Facial Trauma (FRONTAL, ORBITAL)

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Ocular, Eyelid, Eyebrow Trauma → see p. Eyelid >>
Extracranial Trauma → see p. Excr40 >>

ORBITAL RIM FRACTURES

Orbital rim is strongest part of orbit - isolated rim fractures are uncommon.

ORBITAL FLOOR FRACTURE

EtioPathophysiology

a) part of complex fractures (Le Fort II and III fractures, nasofrontoethmoidal fractures, zygomaticomaxillary complex ["tripod"] fractures).

b) isolated (blow-out) fracture - violent impact to anterior globe → hydraulic force transmission to interior of orbit → orbital contents are incompressible → orbital floor (weakest area) is usually area to give way → herniation of orbital contents down into maxillary sinus.

Fractures of orbital roof have also been reported, with herniation of contents into frontal sinus.

*only by objects with ≤ 5 cm radius of curvature, i.e. slightly larger than orbital inlet - penetrates orbital space for only short distance (e.g. fist, ball); large objects cannot compress globe because of protective architecture of orbital rim.

• second weakest part is medial wall (tamina papyracea)!

Clinical Features

1. Entrapment of inferior rectus / oblique muscle → impaired upward ocular motility → diplopia.
2. Exophthalmos (often obscured by early postinjury edema), periorbital ecchymosis.
3. Infraorbital hypoesthesia
4. Malar deformity.
5. Blowing nose → momentary exophthalmos → periorbital emphysema.
**Clinical Features**

Primary position: right eye lower than left.

Upward gaze: limitation of motion of right eye.

**DIAGNOSIS**

Thin-section coronal CT:

1) herniation of orbital contents through fracture into maxillary sinus (“hanging drop” sign)
   - in some cases, soft tissue is trapped in maxillary sinus by rectangular trapdoor of bone (bony fragment is momentarily displaced, allowing periorbital tissue to extrude into maxillary sinus, and then snaps back into place, catching soft tissue).
   - in rare fractures of medial wall of orbit, orbital contents protrude through lamina papyracea into ethmoidal air cells.
2) depression of bony fragments into maxillary sinus
3) orbital emphysema (from interruption of adjacent sinus wall)
4) clouding (or fluid level on upright films) of maxillary sinus (hemorrhage)

Sonography (alternative if CT unavailable): sensitivity 92%, specificity of 100%.

X-ray (Waters’ view): disruption & displacement of line representing orbital floor; fluid & herniated mass in maxillary sinus.

MRI is superior in showing soft-tissue herniations.

**TREATMENT**

Spontaneous resolution may occur!

- (peri)orbital emphysema is usually benign, self-limited condition.
  - N.B. if patient complains of sudden decrease in visual acuity (esp. after sneezing nose), air may have built up under pressure in orbit (= cessation of blood flow in central retinal artery);
  - H: immediate pressure release via lateral canthotomy with cantholysis or intraorbital needle aspiration of trapped air.

Repair of orbital floor (to relieve restricted extraocular muscle function + elevate lowered globe)

- many consultants delay decision to operate for 10-14 days – if diplopia or enophthalmos are still persistent (cause of impaired eye motility may be only edema of structures surrounding globe).

Infracostral approach with stepped incision: infraorbital incision or incision in one of most superior natural skin creases of lower eyelid (= intraorbital rim and floor of orbit are exposed through incision under skin-muscle flap but external to orbital septum = periosteum is incised 0.5-1 cm below attachment of orbital septum at infraorbital rim (to prevent herniation of orbital fat into surgical field).

- ORBITAL FLOOR RECONSTRUCTION using alloplastic implant (autogenous bone has no advantage)
  - as thin as will allow proper support of soft tissues.
  - placed over defect subperiosteally and rests passively in place.
- If implant protrudes from orbit without being held in place, it is too large (→ make smaller until it lies passively within orbit).

- If there is extensive comminution of orbital floor and repair cannot be maintained in reduced position → ANTRAL PACKING. see p. TH29 >>

### ORBITAL APEX FRACTURES

- May be linear and undisplaced or comminuted.
- Occasionally, entire orbital apex is completely avulsed, with apical fragment containing intact optic foramen.
- Complication - ORBITAL APEX SYNDROME: traumatic optic neuropathy + superior orbital fissure syndrome (CN3, 4, 6 injury).

