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Original Article

Management of Compound Depressed Fractures over Venous Sinuses

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Abstract

Objective The aim of this study was to report our experience in the surgical treatment of compound depressed fractures over the venous sinuses with special highlights on the prediction and dealing with intraoperative sinus injury.

Materials and Methods We conducted a retrospective review of all patients who underwent surgery for compound depressed fractures overlying the dural venous sinuses in our hospital between January 2019 and December 2021.

Results A total of 34 patients were included in our study. The mean age of the patients was 19.85 years, most of our patients were males 27 (79.4%), and isolated head trauma was the most common mode of trauma (76.5%). The superior sagittal sinus (SSS) was distinguished as the most commonly involved venous sinus below the fractures in 28 patients (82.4%). An intraoperative tear in the sinus was found in 17 patients (50%), which was easily controlled with different methods. In two patients who had a severe head injury with a Glasgow Coma Scale (GCS) score of $\leq$8 associated with a fissure fracture crossing the sinus, there was a complete tear of the sinus followed by massive bleeding, which required sinus ligation. We lost both of them in following days.

Conclusion In experienced tertiary neurotrauma centers, compound depressed fractures over the venous sinuses should be surgically elevated in most cases, taking into consideration that bleeding from the sinus can be controlled in most cases, and complete tear of the sinus with massive bleeding is the least scenario faced in reality and is usually associated with a severe head injury. If expert opinion favors the conservative approach, then close follow-up for months is recommended due to the high possibility of sinus thrombosis and intracranial hypertension, especially in children.

Keywords
- depressed
- skull fracture
- compound
- open depressed fracture
- sinus thrombosis
- head injury
- dural venous sinus

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Introduction

Up to 11 to 18% of cranial depressed fractures are located over the venous sinuses (VSs), mostly over the superior sagittal sinus (SSS).[1,2] Intraoperative significant injury to the dural sinus was reported in up to 5% of civilian traumatic head injury patients, and a higher incidence was reported in missile head injury cases.[3–6] Neurosurgeons usually think twice before reaching the ideal decision in those cases. The surgery has a considerable risk of bleeding from the VS, which could be fatal,[3,4,6–8] and the conservative option is not free of complications; on top of it, sinus thrombosis is followed by increased intracranial pressure.[9–17]

Many authors advocate the conservative option in simple (closed) depressed skull fractures over the VSs,[1,2,18] and although surgical complications are possible, compound (open) depressed skull fractures should be elevated especially in those with severe contaminated wounds, presence of a foreign body, severe disfigurement, clear evidence of dural tear, for example, cerebrospinal fluid (CSF) leak from the wound, presence of neurological deficit, for example, compression over the motor area, evidence of elevated intracranial pressure via a monitor in a patient with proved sinus compression in magnetic resonance venography (MRV), proved sinus occlusion or compression through venography studies, for example, MRV; aiming to prevent future sinus thrombosis, and increased intracranial tension.[1,4,7,8,13,19–23]

In this retrospective study, we report our experience in the surgical treatment of compound depressed fractures (CDFs) over the VSs with special highlights on the prediction and dealing with intraoperative sinus injury.

Materials and Methods

Study Design

We retrospectively reviewed and analyzed the prospectively collected data of traumatic brain injury patients in our institute from January 2019 to December 2021. We included only patients with CDF over the VS who were surgically treated.

We excluded patients with CDF over the VS who were managed conservatively, patients with CDF away from the VS, patients with closed depressed fractures even over the VS, and patients with incomplete operative data.

Ethical Considerations

This study was approved by the research ethics committee of the Faculty of Medicine at Cairo University (N129-2023).

Data Collection

Variables collected included demographic data like age, gender, mode of trauma, Glasgow Coma Scale (GCS) on admission, location of the fracture, the related VS, associated hematoma, and associated pneumocephalus.

