

Clinical Article



Traumatic Frontal Sinus Fractures Management: Experience from High-Trauma Centre

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Conflict of Interest

The authors have no financial conflicts of interest.

ABSTRACT

Objective: Analysis of our traumatic brain injury data, reviewing current literatures and assessing planning valuable decision making in frontal sinus fracture for young neurosurgeons.

Methods: Hospital data base for head trauma was retrieved after board permission for retrospective analysis of cases admitted from 2010–2020. Patients with frontal sinus fractures and head trauma were identified according to a flow chart. Variables of the study included patients' demographics, mechanism of injury, incidence of cerebrospinal fluid (CSF) leakage, types of associated injuries, imaging findings and operative techniques.

Results: Three-hundred eighty two patients were eligible to be screened in our study and represented the sample size under investigations in the following sections, 206 (53.9%) of patients were treated conservatively while 176 patients (46.1%) were identified as having an indication for surgical intervention. Eighty-four percent of patients were males. The mean age was 36.2±9.4 years (14–86 years). Depressed skull fracture was commonly associated injury (17.61%). Leakage of CSF was found in 32.95% of patients.

Conclusion: Frontal sinus fracture is not an easy scenario. It harbors many proportions and deliver many varieties in which, deep understanding of anatomy, naso-frontal outflow tract status, CSF leakage and neurological injury are of important points in decision. Our institutional algorithm provide rapid, accessible and applicable treatment protocol for resident and young neurosurgeons which minimizes consultations of other specialties.

Keywords: Frontal sinus; Anterior cranial fossa; Trauma

INTRODUCTION

Frontal sinus fractures (FSF) constituted 5%–15% of all facial fractures.^{2,12,18,48} Sinus fractures are usually a result of high-velocity fracture.^{34,40} The acute complications of FSF are cerebrospinal fluid (CSF) leak,² meningitis,⁴¹ cerebritis,^{10,14} mucocele and muco-pyocele.²⁹ FSF are common shared area of interest between neurosurgeons, plastic surgeons, otolaryngologists and maxillofacial surgeons.^{8,17,37} Naso-frontal outflow tract (NFOT) obstruction can change the algorithm of treatment.⁴⁹ The treatment indications of our institution is based on the fracture type, posterior table integrity, NFOT, head trauma

severity, CSF leakage and neurological status.^{3,25,31,37,44,45)} The NFOT is an hourglass-shaped structure, which drains secretions from the FS to the frontal recess which continues as the nasofrontal duct (NFD), which opens into the middle meatus of the nasal cavity.²³⁾ This structure is important to be evaluated early in order to prevent complications in long term follow up like CSF leakage, mucocele and infection.³⁷⁾ Comminuted fractures are totally different from linear fracture in terms of disfigurement and efforts spent to achieve an aesthetic results. Linear fractures are used to heal conservatively while comminuted fractures are in need for surgical intervention to achieve good integrity.^{11,38)}

We retrospectively reviewed our data and the previous literature with the base in frontal sinus fracture management to build a more desired algorithm for the treatment of FSF.

MATERIALS AND METHODS

Study design

Our study aimed to investigate our traumatic brain injury (TBI) data, review current literature, and assess planning valuables in treatment decision making. Hospital data base for head trauma of Al-Ahly Bank Hospital was retrieved after hospital board permission for retrospective analysis of cases admitted from 2010–2020 by collecting the targeted medical records. Patients with FSF and head trauma were retrieved from the database. Variables of the study included patients' demographics, mechanism of injury, incidence of CSF leakage, grade of TBI, imaging findings and operative techniques (**FIGURE 1**).