Comminuted right orbital apex fracture ( axial CT): fractured right greater sphenoid wing (large arrowhead), displacement of fragments into superior orbital fissure (small arrowheads).

### ORBITAL ROOF (BLOW-IN) FRACTURES

- Frequently associated with frontal sinus and nasoethmoidal fractures.
- Involvement of superior rectus (superior oblique) muscle → loss of upward gaze. N.B. Most common cause of loss of upward gaze is orbital floor fracture! see above
- Decreased orbital volume → proptosis, much higher incidence of injury to globe and periorbital contents (than with blow-out fractures).

### FRONTAL SINUS FRACTURES (i.e. FRONTAL FRATURES THAT EXTEND INTO PARanasal SINUSES)

- Treated as “open fractures” (because of communication with paranasal sinuses).
- Look for pneumocephalus, fluid in frontal sinuses.
- If posterior wall of frontal sinus is fractured (esp. if sinus duct is violated → affected drainage → mucocele → subdural abscess) → surgical treatment (frontal sinus exenteration and craniolization):
  - Open adequate scalp flap (bicoronal incision) → develop periocular flap (alternatively – make full thickness scalp flap and dissect periocular flap immediately before using it) → frontal craniotomy.
  - Take cultures.
  - Sinus is exenterated (mucosa removed and superficial bone layer drilled with heat-generating diamond drill) and occluded with muscle, fat, or Gelfoam soaked in antibiotic solution.
  - Lacerated dura (thin in this region!) is closed (running silk suture) → reinforced with pericranial flap; graft may be performed on outer surface of dura, but it is frequently easier to perform it from inner surface after dura has been opened and frontal lobe retracted.
  - It may be necessary to ligate anterior extent of sagittal sinus if it has been injured.
  - Close sinus opening by periocular flap.
The optimal management of frontal sinus fractures remains controversial. Fortunately, the severity of these injuries has diminished with more stringent auto-safety regulations, changing the treatment paradigms used to repair these injuries. Appropriate patient selection and close follow-up may allow for conservative management strategies when dealing with frontal sinus fractures, largely replacing the more morbid and invasive techniques that have been the mainstay for years. Because acute and delayed sequelae can arise after the initial injury, patients should be thoroughly counseled about the importance of follow-up and the need to seek medical care if they develop any concerning signs or symptoms.

**KEY POINTS**

- Frontal sinus fractures represent 5% to 15% of all maxillofacial fractures; their location near the brain and orbit can predispose them to several extracranial and intracranial complications.
- Management of frontal sinus fractures is controversial, especially with regard to fractures of the frontal sinus outflow tract. Recently, there has been a trend from aggressive surgical management to more conservative therapies. The most important goal of frontal sinus fracture management is to create a safe sinus by (1) reestablishing frontal bone contour, (2) restoring patency of the drainage system, (3) obliterating or cranializing the sinus cavity if a patent drainage system cannot be reestablished, and (4) creating a watertight barrier between the intracranial system and nose to prevent infectious complications.
- Lifelong follow-up and heightened awareness for symptoms/signs of infection or mucocoele are imperative in the management of frontal sinus fractures.

**INTRODUCTION**

Frontal bar and sinus fractures constitute approximately 5% to 15% of maxillofacial fractures and typically result from high-energy collisions associated with motor vehicle accidents, assaults, and sporting injuries. 1 2 3 4 5 6 Considerable force is required to cause these fractures, and thus patients usually have other associated injuries, which should prompt a thorough initial survey and examination. To place into perspective the amount of energy required to cause frontal sinus fractures, 2.4 kN to 4 kN are required for mandibular fractures, 0.7 kN to 1.3 kN for alveolar ridge fractures, 0.9 kN to 2.9 kN for malar fractures, and 3.6 kN to 7.1 kN for frontal bar/sinus fractures 7 (Fig. 1). The anterior wall of the frontal sinus is thick and resistant to injury. It requires greater force to fracture this bone than any other facial bone. (From AO surgery reference cranial vault & skull base. Available at: www.aosurgery.org; with permission. Copyright by AO Foundation.)

