Frontal Sinus Fractures: A Conservative Shift

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Abstract

Keywords

- frontal sinus fractures
- cranialization
- sinus obliteration
- nasofrontal duct
- injury

This article reflects on the changing management of frontal sinus fractures. Severity of these injuries has decreased tremendously since the universal adoption of seat belts and air bags. Recently, there has been a shift from aggressive surgical management to more conservative management strategies, some forgoing surgery all together. New technologies, such as bioabsorbable plates and endoscopic sinus surgery, are leading the way in improved surgical management strategies and offer promising alternatives to the more traditional approaches.

Frontal sinus fractures are relatively uncommon, associated with only 5 to 12% of all facial injuries.^{1,2} Majority of these injuries are secondary to assault and motor vehicle accidents (MVA).³ Airbags and safety belts have led to a decrease in severity and frequency of MVA-related frontal sinus fractures over the past 30 years.⁴ Most of the guidelines we use for management were derived from old studies where the injuries were typically more devastating. Decreased severity of injuries and advancements in technology may give us the opportunity to employ more conservative approaches to fracture management.

Studies by Rohrich and Hollier and Manson attempted to establish guidelines for modern management of frontal sinus fractures.^{2,5,6} With improvement in multiple technologies, the reconstructive surgeons' armamentarium has grown over the past 20 years. This article highlights the advancements in frontal sinus fracture management and documents the trend from aggressive to conservative management strategies.

History

Management of frontal sinus fractures has evolved tremendously over the past 100 years. The early surgical techniques for management of frontal sinus fractures were derived from the treatment of frontal sinusitis and resultant complications, such as mucopyocele. The ablation technique was used for management of sinusitis as early as 1898. This procedure

involved permanent removal of the anterior table, resulting in significant disfigurement.^{7,8} The osteoplastic flap, created in 1955, represented a significant advancement in frontal sinus management. This flap removed the frontal wall of the sinus along with a pericranial pedicle. This allowed replacement of the bone after exploration of the sinus and resulted in improved cosmesis.⁹ This flap was modified for use in frontal sinus trauma and has been associated with minimal morbidity.^{10–13} These procedures paved the way for open reduction and internal fixation (ORIF), sinus obliteration, and cranialization of the frontal sinus.

Seatbelts and airbags have changed the nature and incidence of frontal sinus fractures. Until around 1986, 70% of frontal sinus fractures were caused by MVA.¹⁴ This decreased significantly to around 52% in 2002, with a larger proportion attributable to assault.⁴ Over this same time period, a decrease in severity of frontal sinus fractures was observed. "Through and through" injuries with violation of the anterior cranial fossa fell from 40 to 11% from 1987 to 2002. Improvements in motor vehicle safety standards have contributed significantly to the decline in facial trauma. Roden et al, found that facial fractures from motor vehicle collisions decreased from 40 to 27% from 2005 to 2010.¹⁵ As the incidence has declined, experience in caring for these injuries has also dropped. Truly devastating frontal sinus fractures are rarely seen. Airbags and safety belts have lessened the injuries sustained in car crashes and aggravated assault cannot

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generate the same destructive energy as a car crash. This decrease in severity has led to the increased use of conservative management for frontal sinus injuries.

Anterior Table Fractures

The principles of management of anterior table fractures have changed very little over the years. New technologies and techniques have expanded the surgeon's tool box for restoration of forehead cosmesis. Since the primary aim of surgery in isolated anterior table fractures is cosmetic, adequate counseling of the patient regarding observation and various surgical options should be undertaken.

Isolated anterior table fractures are the most common frontal sinus injuries, representing one-third of all frontal sinus fractures.¹⁶ The decision to operate is dependent on two things: (1) amount of aesthetic deformity and (2) involvement of the nasofrontal duct.^{2,7,17} Duct involvement should be assumed if the fracture involves the ethmoids, medial superior orbital rim or orbital roof (→**Fig. 1**).^{2,7} Minimally displaced anterior table fractures can be observed if there is no involvement of the nasofrontal duct.^{7,18} For simple fractures without duct involvement, surgical correction can be left to patient preference and the desire to restore forehead contour.

ORIF of isolated anterior table injuries is the most commonly employed treatment. Microplates have been used for fixation of fracture fragments, including severely comminuted fractures, with great success (→**Fig. 2**).¹⁹ Despite their success, these metallic microplates have some drawbacks, such as palpability, migration, and extrusion.²⁰ The development of bioabsorbable plates for fracture fixation may help address these issues while still providing rigidity and strength during the healing process. Bioabsorbable plates have been shown to be effective for anterior table fracture fixation in several limited studies.^{21,22} Kim et al used bioabsorbable mesh plates for fixation of 14 patients. At a mean follow-up of 17.5 months there were no reported complica-

Figure 1 Computed tomography slice demonstrating involvement of the medial orbital wall and the ethmoids associated with a frontal sinus fracture. It should be assumed that the nasofrontal duct is injured with these findings.