Indications of surgical treatment of frontal sinus fracture

The indications for frontal sinus repair were assessed heavily before planning a decision with taking into consideration the general assessment of patient's ability and prognosis. The indications included the following:

1. Presence of CSF leakage.
2. Displaced posterior table for more than one cortex thickness.

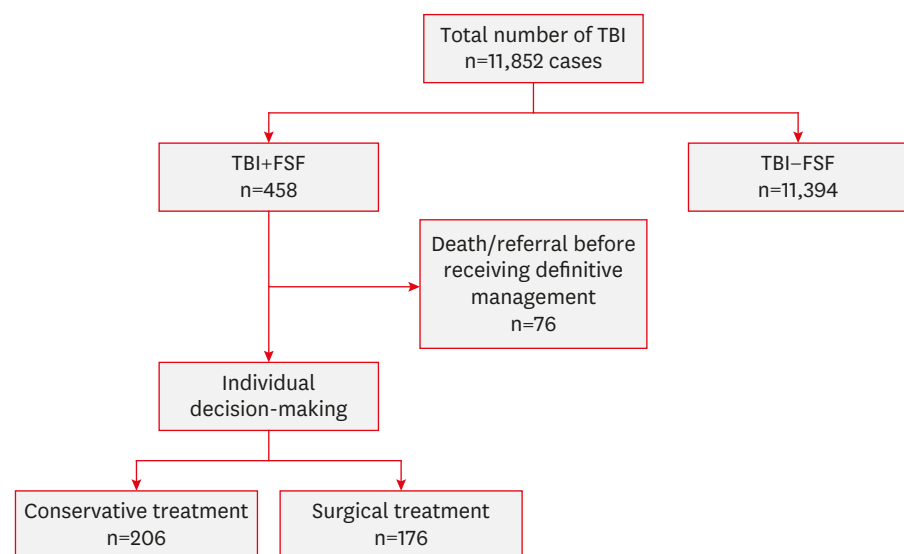


FIGURE 1. Flow chart of study population.
TBI: traumatic brain injury, FSF: frontal sinus fractures.

3. NFD blockage or injury, sinus obliteration needs to be done to prevent sinusitis and mucocele.

Surgical treatment of frontal sinus fracture

We performed a bifrontal craniotomy with total removal of posterior wall of frontal sinus but in case of totally separated sinuses we may start to do unilateral craniotomy. However, the intersinus septum is extremely thin and may be fractured during the mucosal marsupialization. This is followed by removing of mucosa to close any potential space of infection. Dural repair is done as well as sinus plugging with fat graft and vascularized flap at the same time. There is no difference between fat, fascia or muscle in term of closing the NFDs, all materials are capable of even distribution inside the cavity. The fat tissue used for repair was taken by dissecting gently a small abdominal incision at para-umbilical area. Muscle tissue are used to be harvested from adjacent temporalis muscle.

In the presence of high flow leaks, CSF diversion procedure (ventriculostomy or lumbar drain) will add success to repair procedure if it left for 7 days. Any lacerations or perforations of the pericranial graft are repaired primarily with 4-0 Prolene suture. Care must be taken to replace the frontal bone flap in such a manner as to provide good cosmetic and still allow for vascularity of the flap. Pericranial flap compression by bone replacement can cause pericranial flap ischemia and injuries and critical illness in blunt trauma patients, which can lead to delay in the surgical treatment of these patients. Insufficient pericranial flap for cranialization or even inappropriateness due to compound nature of fracture was solved by harvesting tensor fascia lata flap.

Cranialization in this procedure the patient was made to lie in the supine position with the head fixed on the head ring in its neutral position. In cases with extensive wounds in the forehead on the sinus, surgery was performed in the same site and in patients without wounds or with small wounds, a bicoronal incision was made on the back of the hairline. The sinus was exposed in most of the cases by removing fractured bone fragments. In cases where removal of bone fragments was not possible trephining adjacent to the sinus was performed to enable fragment removal. Next the posterior walls of the sinus were removed. In cases where there wasn't enough space for brain and dural repair, an adequate craniotomy was performed. After that the sinus mucosa was removed carefully from the remaining area including the nasofrontal ostium. The area around the ostium or nasofrontal canal was decorticated with a rotating cutting burr and plugged using pieces of temporalis muscle and associated fascia.

Statistical analysis

The statistical analysis was done by the Statistical Package of Social Sciences version 25 (Chicago, IL, USA). Categorical data were presented as percentages and compared using χ^2 *t*-test. Numerical data were presented as mean and standard deviation and compared by using Student's *t*-test. *p*-value below 0.05 were regarded statistically significant.