The goals of frontal sinus fracture repair are multifield: (1) avoidance of short-term and long-term complications, (2) return of normal sinus function, and (3) reconstruction of the frontal bar to obtain preinjury aesthetics. In the pursuit of these endeavors, there has been a paradigm shift from aggressive surgery toward more conservative approaches with close patient follow-up.
The frontal sinus is a cavity located anterior to the frontal lobes and superior to the bony orbits. It has been thought to play a protective role for the ocular globes and brain. The sinus is bounded anteriorly by a thick table that provides the forehead with its contour. The posterior table forms the anterior wall of the anterior cranial fossa. The frontal bone surrounds the sinuses superiorly and laterally, with the sinus infundibulum above the osia and the frontal recess below. The sinus drains via a small outflow tract into the ethmoid sinus/nasal cavity. The outflow tract is hour-glass shaped with the true ostium (3–4 mm) at the narrowest portion. (From AO surgery reference cranial vault & skull base. Available at: www.aosurgery.org ; with permission. Copyright by AO Foundation.)

Fig. 2 Frontal sinus anatomy. The anterior table provides the forehead contour and is thicker than the posterior table. The sinus floor constitutes a portion of the orbital roof. The posterior table lies anterior to the anterior cranial fossa. (From AO surgery reference cranial vault & skull base. Available at: www.aosurgery.org ; with permission. Copyright by AO Foundation.)

Given its unique location, injury to the frontal bone and sinuses may be associated with potentially catastrophic consequences. 4 10 11 12 Mismatch of management of frontal sinus fractures or unpredictable scarring during healing could result in a range of complications from sinus outflow obstruction to meningitis, encephalitis, and even brain abscesses.

**Physical Examination**

Given the relatively higher force required to cause frontal bar and sinus fractures, patients should be carefully examined for accompanying injuries. Cerebrospinal fluid (CSF) rhinorrhea, orbital trauma, and neurologic abnormalities should be evaluated for. 5 6

**Imaging**

Thin-cut (1.5–5 mm) CT scans are typically obtained to help diagnose frontal sinus fractures. The axial, coronal, and sagittal images provide detailed information regarding the state of the anterior and posterior tables, the orbital roof and sinus floor, and the patency of the frontal recess, respectively. Additionally, reconstructed 3-D images are invaluable in providing a more comprehensive view of the nature and extent of frontal sinus injury. 1 3 12

**Fracture Repair Strategy**

Patients who are stable and awake can be evaluated for salty-tasting postnasal drainage and CSF rhinorrhea. Collected fluid can initially be placed onto filter paper to assess for a halo sign and sent to a laboratory for a beta-2 transferrin assay. Intraoperatively, nasofrontal outflow tract patency can be evaluated with saline, dye, and contrast studies; however, these tests may not always accurately diagnose a CSF leak because evaluation can be complicated by mucosal edema or obstructive bony debris.

Types of frontal bone/sinus fractures Frontal sinus fractures can be classified by the evaluation of 4 anatomic parameters: (1) anterior table, (2) posterior table, (3) nasofrontal recess, and (4) dural violation with or without CSF leak. 4 mm) CT scans are typically obtained to help diagnose frontal sinus fractures. The axial, coronal, and sagittal images provide detailed information regarding the state of the anterior and posterior tables, the orbital roof and sinus floor, and the patency of the frontal recess, respectively. Additionally, reconstructed 3-D images are invaluable in providing a more comprehensive view of the nature and extent of frontal sinus injury. 1 3 12

**Treatment**

The most important goal of frontal sinus fracture repair is to create a safe sinus, 12 13 using 4 basic guidelines:

1. Reestablish frontal bone contour. 2. Restore patency of the drainage system (if feasible). 3. Oblitrate the sinus cavity if a patent drainage system cannot be reestablished. 4. Create a watertight barrier between the intracranial system and nose to prevent infectious complications. 12 In general, the frontal sinus treatment algorithm usually follows one of the following approaches: observation, endoscopic repair, open resection, and internal fixation, sinus obliteration, or sinus cranialization. 5 8

**Approaches**

**Preexisting lacerations**

If a patient has a preexisting laceration over the glabella or forehead, this can be used to access the anterior table. Care should be taken not to extend the laceration.

