a similar procedure in 1904, with a rim of bone over the supraorbital region, which lessened the defect, but did not entirely remove it.

It was not until 1921, when Lynch was first credited with the frontoethmoidectomy, which is removing the frontal sinus floor and ethmoids. This left the anterior table alone. Next to come along, were Bergara and Itoiz, who performed the first osteoplastic flap procedure in 1951. The flap was an anterior table flap based on an inferior pedicle of pericranium. Improvement was made by Goodale and Montgomery when they introduced obliterative frontal sinus surgery using autogenous fat. It was during this time that obliteration became popular, due to the understanding that the mucosa needed to be completely removed to prevent complications. Finally, Donald and Berstein in 1978, described the first cranialization technique, which included stripping the mucosa, plugging the nasofrontal duct and removing the entire posterior table.

Introduction

The frontal sinus is absent at birth and begins to form at age two. It is believed that this gives toddlers a harder head and protects them from fractures as they learn coordination. The anterior ethmoids begin to migrate superiorly and the frontal sinus reaches adult size at age 15. The size of the sinus reaches 30 mm tall by 25 mm wide and 19 mm deep with a total volume of 10 cm³. The sinus shape is pyramidal and asymmetrical with the base forming the medial portion. In approximately 10-20% of the population, the sinus is unilateral and missing in 4%. The sinus has two ostia on the inferior posterior floor, that are 3-4 mm in diameter and are the only drainage spot for the sinuses. They each drain into their respective infundibulums to the ethmoid sinuses. Only 15% of the population actually have a true duct, the rest, 85%, have a foramen.

The anterior table forms the glabella, forehead and brow, and averages in size from 4mm to 12 mm thick. The posterior table is significantly less thick, at 0.1 mm to 4.8 mm in size and is the boundary of the anterior table. However, the anterior table is fractured more often due to its location.

The arterial supply is from supraorbital and supratrochlear vessels. Venous drainage is through the facial veins, which go the ophthalmic vein and cavernous sinus, which connects to the foramina of Breschet. The sensory output is via the first branch of the trigeminal nerve, VI

The amount of force to create a frontal sinus fracture equals to 800-200 lbs of force. The frontal sinus is about 5-12 % of facial fractures, and therefore the incidence is 9/100000 adults. This includes about 71% causes by motor vehicles, 10% from assaults, 5% from industrial accidents, 4% from recreational activities and 6% other.

Etiology

Frontal sinus fractures are divided into three categories, anterior table, posterior table, and combinations of the two. First, the anterior table, accounts for about 33-39% of frontal sinus fractures. This type of fracture can be either displaced or non-displaced. Displaced fracture can cause nasofrontal duct obstruction. Displaced fracture can also cause cosmetic deformity. The anterior table also serves as one of the frontal bars for the horizontal buttress system of the facial skeleton. The horizontal buttress serves to help the mastication system, so frontal sinus fractures may disrupt mastication.

Isolated posterior fractures occur in <6% of fractures. As many as 33% of patients have associated CSF leaks. This chance is at its most when the posterior table is one table width displaced. The combined fractures occur in 55-67% of frontal sinus fractures. This includes nasofrontal recess fractures.

The complications of untreated sinus fractures are split into two groups, acute and chronic. Acute complications which are less than 6 month from the initial fracture include sinusitis, wound infections, meningitis, and CSF leaks. Chronic complications are chronic headaches, deformity, mucocele, delayed CSF leaks, abscess of the brain, chronic nasal drainage, and diplopia.

Workup

Initial presentation includes forehead swelling, lacerations, paresthesia, concavity of forehead, and CSF leak. All trauma patients must be triaged accordingly with evaluation of airway, breathing and circulation. Neurosurgery and Ophthalmology are best consulted with suspected frontal sinus damage. Of note, approximately 20-76% of patients with frontal sinus fractures present with coma, and 93% will have multiple fractures.