RESULTS

Three-hundred eighty two patients were eligible to be screened in our study and represented the sample size under investigations in the following sections, 206 (53.9%) of patients with FSF were treated conservatively according to treatment strategy. The rest 176 patients were

identified as having surgical intervention for correction of fractured frontal sinus. Eighty-four percent of patients were males. The mean age was 36.2 ± 9.4 years (14–86 years).

The most common mechanism of injury was motor vehicle accidents (44%), followed by pedestrian accidents (31%), fall from high (12%), motorcycle accidents (7%) and blunt force trauma (6%).

Leakage of CSF was found in 58/176 (32.95%) during history taking and provocative tests. Persistent rhinorrhea was the most common complain. The radiographic incidence of NFOT was 95.4% (168/176) while clinical NFOT was seen in only 49.4% (87/176). Surgery to repair frontal sinus was either part of a cranial surgery (64.2%) or doing it standalone (35.8%) as seen in **TABLE 1**.

The time-to-surgery was ranging from 5–8 days (6.6 ± 4.1 days) after admission. Cranialization surgery was done to 176 patients. Greater than full width displacement was seen in 79% of our series and the remaining had had less than full thickness displacement. Since obliteration packing was done by temporalis muscle harvested during craniotomy in 86.3% of cases, bone chips were used in adjuvant to muscle in 13.6% of cases.

Frontal sinus overlying after cranialization was achieved mainly by pericranial flap with attached vascular pedicle in 75% (132/176) of patients. Other materials are summarized in **TABLES 2 & 3**. Forty-five patients (25.5%) had delayed onset abscess requiring reoperation. Eleven patients (6.25%) had persistent CSF leakage necessitate lumbar drain insertion for 5 days were all of the leakage subset with no further intervention.

TABLE 1. Type of surgeries done in conjunction with frontal sinus fractures repair

Surgery	Value
Epidural hematoma	23 (13.06)
Subdural hematoma	20 (11.36)
Frontal lobe hematoma	29 (16.4)
Depressed skull fracture	31 (17.61)
Compound depressed fracture	10 (5.68)

Values are presented as number (%).

TABLE 2. Frontal sinus overlying materials used in our patients

Material	Value
Pericranial flap	132 (75)
Pericranial flap with duragen	20 (11.36)
Tensor fascia lata	9 (5.11)
Not recorded	15 (8.5)

Values are presented as number (%).

TABLE 3. Frontal sinus packing materials used in our patients

Material	Value
Temporalis muscle	63 (35.8)
Bone graft	30 (17.05)
Pericranial flap alone	20 (11.36)
Tensor fascia lata	13 (7.4)
Pericranial flap+fat	11 (6.25)
Fat alone	9 (5.11)
Not recorded	30 (17.05)

Values are presented as number (%).

DISCUSSION

Frontal sinus fracture is a common phenomenon in TBI either due to road traffic accident or direct head trauma.³⁷⁾ Various algorithms have been postulated to treat FSF in the literature.^{3,25,31,37,44)} Little did we introduced algorithms in neurosurgery. Misdiagnosis and poor treatment strategy may lead to infection and complications on the long run.⁵³⁾ Involvement of NFOT is an indication of repair in plastic surgery literatures. Occlusion of the NFOT may participate mucocele formation and abscess thereafter.^{20,32,42,53)} However, missing NFOT obstruction is a common unless picked up by a neuroradiologist. Association of intracranial injuries are common co-existence.^{15,38)} Several studies found un-necessary repair was done due to operative intracranial injury.⁷⁾ In contrast, repairable FSF may left conservatively treated due to a “benign” concomitant intracranial lesion.⁴⁵⁾

Anatomical variations

Normal anatomical variations can complicate decision making process.⁶⁾ Hypoplasia or aplasia may add a protective effect against CSF leakage. In contrast, hyperpneumatization may add further complications.⁹⁾ The answer of this dilemma is achieved by careful evaluation of frontal sinus anatomy in the requested image.¹²⁾ The NFOT is a communication between frontal and nasal cavity. It can be manifested as a duct or ostium.⁴⁸⁾ Occlusion of the NFOT may be due to direct trauma or nasal cavity swelling. There are 2 types of obstructions; short-lasting and long-lasting.⁴⁰⁾ Either type, of obstruction, masking of CSF leakage is frequently occurred.²⁶⁾

Imaging studies like computed tomography (CT) scan may be blinded to diagnose NFOT obstruction.³³⁾ Leakage of CSF may be assessed with CT cisternography or endoscopy with introduction intrathecal fluorescein.