- Advantages: there is no need for a secondary incision, and there is less soft tissue dissection to obtain exposure. • Disadvantages: if the laceration proves limited or located in a suboptimal position to obtain adequate exposure, secondary incisions (discussed later) may be required.

**Endoscopic**

The endoscopic approach uses similar incisions used in an endoscopic brow lift surgery and is best suited for mildly depressed fractures located at or above the orbital rim. 2 3 A subperiosteal dissection

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Convexity.

Clots. (E) A5
evaluation of the sinus outflow tract (which appeared patent), and extraction of bony debris and blood perforations along the fragment edges centrally; this allowed a window through which an elevator was be placed in between the fragment impacted anterior frontal table fracture. (C) A bicoronal approach was used to access the fracture.

During a soccer match. He immediately noticed (visually and tactilely) a convex deformity in the lower Fig. 5 (A) This is a 15 (see Fig. 5 E).

Smooth contour. This technique allowed direct visualization of the sinus cavity, specifically of the fixated with mesh. A thin layer of hydroxyapatite cement was pasted over the mesh, providing a

Operating room 5 days afterward. A bicoronal incision was used to gain exposure, and the collision with another individual elevation. 5 This particular technique was used in a patient of the authors' who suffered a head fracture. Comminuted, depressed fractures can result from severe trauma or from the impact of a blunt object. In such cases, the fragments may be displaced or rotated, and reduction may be difficult to achieve. Various techniques have been described for the management of comminuted, depressed frontal sinus fractures, including open and endoscopic approaches.

In situations where the fragments are unable to be elevated adequately, severe comminution typically requires a more invasive approach like a bicoronal incision to obtain optimal exposure. Prior to reapproximating the bone fragments, it is important to remove any trapped sinus mucosa between the segments, because this could lead to mucocele formation. 2

Severely impacted fractures or those that have begun to heal can be challenging to reduce. During the course of trauma to the frontal region, the frontal bone goes through a compression phase before becoming concave; the fragments need to be pulled back through the compression phase before reduction can be achieved. 5 In situations where the fragments are unable to be elevated adequately, postoperative perforations can be drilled along the edges of bone, releasing the tension and reducing the interfragmentary resistance. A bone hook can then be placed between the fragments to help with elevation. 5 This particular technique was used in a patient of the authors' who suffered a head-on collision with another individual during a soccer match and developed an isolated, impacted anterior table fracture (Fig. 5 A, B). The patient presented 2.5 weeks after his injury and was taken to the operating room 5 days afterward. A bicoronal incision was used to gain exposure, and the anterior table fractures were found to be impacted (see Fig. 5 C). A drill was used to create postoperative perforations along the front fragments, at which time a percutaneous incision is made and a burr is extended. A microplate is then screwed into place to camouflage the defect. 3 15

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Facial trauma. Philadelphia: Jaypee; 2016. p. 64; with permission.)

The latter approach allows the complete repair occurs in a bimodal pattern; it can either be repaired acutely within 1 day to 10
rightful scar in patient

Direct brow incision

Direct brow incision

Isolated nondisplaced anterior table fractures

Isolated nondisplaced anterior table fractures

Comminuted, depressed fractures

Fractures with 2 mm to 6 mm of displacement are associated with increased risk of forehead contour deformity, and either acute reduction or delayed camouflage is recommended. In general, fracture depression requires a prolonged course of treatment, including physical therapy and orthotic devices. 2

If a fracture is not severely comminuted or impacted, an endoscopic approach may be used to reduce the bone fragments and restore contour with mesh. More severely comminuted fractures typically require a more invasive approach like a bicoronal incision to obtain optimal exposure. Prior to reapproximating the bone fragments, it is important to remove any trapped sinus mucosa between the segments, because this could lead to mucocele formation. 2