Figure 2 Microplate fixation of an anterior table fracture.

tions. The authors state that mesh bioabsorbables are easier to work with than the traditional bioabsorbable plate and screw system. These meshes allow the surgeon to place a screw anywhere within the implant allowing easy fixation of complex fractures.²¹ Despite the benefits of bioabsorbable plates, there are pitfalls that the surgeon should be aware of. These plates have been associated with late-onset sterile abscess and granuloma formation.^{23–25} The thick conventional bioabsorbable plates can be difficult to handle and use in the frontal sinus region.²¹ There are pros and cons to both bioabsorbable and metallic plates. Ultimately, the type of plate used in repair of frontal sinus fractures is determined by surgeon preference.

Advancements in endoscopic surgery have led to promising minimally invasive techniques for simple anterior table fracture fixation. Simple anterior table fractures have been successfully reduced and fixated using endoscopes.²⁶ This technique was first described in 1996 by Graham and Spring.²⁷ Endoscopic fixation of anterior table injuries is based on the endoscopic brow lift procedure. One additional incision is made over the fracture for placement of a screw for elevation of the fracture fragments.^{28,29} This technique is advantageous since it avoids the coronal incisions used in ORIF. Coronal incisions have been associated with alopecia, paresthesias, and temporal wasting.²⁹ Coronal incisions can be avoided in open frontal sinus fractures as well. The laceration overlying the frontal sinus fracture can be extended laterally to provide adequate exposure with fixation performed through the laceration.³⁰

Posterior Table Fractures

Posterior table fractures are frequently associated with severe anterior table, fovea ethmoidalis, and cribriform plate fractures.⁵ The anterior table can withstand from 800 to 2200 lb of force before fracture, making it one of the strongest bones of the face.^{2,31} This quality acts as protection for the posterior table, adjacent dura, and brain parenchyma in low-velocity injuries. Only with a substantial amount of force can injuries to the posterior table occur. As a result of this, they are often

Figure 3 Operative photo of a mucocoele that formed a year after initial repair of frontal sinus fracture.

associated with intracranial injuries, dural tears, and other injuries associated with high-impact trauma.^{14,31–34} The major sequelae of a dural tear and a posterior table fracture is the creation of a communication between the once isolated intracranial contents and the sinuses. This injury creates a pathway for infections to ascend into the intracranial region and has historically required surgical intervention.^{2,7,14}

Complications from this injury have been classified as early (< 6 mo) and late ($\geq$ 6 mo). Early complications include sinusitis, cerebrospinal fluid (CSF) leaks and meningitis. Late complications include mucocoeles, mucopyoceles, and brain abscesses (**Fig. 3**).^{2,35} The goal of management is to prevent these early and late complications, but the best way to do this is under considerable debate.

CSF leaks are some of the most common problems following combined anterior and posterior table fractures. After 7 days, persistent CSF leaks increase the likelihood of meningitis.³⁶ This is important since meningitis can be easily missed in patients with severe head trauma. Therefore, persistent CSF leaks are generally treated aggressively with cranialization. Rohrich and Hollier (1992) came up with an algorithm for cranialization that is still used today. They recommend urgent

cranialization for posterior table fractures with severe comminution, displacement greater than one table width, and a CSF leak.² Posterior table fractures with CSF leaks in the absence of these other findings are generally observed for 7 days before attempting cranialization.^{2,35} It has been observed that many of these leaks will resolve on their own. A minimally or nondisplaced posterior table fracture without CSF leak requires no intervention.² Associated nasofrontal duct injuries and anterior wall fractures are treated as they would be typically.

Recently, an argument has been made for conservative management of these injuries despite meeting criteria for cranialization. Cranialization requires craniotomy, removal of the posterior table, removal of all sinus mucosa, closure of the dura, and closure of any communication with the sinonasal tract (**Fig. 4**).^{2,33,34,37–40} This procedure is aggressive and not without risk. It requires a plastic surgeon, a neurosurgeon, and significant operative time. Recently, Choi et al reviewed 59 patients with posterior table fractures. Of these, seven patients met the above criteria for cranialization. However, none of these seven patients underwent cranialization and there were no complications at a mean follow-up of 92 days.³ This article demonstrates that conservative management could be a safe and effective strategy for patients who traditionally meet the requirements for cranialization. A significant limitation of this approach is that close follow-up is necessary to ensure that patients do not develop complications (**Fig. 5**). This study promotes a significant departure from the established school of thought. It replaces the idea of radical surgery with a watch and wait approach for severe posterior table fractures with CSF leaks. The incidence of long term complications, such as mucocoeles, in these patients remains to be seen and further follow-up is warranted.

Nasofrontal Duct Injury

Nasofrontal duct injuries are seen with approximately 25 to 50% of anterior table fractures that involve the supraorbital rim or the nasal–orbital–ethmoidal region.^{11–13,41} Patency of

Figure 4 (A) Intraoperative picture of a cranialization procedure before exclusion of the sinonasal tract. (B) Intraoperative picture demonstrating exclusion of the sinonasal tract using a pericranial flap.