Normally, CT paranasal sinuses may show a small duct extending from frontal sinus to nasal cavity (middle meatus).⁴⁰⁾ The frontal opening is located postero-medially and directed postero-inferiorly. The duct is not usually an anatomic duct but as an ostium. Medial to the duct is formed middle turbinate, lateral to it is made by lamina papyracea, anterior to it is made by agger nasi cell and posterior to it is made by frontal recess.⁶⁾

Treatment goals

The goals of treatment were: (a) repair of the defect and elimination of the conduit from the intracranial space to the outside and (b) elimination of any CSF pressure gradient that may develop across the surgical repair.³⁷⁾

Treatment algorithms for FSF are extensively discussed in literature. In our department, we build up a local algorithm for treatment of FSF based on fracture type, NFOT status, CSF leakage and fracture displacement. The net result of all decisions is either observation, obliteration or cranialization (**FIGURE 2**).

Ravindra et al.³⁷⁾ established a reasonable algorithm respecting NFOT obstruction status. The algorithm proposed by Ravindra and colleagues missed the situation of comminuted table. Strong⁴⁴⁾ published his algorithm based on reviewing of the frontal sinus fracture situations. The net result of his algorithm containing endoscopic repair and rare procedure (sinus ablation or Reidel procedure) beside the above mentioned decisions. It contains certain subjective judgmental steps like "mild, moderate and severe" where is no exact definition

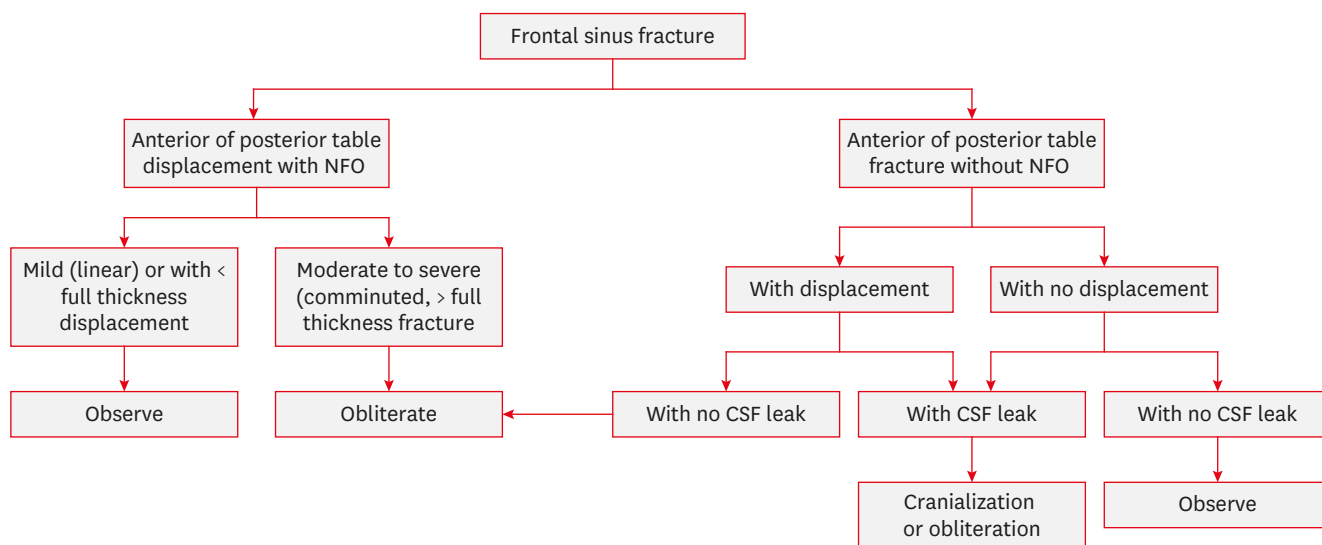


FIGURE 2. Treatment algorithm of FSF used in our institute. FSF: frontal sinus fractures, NFO: naso-frontal outflow, CSF: cerebrospinal fluid.

of severity at all. We deviate ourselves from this dilemma by performing simple, objective, applicable for neurosurgeons and reasonable algorithm with only three decisions in respect to a traumatized patient with good prognosis.