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In cases of severe comminution, attempted reduction of fragments may lead to large bone gaps that need to be replaced with split bone grafts, usually from the calvarium. 8 Sinus obliteration is typically reserved for cases in which severe fractures of the anterior and/or posterior table render the frontal sinus nonfunctional. During the procedure, there must be complete removal of the sinus mucosa, especially of the scalloped areas around the orbits and laterally at the periphery of the sinus. The frontal sinus obliteration is performed using a mucosal stripping technique, which involves invaginating the sinus mucosa (Fig. 6A) and inverted invagination may be created to seal the sinus. The frontal sinusal muscularis of the anterior table is allowed to expand into the space previously occupied by the frontal sinus. The sinus cavity is obliterated with one of many autologous materials (such as autogenous fat, pericranium, cancellous bone, and/or muscle). Complete removal of the sinus mucosa is imperative for successful outcomes, because residual mucosa can lead to chronic sinusitis, mucoceles, and pain, which can require secondary interventions. 5 On removing the sinus mucosa, the inner bony cortex is burred, because this ensures a clean cavity as well as the potential for vascularization of the fat graft used for obliteration. 15

Delayed presentation
In patients who present for treatment many weeks or months after their injury, forehead edema has largely resolved, and contour deformity may be better assessed. Certainly, fully healed fractures are not amenable to traditional open reduction. 3 If the aesthetic deformity remains obvious, the defect can be camouflaged. Through an endoscopic or coronal incision, bio compatible materials that are malleable and stable over time (titanium mesh, hydroxyapatite cement, methyl methacrylate, and polyether ether ketone implants) can be used to improve forehead contour. 17

Posterior table fractures
Treatment recommendations for posterior table fractures are complex and controversial, because they are usually associated with the anterior table, fovea ethmoidalis, and cribiform plate as well. 15 Because the anterior table can withstand up to 998 kg of force, it serves to protect the posterior table and brain parenchyma; thus, if the posterior table is indeed fractured, there is a higher likelihood of other severe injuries (central nervous system, truncal, and extremity). 8 10 15 18 Although some surgeons use the thickness of the posterior table (approximately 2 mm) as a metric for determining the acceptable posterior wall displacement for nonsurgical therapy, 5 others believe that all posterior table fractures warrant surgical exploration to rule out dural tears and frontal sinus recess injury. 8 12 Comminuted posterior table fractures with CSF leaks and nasofrontal ostia involvement have traditionally led to surgical exploration because of the risk of long-term complications. 12 13 18

Many investigators believe that the amount of displacement of the posterior table is not the main factor in determining whether surgical intervention is required, rather, the presence or absence of a CSF leak and the presence of absence of frontal outflow tract injury are key determinants in making treatment decisions. 18

Minimally displaced fractures plus cerebrospinal fluid leak plus no frontal outflow tract injury
Patients with minimally displaced posterior table fractures and no apparent frontal outflow tract injury may be observed. If a CSF leak is apparent at the time of examination, conservative therapy (snood softener, head of bed elevation, and sneezing through open mouth) for 1 week is indicated. A lumbar drain can be considered to lessen the pressure at the level of the dural tear. If there is no spontaneous resolution within 1 week to 2 weeks, exploration with possible dural repair and/or sinus obliteration is recommended. The incidence of posttraumatic meningitis can range anywhere from 3% to 30%, but it increases when the leak persists beyond 7 days. Dural repair can be performed with several biocompatible materials as well as native tissue like temporalis fascia, after which it may be reinforced with a pericranial flap to provide additional vascularized tissue. 12

Gassner and colleagues 16 describe a minimally invasive transorbital approach to sealing dural defects (eg, for subdural air) after posterior table fractures. Through a suprasupratarsal incision, the fractured posterior table is encountered, and sealing material (autologous tissues or sponge, like fibrin sealant patch) can be used to seal the defect ( Fig. 6 ).

Fig. 6 ( A ) This CT scan is of a 55-year-old man who presented with a fractured posterior frontal table as well as subdural air on the right side. ( B ) A suprasupratarsal incision was used to expose the comminuted anterior table and gain access to the lateral posterior table fracture with subsequent placement of fibrin sealant patch to seal the subdural air. ( From Gassner HG, Schovan F, Scheschke KM. Transorbital approaches: minimally invasive access to the anterior skull base. Chapter 6. Boahene KD, editor. Minimal access skull base surgery. Philadelphia: Jaypee; 2016. p. 69. With permission.)