Neuroimaging included computed tomography (CT) of the brain including brain window, bone window, and three-dimensional (3D) reconstruction. Reviewing the coronal, sagittal, and axial cuts in bone windows is a must in all surgeries (►**Fig. 1**). We do not perform MRV as a routine in all cases.

Location of Fractures and Intraoperative Status of the Venous Sinus

We classified the CDF as either of the following:

- Midline, which points to fractures located exactly over the VS as obvious in the coronal cut bone window and 3D reconstruction films (►**Fig. 1A–D, I,** and **J**).
- Off-midline, which points to fractures located just beside the VS as obvious in the coronal cut bone window and 3D reconstruction films (►**Fig. 1E–H**).

In the case of the transverse sinus (►**Fig. 1K, L**), if the fracture was located exactly over the sinus, it was included with the midline group, and if it was located just below or above the sinus, it was included with the off-midline group.

We classified the intraoperative status of the VS as either of the following:

- Intact: The VS is completely intact and the CDF just compressing it from the outside or in case of minimal superficial lacerations that stop easily with Gelfoam and compression over cottonoid.
- Tear: This could be a side tear (more common with off-midline fractures) or a top tear (more common with midline fractures). For both of them, the bleeding can be controlled with Gelfoam and compression over cottonoid, hitch stitches tenting the dura to the adjacent bone, or bilateral hitch stitches crossing the sinus.

A complete tear was found in two cases intraoperatively that required sinus ligation.

Operative Strategy, Pearl, and Pitfalls

- All the patients start antibiotics once admitted to the hospital, and tetanus prophylaxis is not a routine in our hospital.[5]
- A cross-matched blood must be available in the operating room before starting the surgery; in the case of infants and children, extra volume of blood should be available.
- Any coagulation abnormalities should be corrected before surgery, watching for complications of massive blood transfusion after surgery; thrombocytopenia was reported in 85% of cases postoperatively.[3]
- Special consideration should be given to young children with CDF as they may have anemia from blood loss from the scalp before reaching the hospital; correction of low hemoglobin should be done before proceeding with surgery.
- At least two wide-bore intravenous cannula should be placed, and placement of a central venous line is a must in all cases of CDF over the VS in our center. This will give extra access for rapid intravenous crystalloids, blood constitutes (packed red blood cells, fresh frozen plasma, and platelets) once indicated, and possibility of suction of air embolism through the venous line once detected.