Once the trauma patient is stabilized, then a thorough head and neck examination is warranted. One must be careful, because a cosmetic deformity of the frontal anterior table may be hidden due to swelling or hematoma. Forehead laceration should be explored for frontal sinus integrity. Always clean and examine the nasal cavity or CSF rhinorrhea, and palpate the nasal bone while you at it. The medial canthal ligament should be examined at this time, as easy movement of the medial canthus suggest fractures.

Any concern for CSF should be evaluated by collection of the fluid with a beta-transferrin test as gold standard, for which least 1 millimeter of fluid is needed. A halo sign is also useful and well as routine chemistry of the fluid to check for elevated glucose of CSF.

When obtaining x-rays, the CT is gold standard, as plain films will miss about 50% of fractures that present to the ED. The CT should be axial and coronal with 1.5mm cuts. Axial views show anterior and posterior table location, severity, and degree of severity. Coronal images can help with evaluation of the sinus floor and orbital roof. Sagittal view are useful for the evaluation of the nasofrontal duct.

Treatment

The management of frontal sinus fractures can be controversial, but universal rules apply. First, long term complications can be reduced by initiating surgical treatment within the first 12-48 hrs. Also, if a CSF leak is left untreated for longer than 8 days, then rates of infection increase.

Anterior tables nondisplaced fractures can be managed with observation. Displaced fracture require surgical exploration with fixation. Mucoceles are frequent with these fractures. When exploration is performed, the integrity of the nasolacrimal duct should be tested.

Posterior fractures that are not displaced should be managed with conservative treatment. If CSF leakage is suspected, the management includes bed rest, head of bed elevation, and lumbar drain running at 10cc/hr. Again, surgical treatment is needed if the posterior table is more than one table length thick. Also, surgery should be performed before 8 days of CSF leak. With mild comminution, without CSF leak, an osteoplastic flap and sinus obliteration is used. Moderate to severe comminution, >30% fracture, requires cranialization with a pericranial flap with dural repair.

With all surgeries, exploration of the nasolacrimal duct should be done. This can be done with a probe, fluorescein dye, or methylene blue. Repair of the nasofrontal duct has a poor success rate of 30% and therefore is usually abandoned.

All patients should be counseled about the risk involved. This includes but is not limited to scar, pain, bleeding, infection, paresthesia, deformity, diplopia, CSF leak, meningitis, and mucocele for sinusitis.

In a review of cases, it was noted that out of 96 cases of frontal sinus fractures, half were anterior and half were combined fractures. Observation was employed in half the cases, and ORIF was used most often over cranialization and obliteration. The ORIF of the anterior table requires coronal incision approach. Titanium was found to be the best material when used with miniplates, otherwise there was no difference in material across the other plates.

Of recent interest is the use of endoscopy for repair of the frontal sinus. Use of this technique should be done with anterior table fractures that do not have nasofrontal duct involvement. This involves a central and two lateral hairline incisions. Soft tissue is elevated with visualization of 30-degree scope. Another incision is made through the brow and skin hooks can be used to reduce the fracture fragments, and a titanium mesh is typically applied to stabilize the fracture. It was also noted in 2008, a case report of reduction of a nasal fracture with a balloon dilator into the frontal sinus to reduce the fracture under image guidance. The balloon was left in place for 20 days to maintain reduction and removed afterward with not cosmetic deformity noted. These techniques can be

advantageous due to the less invasive nature of the procedure, less scarring, shorter OR time, reduced hospital stay and easier post operative monitoring.

Obliteration

The indications for this procedure include nasofrontal duct disruption, mucopyocele, sinusitis, displaced posterior table, anterior frontal sinus missing tissue, abscess and tumor. This procedure involves removal of all the visible mucosa. This includes the inner cortex, and typically involves the occlusion of the nasofrontal duct with a material that creates a barrier between the sinus and nasal cavity. The types of material varies greatly, but include adipose, hydroxyapatite, pericranium, bone chips, temporalis fascia, calcium phosphate, and glass ionomers. With hydroxyapatite, 30% is replaced at 12 months, 68% at 18 months. Pericranial flap obliteration is a good vascular flap, which can be supplied from the anterior supraorbital flap and the lateral anterior superficial temporal artery. It has been noted that the use of a pericranial flap between the posterior table and nasofrontal duct with the use of hydroxyapatite reduces retrograde infections. Also, in a comparison of avascular and pericranial flaps, that vascular flaps had less infection, less reabsorption, but increase donor morbidity. Obliteration success depended less on type of material used but more on technique of surgery.