Moderately to severely displaced fractures plus cerebrospinal fluid leak plus frontal outflow tract injury
More severely displaced and fractured posterior tables are associated with frontal outflow tract injury and meningitis. 18 If there is a severely comminuted posterior table fracture or CSF leak if the injury or repair causes disruption of greater than 25% to 30% of the posterior table, sinus craniolization has traditionally been the recommended treatment modality. During sinus craniolization, a pericranial flap should be carefully elevated and harvested for use as a barrier to separate the anterior skull base from the nasal cavity. 6 Bone fragments from both the anterior and posterior tables are removed, and the dura is carefully separated from the remaining posterior table. The sinus mucosa is completely stripped, and the remaining bone is burred to remove mucosal lining invaginations along the channels of Brochet. The frontal recess is occluded, and the posterior table is reconstructed after the anterior lobe is allowed to expand into the space previously held by the frontal sinus. Some surgeons prefer to use a pericranial flap with fibrin glue to occlude the

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In patients who present for treatment many weeks or months after their injury, forehead edema has largely resolved, and contour deformity may be better assessed. Certainly, fully healed fractures are not amenable to traditional open reduction. 3 If the aesthetic deformity remains obvious, the defect can be camouflaged. Through an endoscopic or coronal incision, bio compatible materials that are malleable and stable over time (titanium mesh, hydroxyapatite cement, methyl methacrylate, and polyether ether ketone implants) can be used to improve forehead contour. 17

Posterior table fractures
Treatment recommendations for posterior table fractures are complex and controversial, because they are usually associated with the anterior table, fovea ethmoidalis, and cribiform plate as well. 15 Because the anterior table can withstand up to 998 kg of force, it serves to protect the posterior table and brain parenchyma; thus, if the posterior table is indeed fractured, there is a higher likelihood of other severe injuries (central nervous system, truncal, and extremity). 8 10 15 18 Although some surgeons use the thickness of the posterior table (approximately 2 mm) as a metric for determining the acceptable posterior wall displacement for nonsurgical therapy, 5 others believe that all posterior table fractures warrant surgical exploration to rule out dural tears and frontal sinus recess injury. 8 12 Comminuted posterior table fractures with CSF leaks and nasofrontal ostia involvement have traditionally led to surgical exploration because of the risk of long-term complications. 12 13 18

Many investigators believe that the amount of displacement of the posterior table is not the main factor in determining whether surgical intervention is required, rather, the presence or absence of a CSF leak and the presence of absence of frontal outflow tract injury are key determinants in making treatment decisions. 18

Minimally displaced fractures plus cerebrospinal fluid leak plus no frontal outflow tract injury
Patients with minimally displaced posterior table fractures and no apparent frontal outflow tract injury may be observed. If a CSF leak is apparent at the time of examination, conservative therapy (snood softener, head of bed elevation, and sneezing through open mouth) for 1 week is indicated. A lumbar drain can be considered to lessen the pressure at the level of the dural tear. If there is no spontaneous resolution within 1 week to 2 weeks, exploration with possible dural repair and/or sinus obliteration is recommended. The incidence of posttraumatic meningitis can range anywhere from 3% to 30%, but it increases when the leak persists beyond 7 days. Dural repair can be performed with several biocompatible materials as well as native tissue like temporalis fascia, after which it may be reinforced with a pericranial flap to provide additional vascularized tissue. 12

Gassner and colleagues 16 describe a minimally invasive transorbital approach to sealing dural defects (eg, for subdural air) after posterior table fractures. Through a suprasupratarsal incision, the fractured posterior table is encountered, and sealing material (autologous tissues or sponge, like fibrin sealant patch) can be used to seal the defect ( Fig. 6 ).

Fig. 6 ( A ) This CT scan is of a 55-year-old man who presented with a fractured posterior frontal table as well as subdural air on the right side. ( B ) A suprasupratarsal incision was used to expose the comminuted anterior table and gain access to the lateral posterior table fracture with subsequent placement of fibrin sealant patch to seal the subdural air. ( From Gassner HG, Schovan F, Scheschke KM. Transorbital approaches: minimally invasive access to the anterior skull base. Chapter 6. Boahene KD, editor. Minimal access skull base surgery. Philadelphia: Jaypee; 2016. p. 69. With permission.)