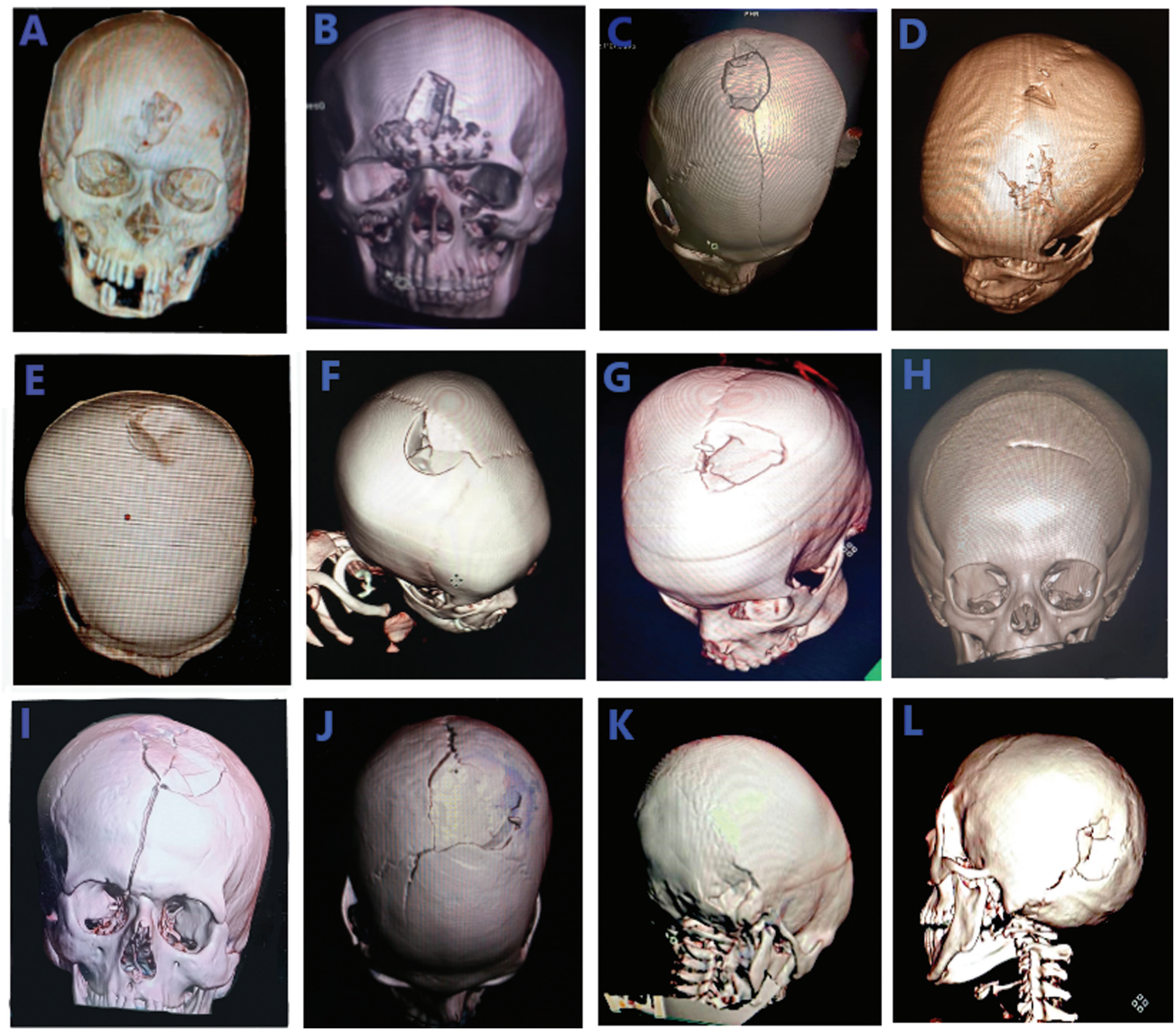

Fig. 1 Different fractures shown in three-dimensional (3D) reconstruction films. Midline fractures: (**A, B**) frontal bone and (**C, D**) parietal bone. Off-midline fractures: (**E–G**) parietal bone and (**H**) frontal bone. (**I**) Large comminuted midline depressed frontal fracture with fissure fracture. (**J**) Large comminuted midline depressed parietal fracture with fissure fracture. (**K**) Depressed fracture over the right transverse sinus. (**L**) Depressed fracture over the left transverse sinus.

- Invasive arterial line for accurate following of arterial blood pressure is highly indicated, a capnography for detection of fall at the end-tidal pCO_2, which is an early sign for air embolism, is a must, and precordial Doppler whenever available will add extra value for critical monitoring.
- Patients are placed in the supine position with the head elevated 30 degrees above the level of the heart or placed in the reverse Trendelenburg position to decrease the venous bleeding from the VS in cases of injury. It should be noted that excessive elevation of the head elevates the risk of air embolism in case of profuse bleeding.
- The neck should be inspected to avoid excessive flexion, which will increase venous congestion.
- Before starting elevation of the CDF, generous bony exposure around the fracture should be done in all directions after subperiosteal elevation. Two large-bore suctions should be working in the operative field to allow clearing of the surgical field for better localization of the injury in case massive bleeding occurs.
- Elevation of the depressed bone can be done either directly through elevation of the depressed fragment itself using dissectors and Kerrison rongeur or through a craniotomy surrounding the depressed fragment, so the free bone flap including the depressed segment will get out in one piece.[3,4,24,25] The craniotomy method is usually preferred and safer, especially in cases of CDF caused by sharp penetrating injury, for example, fan blade at which the depressed segment has a linear shape and in cases of extensive CDF, which is usually associated with fissure fractures.
- We usually start manipulations through the edge of the depressed fragment using a dissector and Kerrison rongeur. In cases of large sinus tears with massive bleeding,