Figure 5 Computed tomography (CT) scan follow-up after conservative management following anterior and posterior table injuries. (A) Initial CT scan at the time of injury. (B) A 3-month follow-up CT scan demonstrating no complications and adequate bony healing. If the frontal sinus is opacified, this may indicate an occult nasofrontal duct injury.

the nasofrontal duct is paramount in preventing serious early and late complications, such as formation of a mucopyocele or infection.^{18,42} Stents have been used with limited success and up to 30% fail to maintain patency after removal.^{2,40} The current mainstay of treatment is to obliterate the nasofrontal duct and frontal sinus, isolating the frontal sinus from the sinus tract. The principles of this technique are extirpation of all frontal sinus mucosa using a microscope, removal of the inner cortex of the sinus wall, and permanent occlusion of the nasofrontal duct with muscle, fascia or bone chips.^{2,43} Once these steps are done, obliteration of the frontal sinus is completed by filling the dead space of the sinus cavity. It is believed that filling the frontal sinus may mitigate the risk of infection and prevent accumulation of serosanguineous fluid.^{9,19}

Spontaneous osteogenesis, bone, bone substitutes, autologous fat, pericranial flaps, and muscle have all been used to effectively fill the frontal sinus.^{44–49} Autologous fat is one of the most studied and commonly used materials.^{9,50–52} It is thought that some of the fat graft becomes vascularized by the blood supply of the frontal sinus after removal of the inner bony cortex.⁹ This viable fat tissue may be more resistant to infection while the nonviable fat graft becomes fibrous tissue filling the dead space of the frontal sinus.^{9,53} Spontaneous osteogenesis, another commonly used technique, is based on the principle that a cavity surrounded by healthy, bleeding bone will fill in with new bone obliterating the dead space.^{19,45,54,55} Animal studies have not demonstrated a significant difference between the use of fat, muscle, bone or spontaneous osteogenesis for filling the frontal sinus dead space.⁴⁵ Human studies are limited to noncomparative studies without uniform operative techniques. Since no clear superior choice has emerged in the literature, filling material is usually based on the surgeon's preference. Use of synthetic

bone substitutes should generally never be used, especially in acute or contaminated fractures. The risk of infection and reoperation is too high.^{7,47,56–60}

Advancements in endoscopic sinus surgery have led to promising new techniques in limited situations.^{61–63} Smith et al described a new algorithm for the treatment of simple anterior table fractures with nasofrontal duct injury. In this algorithm, open repair and internal fixation was performed without obliteration. Patients were closely followed undergoing serial computed tomography and 4 weeks of antibiotic therapy. The majority of the patients they observed spontaneously regained patency of the nasofrontal duct. Two patients underwent endoscopic sinus surgery for persistent frontal sinus outflow obstruction without significant complications or restenosis at 21 and 25 months after injury.⁶¹ Despite these results, Smith's work is still a cautionary tale. Reliance on patient follow-up is a big limitation seen with these more conservative approaches. Also, manipulation of the nasofrontal duct with an endoscope can lead to edema in the acute setting and scarring/stenosis in the long term.⁶⁴ Ung et al described the use of endoscopic surgery for obliteration of the frontal sinus in chronic frontal sinusitis. They also compared this technique to the traditional open technique and found decreased morbidity using the endoscopic technique.⁶³ How endoscopic obliteration will fare in the setting of trauma remains to be seen and further studies are still needed. The watch and wait approach with close follow-up and intervention as needed is becoming more mainstream for all types of frontal sinus injuries.

In summary, the current management of frontal sinus fractures with associated nasofrontal duct injury calls for obliteration of the frontal sinus. Untreated obstruction of the nasofrontal duct, incomplete removal of sinus mucosa, and failure to close the nasofrontal duct can lead to mucopyocele

and mucocele formation, even years after the injury.^{19,40,43,45} The basic tenets of frontal sinus obliteration described by Rohrich and Hollier (1992) are still the guiding principles in the treatment of nasofrontal duct injuries. However, watch and wait approaches for management of frontal sinus fractures are promising when close follow-up can be assured.

Conclusion

The management of frontal sinus fractures has evolved tremendously over the years. Multiple new techniques and technologies have the potential to revolutionize frontal sinus fracture management. Decreased reliance on major procedures, such as cranialization, with increased utilization of minimally invasive techniques will provide surgeons more options to safely and effectively care for these injuries. Endoscopic procedures are promising and will likely lead the way. Not only are the techniques and technologies changing, but so are the management strategies. Careful patient selection to ensure close follow-up may allow the utilization of conservative management strategies when appropriate. The mechanisms of injury have changed over the years as have the severity of injuries. New treatment algorithms should be established to include these newer techniques and devices.

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