Moderately to severely displaced fractures plus cerebrospinal fluid leak plus frontal outflow tract injury
More severely displaced and fractured posterior tables are associated with frontal outflow tract injury and meningitis. 18 If there is a severely comminuted posterior table fracture or CSF leak if the injury or repair causes disruption of greater than 25% to 30% of the posterior table, sinus craniolization has traditionally been the recommended treatment modality. During sinus craniolization, a pericranial flap should be carefully elevated and harvested for use as a barrier to separate the anterior skull base from the nasal cavity. 6 Bone fragments from both the anterior and posterior tables are removed, and the dura is carefully separated from the remaining posterior table. The sinus mucosa is completely stripped, and the remaining bone is burred to remove mucosal lining invaginations along the channels of Brochet. The frontal recess is occluded, and the posterior table is reconstructed after the anterior lobe is allowed to expand into the space previously held by the frontal sinus. Some surgeons prefer to use a pericranial flap with fibrin glue to occlude the
Recently, changing guidelines that reflect recent trends (mechanism and severity of injury) have encouraged more conservative management of injuries that may not previously meet the criteria for craniolization. In 1 study, for example, 7 of 59 patients who met the criteria for craniolization were instead observed; no complications were seen at 92 days, but these data are limited by the paucity of long-term follow-up.

Frontal sinus recess/frontal sinus outflow tract injury

Considered fractures of the anterior and posterior tables are usually accompanied by injuries to the frontal-outflow tract (6) Fig. 7. Patency of the tract is essential in preventing serious early and late complications, 13 but the decision to treat these injuries is a challenging one, because high rates of postoperative stenosis have been associated with recanalizing the nasofrontal ostia with mucosal flaps and stents.

Fig. 7 A frontal recess injury involves the floor of the frontal sinus and the outflow tract. The green arrow delineates the frontal sinus drainage pathway. It may also involve the anterior skull base. (From AO Foundation Craniofacial Neurosurgery Cranial Vault and Skull Base. Available at: www.aosurgery.org ; with permission. Copyright by AO Foundation, Switzerland.)

Typically, sinus obliteration is indicated when there is a high likelihood that the sinus will be nonfunctional and the patient is a sequel to a sinus fracture. Obliteration requires (1) complete removal of sinus mucosa, (2) removal of the internal sinus bone cortex with a burr, (3) occlusion of nasofrontal ostia, and (4) filling of the sinus cavity. If the posterior table fracture is significantly comminuted or there is dural injury, craniolization may need to be performed, as previously described.

In the setting of traumatic injury (as opposed to cases of chronic frontal sinuitis), effective obliteration is usually more challenging to achieve secondary to comminution of bone, difficulties with effectively removing all of the sinus mucosa, and inherent issues with bone fragment devascularization and their subsequent resorption. If the adipose fat graft used for obliteration does not have an adequate vascular bed, it can resorb and undergo necrosis, ultimately forcing the sinus to undergo an incomplete process of auto-obliteration.

In light of these challenges, studies have recently come forth examining the role of conservative management in cases of frontal outflow tract injury. A recent study by DeConde and colleagues 4 reviewed 19 patients with frontal sinus fractures; of them had injuries that also involved the frontal recess, and 7 of these patients were managed conservatively. Interval CT imaging (mean: 73.9 ± 49.6 weeks) showed spontaneous clearance of sinus opacification. Only 1 of the 8 patients continued to have persistent sinus opacification and ocular symptoms, but that patient's injury involved the naso-orbitoethmoid complex and had significant comminution of the orbital walls. The investigators extend their findings, suggesting that most patients with frontal sinus fractures (involving the frontal recess) without significant medial wall blowouts and obstruction may be offered conservative management and close follow up.

This study as well as others suggest that in patients with frontal sinus fractures with frontal recess involvement and concomitant naso-orbitoethmoid fractures, there should be stronger consideration to surgically intervene, because obstruction of the frontal recess by orbital contents may impede ventilation. The superior margin of the nasal bones is above the frontal sinus floor, and, therefore, displaced fractures involve the frontal outflow tract and potentially disrupt the outflow tract into the ethmoid sinuses.