we noticed that starting to manipulate the pieces of bone leads to noticeable bleeding. This mandates stopping the steps and compression, then changing the plan to perform a wide craniotomy around the depressed fragment.
- After elevation of the depressed bony fragments, we inspect the dura for any tears. If a dural tear is found, it should be repaired either primarily or with a free periosteal flap. In those patients with dural tears, we add prophylactic antiepileptic postoperatively for a short period.
- We soak the bony fragments in an antibiotic/isotonic sodium chloride solution.

Larger pieces are usually wired together and placed again in place.

We did not encounter any case of infection till the last follow-up. It was reported that the replacement of the same bone did not increase the rates of postoperative infection.[13,23,26]

- Any foreign debris must be removed. We trim the edges in cases of badly lacerated or devitalized scalp overlying the fracture back to clean bleeding margins. Then, the wound is copiously irrigated with sterile saline and closed in layers with a subgaleal drain.
- Prophylactic anticoagulant is not a routine and was not prescribed in our study. We think it was mandatory in cases of sinus ligation. However, the two patients in whom we ligated the sinus had a severe traumatic brain injury and passed away early. It was also not prescribed in many studies after surgical elevation of CDF over the VS even when intraoperative repair was done with Gelfoam or a piece of muscle.[4,16,24,25]

Studies that reported sinus occlusion with a preoperative MRV that mandates intervention did not mention prophylactic anticoagulant if there was a restored spontaneous flow inside the VS in the postoperative MRV. Otherwise, anticoagulant should be given for a while.[14,15,17]

Statistical Method

Data were coded and entered using Statistical Package for Social Sciences (SPSS) version 28 (IBM Corp., Armonk, New York, United States). Data were summarized using mean, standard deviation, median, minimum, and maximum in quantitative data and using frequency (count) and relative frequency (percentage) for categorical data. Comparisons between quantitative variables were done using the nonparametric Mann–Whitney *U* test.[27] For comparing categorical data, the chi-squared (χ^2) test was performed. The exact test was used instead when the expected frequency was less than 5.[28] Logistic regression was done to detect independent predictors of tears in the VS.[29] A *p*-value less than 0.05 was considered statistically significant.

Case Presentation

Case 1

A 45-year-old male patient presented to the neurosurgery emergency department with a sharply cut wound in the scalp after being hit by a sharp object in a street fight. CT of the brain showed a right frontal depressed fracture (off-midline) compressing the anterior one-third of the SSS (►**Fig. 2**). He underwent elevation of the CDF using a dissector and Kerrison rongeur. Intraoperatively, there was a small tear from the SSS (intact), which was controlled with Gelfoam and dural tenting sutures.

Case 2

A 21-year-old male patient presented to the neurosurgery emergency department with a contaminated wound in the scalp after being hit by a sharp object in a street fight. CT of the brain showed a depressed fracture in the midline of parietal bones. MRV showed attenuation of the flow in the middle one-third of the SSS (►**Fig. 3**). He underwent elevation of the CDF by performing a rectangular craniotomy including the depressed fragment. Intraoperatively, there was a minimal ooze of blood from the SSS (intact), which was controlled with Gelfoam and compression. The patient was discharged without a neurological deficit.

Case 3

A 35-year-old male patient presented to the neurosurgery emergency department with a cut wound in the scalp after being hit by a blunt object in a street fight. CT of the brain showed a depressed fracture in the left parietal bone compressing the middle one-third of the SSS (►**Fig. 4**). He underwent elevation of the CDF by performing a rectangular craniotomy including the depressed fragment. Intraoperatively, there was a small tear in the SSS, which was controlled with Gelfoam and hitch stitches tenting the dura to the adjacent bone. The patient was discharged without a neurological deficit.