There is no specific guideline on timing of repair for FSF per se. However, previous reports found emergence of complications is observed beyond 48 hours from the event.⁵⁰⁾ This logically gave us an intention to deal with FSF as soon as possible within this window of time.^{19,34)} It is suitable to ask a good questions; what are indications of conservative treatment in FSF? Absence of NFOT obstruction and CSF leakage are two major factors for conservative treatment.^{3,37,44)}

Packing materials

Materials used to pack the sinus are variable according to center.^{24,27)} However, pericranial flap is a gold standard material.^{5,23,30,36)} It is easy to use and to be harvested. Easy to be applied and added no infection or rejection.¹⁾ Filling the sinus with autologous bone is sometime difficult to be contoured inside and renders operation lengthy.⁴⁷⁾ In contrast, osteogenic activity can transform the bone into a strong barrier against fluid leak. Muscles are usually implemented in sinus obliteration with good results. Muscle degradation will result in empty sinus on long term follow up. Abdominal fat is also preferred by many surgeons.⁴⁴⁾ Autologous fat and vascularized flap is used after dural repair (if present) in difficult cases.⁴⁴⁾ We see less fat resorption than muscles with advantage of even distribution inside the sinus. Generally, there was no difference in using any material (fat, muscle, or fascia) for plugging the sinus in straightforward cases.³⁷⁾

Complications

Failure to obliterate the sinus is manifested as persistent leakage postoperatively. It is not a rare event. Ventriculoperitoneal shunt may be an added strategy.²⁰⁾ Mucocele is reported previously in retrospective analyses. It can be found in conservatively treated cases and post-surgery even.^{28,39)} The mechanism of mucocele in post-surgery is due to incomplete cranialization and partial stripping of mucosa.^{16,48)}

Bellamy et al.⁴⁾ demonstrated that 36% of patients with surgically managed frontal sinus injuries had a preoperative CSF leak. They also found 14 cases of serious infection with involvement of the posterior table and NFOT compromise. Pollock et al.³⁵⁾ reported a complication rate of 6% in a series of 154 patients who underwent cranialization for FSF. They reported 12 patients with CSF leaks (including 8 noted on initial presentation), none of whom were started on CNS-penetrating doses of antibiotics prophylactically. One patient developed serious intracranial infection in the acute period (<48 hours) prior to operative repair. It has been reported that operative delay beyond 48 hours was associated with a 4.03-fold increased risk for serious infection, external CSF drainage catheter use had a 4.09-fold increased risk for serious infection, and local soft-tissue infection conferred a 5.10-fold increased risk for serious infection.

Cranialization of the sinus means omitting the presence of sinus cavity.⁴⁶⁾ This will add advantage on preventing CSF leakage or infection due to posterior frontal sinus fracture.^{13,21,46)} Disadvantage of it was not recorded before in literatures. Obliteration of the sinus means filling the space or the cavity to prevent falling of mucous or CSF fluids into the nasal cavity with development of retrograde infection.⁵¹⁾ Advantage of this procedure is in its simple technique, easy to harvest the plugging material and complete occlusion is easily achievable.⁴³⁾ Its disadvantages are in their ability to resolve and resultant an empty sinus again,²²⁾ infection or mucocele development.⁵²⁾

CONCLUSION

Frontal sinus fracture is not an easy scenario. It harbors many proportions and deliver many varieties in which, deep understanding of anatomy, NFOT status, CSF leakage and neurological injury are of important points in decision. Our institutional algorithm provide rapid, accessible and applicable treatment protocol for resident and young neurosurgeons which minimizes consultations of other specialties.

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