Calcium phosphate is more soluble than hydroxyapatite, and has osteoconductive characteristics like bone, but creates a foreign body reaction when used over dura and is not recommended for frontal sinus disease. Glass ionomer is a glass polymer that again has similar properties to bone such as conductivity. It is available as alloplast, and currently is recommended for sinus obliteration. As of now, there has been no foreign body reactions to this material. Fat obliteration has been used extensively with success. The half-life of fat is usually 15.4 months with significant decrease of adipose tissue over time.

Cranialization

Approach is similar to obliteration. Sinus exposure rarely requires osteomies because of anterior table injury. Posterior table is removed, and can be used to reconstruct the anterior table. The dura is then repaired with 5-0 nylon sutures, with debridement and pericranial flaps for complex injuries.

Antibiotic use when given preoperatively and outside of perioperative time showed no increase rate of infection in recent article of 220 in the laryngoscope.

Follow up

Close monitoring is the key with postoperative patients. Every week for the first month and then monthly for the first year is recommended. Long term follow up yearly after that is mandatory. Serial CT scans can be useful with patient undergoing fat obliteration. MRI has high T1 intensity with scarring having low intensity. Mucocoeles have high T2 signal.

Complications

If a patient has sinusitis and failed conservative management after frontal sinus fracture, there are few options left. The outflow tract must be evaluated for obstruction. Endoscopic surgical intervention warranted. The patient may need a Lothrop procedure. Draf procedures include Draf 1-3. Draft I is removal of sinus ostium disease, Draf 2 is removal of ethmoid cells and sinus floor from lamina

papyracea to nasal septum. And Draf 3 includes bilateral enlargement with removal of septum. The flow of the sinus is from medial to lateral inferiorly and lateral to medial superiorly.

Pain management may be difficult. One should do a complete examination if the patient has frontal pain to include an MRI, looking for trigger points. Relief may come from the use of neuropathic pain medications, and local nerve block.

Conclusion

Frontal sinus fracture require a great deal of force and therefore need a complete trauma workup. A good understanding of frontal sinus anatomy and function is important for treating frontal fractures. Treatment includes following an algorithm, which is based on type and degree of fracture. One should know the different type of procedures and material available for repair. Endoscopic repair is also a viable option for anterior noncomplex fractures.

Discussant's Remarks – Patricia Maeso, MD

Dr. Martinez, that was a great presentation. Regarding the evaluation of the patient beyond the ABC's, neurosurgical and ophthalmological evaluations are not arbitrary, especially in soldiers returning from Iraqi Freedom with frontal trauma. It was reported that a significant number of them had associated brain and eye injuries that would otherwise have been missed.

The new techniques have been developed over years and we now have significant advantages including CT scans with 3-D reconstruction and image guidance which really allow us to look at the sinus anatomy and the anatomy of the ducts. I'm glad you brought up that Laryngoscope article from B.U. about prophylactic antibiotics. This is indicated for the perioperative period alone, for there is no statistically significant evidence that it will prevent infection if used beyond this period. The exception would be the patient with multiple open contaminated maxillofacial wounds.

Management varies throughout the world. For instance, in Italy they will just reduce the anterior table. In fractures of the posterior table or nasofrontal duct they do not attempt obliteration, instead going directly to cranialization. They favor this based on 98 patients undergoing pericranial flap followed for six years, complications were rare.

Our approach is as conservative as possible, including attempting to re-establish continuity of the nasofrontal duct. Now that we have endoscopic techniques available to us we may consider stenting the nasofrontal duct. Obliteration and cranialization will always be necessary in some cases but in increasingly rare instances. Our neurosurgeons seem to agree with us in this. Incidentally, calvarial bone has been used in these techniques recently.

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