Case 4

A 17-year-old male patient presented to the neurosurgery emergency department with a cut wound in the scalp after being hit by a heavy object on his head while walking in the street. CT of the brain showed a depressed fracture in the midline frontal bone compressing the anterior one-third of the SSS (►**Fig. 5**). He underwent elevation of the CDF using a dissector and Kerrison rongeur. Intraoperatively, the SSS was intact. The patient was discharged without a neurological deficit.

Case 5

A 29-year-old male patient presented to the neurosurgery emergency department with loss of consciousness after falling from a height of 30 m on his head. His GCS score on admission was 7/15, and there was an extensive open wound in his scalp. CT of the brain showed right parietal extensive skull fracture with depressed fragment with linear fissure fracture crossing to the other side over the middle one-third of the SSS, left acute subdural hematoma, and bilateral extensive brain edema (►**Fig. 6**). He underwent left decompressive craniectomy with evacuation of the hematoma and elevation of the right CDF. Intraoperatively, the SSS was torn with massive bleeding and difficulty in controlling the tear,

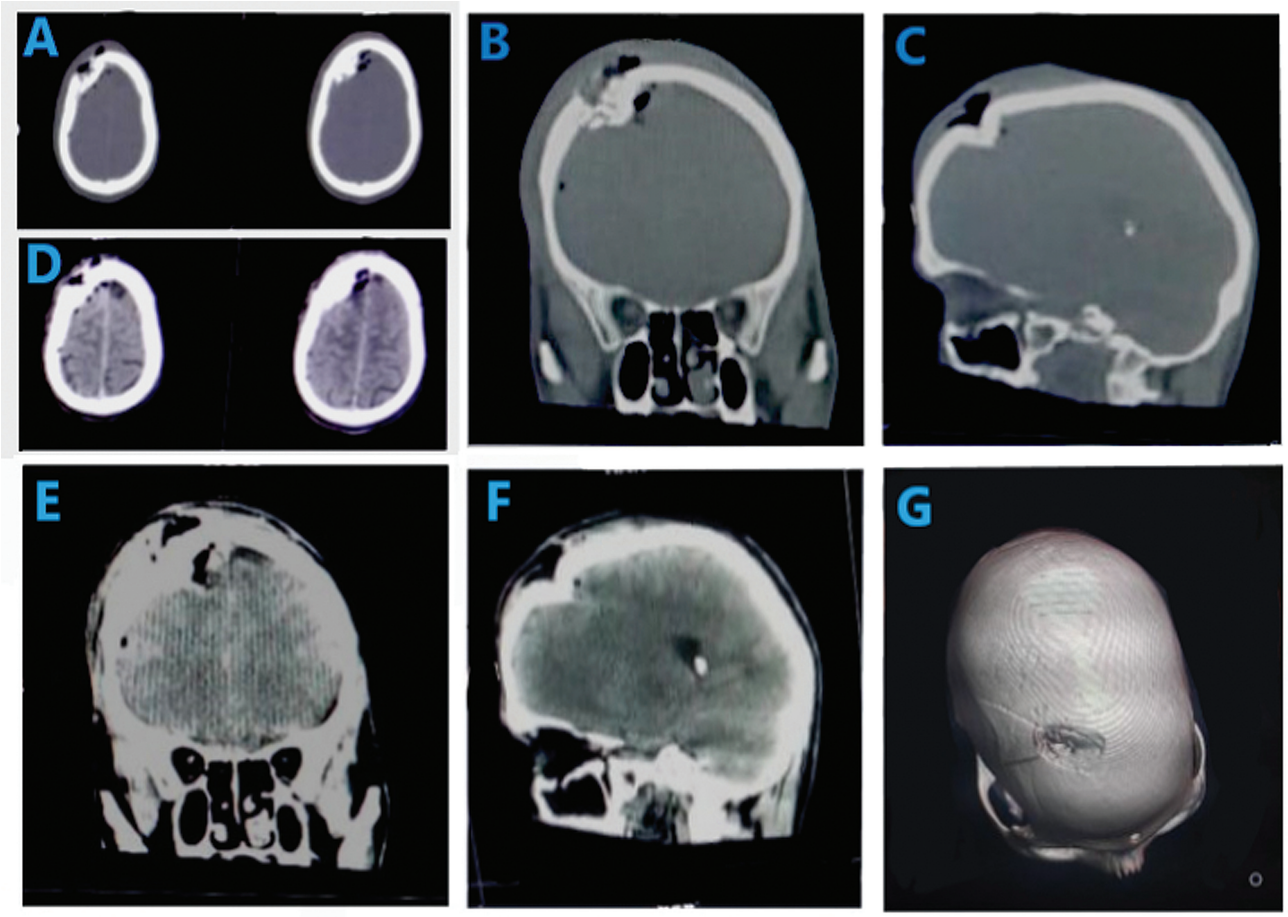

Fig. 2 Computed tomography (CT) of the brain, bone window: (**A**) axial cut, (**B**)coronal cut, and (**C**) sagittal cut; a right frontal off-midline depressed fracture with localized pneumocephalus. CT of the brain, brain window: (**D**) axial cut, (**E**) coronal cut, (**F**) sagittal cut; a small localized hematoma with brain edema was found. (**G**) Three-dimensional (3D) reconstruction showing the accurate location and extension of the fracture.

which ended up with sinus ligation. The patient passed away after 48 hours from the surgery.

Results

Patients Characteristics