Smith and colleagues 9 propose the following treatment protocol in patients with anterior frontal sinus wall fractures with anterior wall fracture injury (1) assessment of nasofrontal outflow tract with CT, (2) restoration of the anterior table fragments with rigid fixation, (3) postoperative broad-spectrum antibiotics for 4 weeks, and (4) serial postoperative CT scans to check for ventilation. After conservative management, in patients whom frontal sinus obstruction persists, endoscopic frontal sinuositytom or an endoscopic Lott procedure is also a viable option to reestablish mucociliary clearance.

These results certainly depend on patient follow-up, and this is a clear limitation—especially in the cohort of patients who suffer facial trauma in the first place. 15 Although the basic tenet of frontal sinus obliteration for the treatment of frontal outflow tract injuries still stands, the more conservative regimen with close follow-up is becoming more mainstream for all types of frontal sinus fractures. Prospective studies with long-term follow-up data need to be analyzed, but there is certainly a current shift in trends.

COMPICATIONS

The immediate consequence of the frontal bone and sinus with the brain and orbit plays a significant factor in the potentially catastrophic consequences that injury to this area can cause. Frontal sinus outflow obstruction can lead to problems like chronic sinusitis, chronic pain, chronic osteomyelitis, Pott puffy tumours, osteoradionecrosis, and meningitis. Other associated problems include meningeal, encephalitis, and brain abscesses may develop as well.

Treatment of fractures, depending on the approach, certainly carries risks. These include bleeding, pain, hematoma, infection, mesh extrusion, infection of biocompatible products, alopecia, scar, paresthesia, frontal nerve injury, and persistent forehead contour deformity. Sometimes, the approach taken to improve the contour may lead to adverse effects on their own. Frontal sinus obliteration and their stenoting in the acute setting can cause restenosis, and frontal sinuositytom at the time of expiration can result in anosmia. 9 Cranialization requires a craniotomy, and it is a morbid procedure associated with complications like abscesses or increased intracranial pressure requiring decompression.

In patients with poor compliance, serial examinations and radiographic imaging may not be feasible, in the patient's best interest, or aggressive intervention with osteotomy may lead to advancements at the time of acute injury is favored. 9 Complications are normally easier to prevent than to treat, so careful surveillance with serial imaging, diligent follow-up, and vigilance on the patient end are imperative.

CONTROVERSIES

The management of frontal sinus fractures has remained debated and will evolve further with time. Typically, anterior table fractures with forehead contour deformity likely necessitate intervention to improve aesthetics. What is not as clearly delineated is the need for surgical intervention in managing the injured posterior table and frontal outflow tract in the absence of persistent CSF leaks or excessive debris. Frontal sinus fracture treatment paradigms were largely established before modern endoscopic and imaging techniques were born and, therefore, may not accurately reflect current trends. Moreover, present-day frontal sinus fracture patterns may not represent the conclusions of previous studies,
because airbag safety systems and improved seatbelt compliance have slowly changed the mechanisms of frontal sinus fractures from high-impact injuries to lower ones associated with interpersonal violence and sports. An obvious trend is the movement away from trephination, frontal outflow tract stenting, and frontal sinus ablation for fracture management.

**SUMMARY**

The optimal management of frontal sinus fractures remains controversial, even among several surgical specialties. Fortunately, the severity of these injuries has diminished with increased seatbelt compliance and with more stringent auto-safety regulations. This, then has changed the treatment paradigms used to repair these injuries. Appropriate patient selection and close follow-up may allow for conservative management strategies when dealing with frontal sinus fractures, largely replacing the more morbid and invasive techniques that have been the mainstay for years. Lengthier follow-up data are required to make any conclusions about these approaches, however.

Acute and delayed sequelae, like mucocele formation, sinusitis, contour deformity, and chronic sinusitis, can occur immediately or years after the initial injury. Therefore, patients should be thoroughly counseled about the importance of follow-up and the need to seek medical care if they develop any concerning signs or symptoms, such as frontal headaches, symptoms consistent with chronic or recurrent sinusitis, and swelling/tenderness.

**BIBLIOGRAPHY** for ch. “Head Trauma” → follow this [LINK]