A total of 34 patients are included in our study. Most of the patients were males (27, 79.4%). The mean age of the patients was 19.85 years (range: 3–60 years), and 19 patients (56%) were in the pediatric age group (≤18 years). Isolated head trauma (IHT) was the most common mode of trauma in 26 patients (76.5%), which could be caused by being hit by a sharp object (fan blade) or a blunt object (a rock or during a street fight). Their GCS score on admission was 15/15 in 29 patients (85%). ►**Table 1** summarizes the clinical data of the patients.

Radiological and Operative Data

Most of the CDFs were located in the frontal bone in 19 patients (56%), followed by parietal bones (26.4%). The fracture was located over the midline in 16 cases (47.1%) and away from the midline (off-midline) in 18 cases (52.9%). The SSS was the most common VS in contact with the CDF in 28 patients (82.4%), and in 16 of the 28 patients (57%), it was located over the anterior one-third of the SSS. There was an associated small localized hematoma in 18 cases (52.9%) and localized pneumocephalus in 20 cases (58.8%). MRV was done only in five cases (14.7%). ►**Table 2** summarizes the radiological and operative data of patients.

The VS was found intraoperatively intact in 17 patients (50%), with a small tear that was easily controlled with Gelfoam or a piece of muscle with added dural tenting and compression for minutes in 15 patients (44%), and a complete tear of the sinus with massive bleeding that ended with sinus ligation in 2 patients (5.8%); both patients died later on.

The univariate logistic regression shows a statistically significant correlation between the presence of intra-operative tear and the patients who came with IHT ($p = 0.034$), the fracture being off-midline ($p = 0.044$), the presence of localized hematoma ($p < 0.001$), and associated localized pneumocephalus ($p = 0.002$), as shown in ►**Table 3**.

Discussion

Massive blood loss is the major concern during the elevation of depressed fractures over the VSs, and this makes those cases challenging and complex even in reaching the ideal decision for each patient. The reported mortality rate

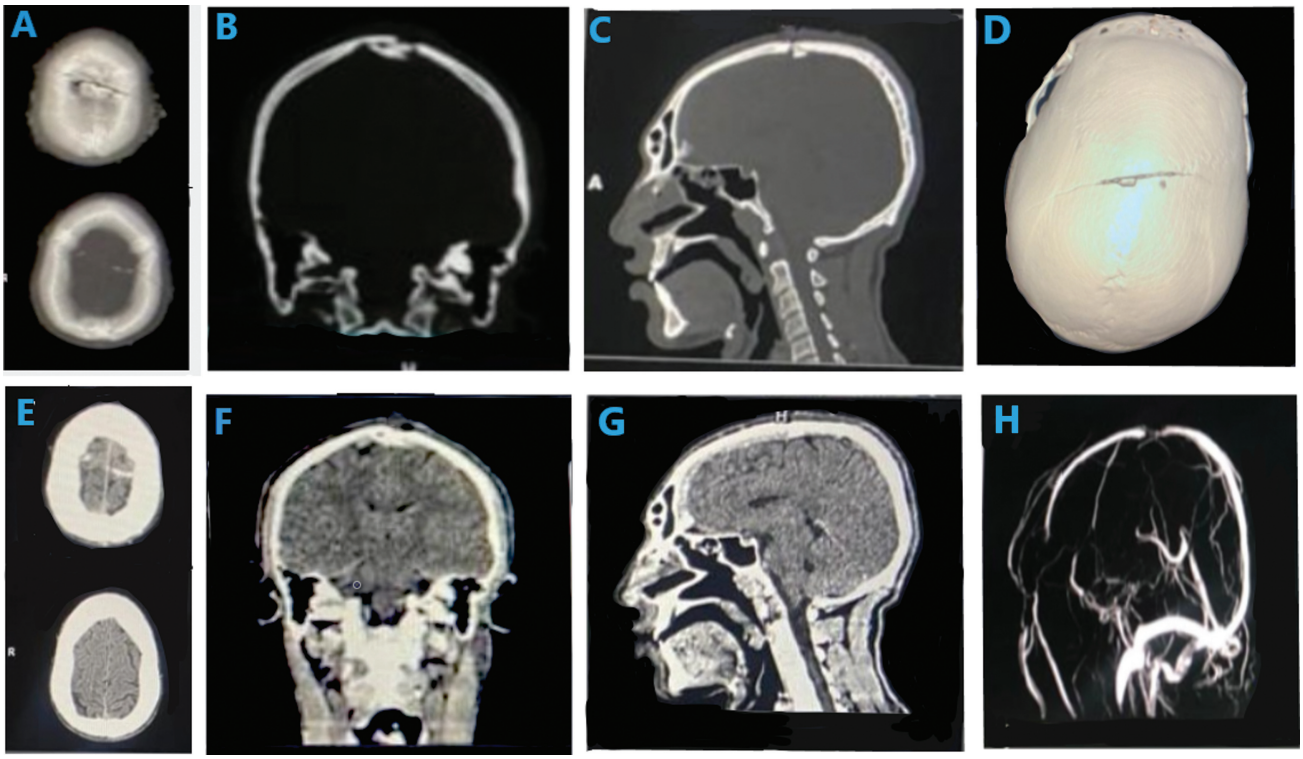

Fig. 3 Computed tomography (CT) of the brain, bone window: (**A**) axial cut, (**B**) coronal cut, and (**C**) sagittal cut; a high parietal linear midline depressed fracture. (**D**) Three-dimensional (3D) reconstruction showing the accurate location and extension of the fracture; there was no pneumocephalus. CT of the brain, brain window: (**E**) axial cut, (**F**) sagittal cut, (**G**) coronal cut; no localized hematoma or brain edema was found. (**H**) Magnetic resonance venography (MRV) showing obliteration of the flow in the middle one-third of the superior sagittal sinus.

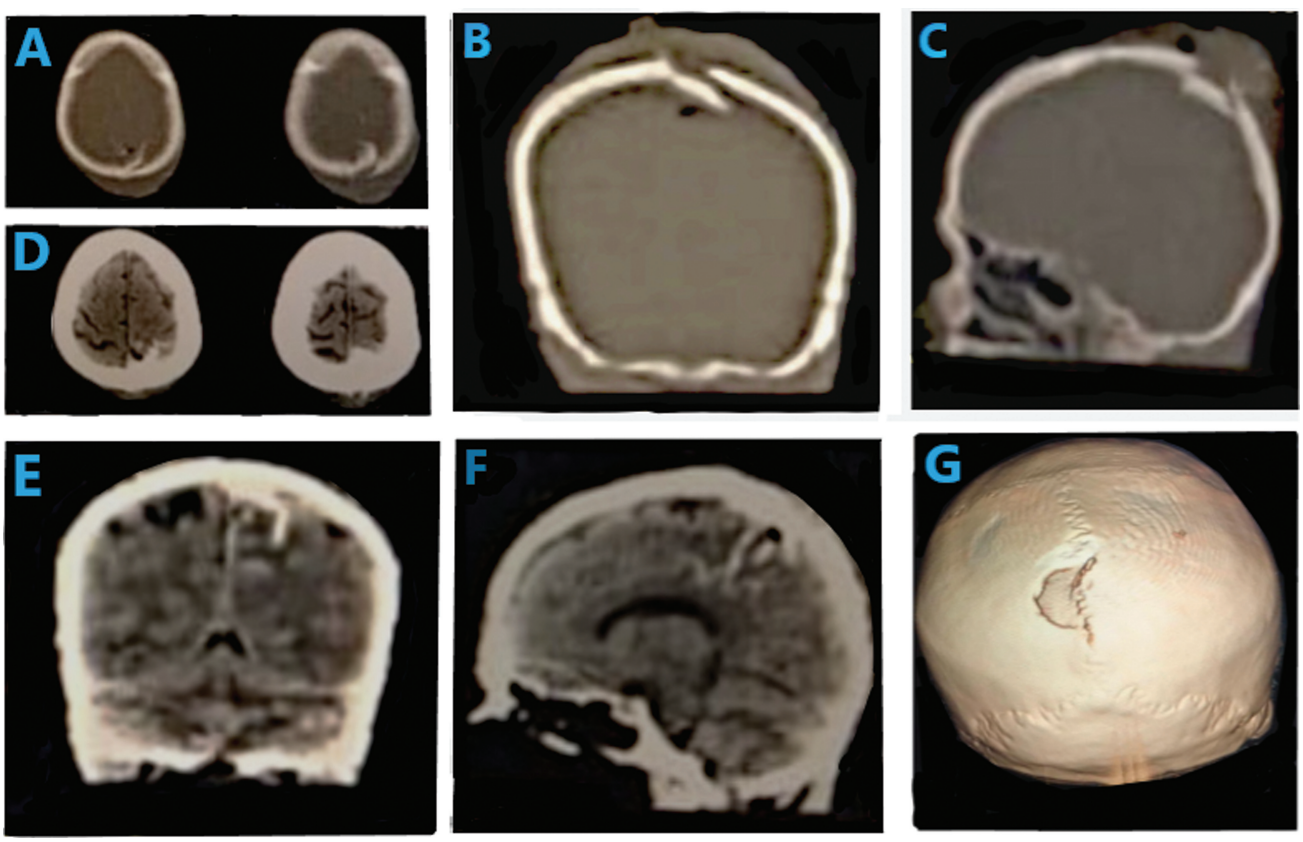

Fig. 4 Computed tomography (CT) of the brain, bone window: (**A**) axial cut, (**B**) coronal cut, and (**C**) sagittal cut; a left high parietal off-midline depressed fracture with localized pneumocephalus. CT of the brain, brain window: (**D**) axial cut, (**E**) coronal cut, and (**F**) sagittal cut; a small localized hematoma was found. (**G**) Three-dimensional (3D) reconstruction showing the accurate location and extension of the fracture.

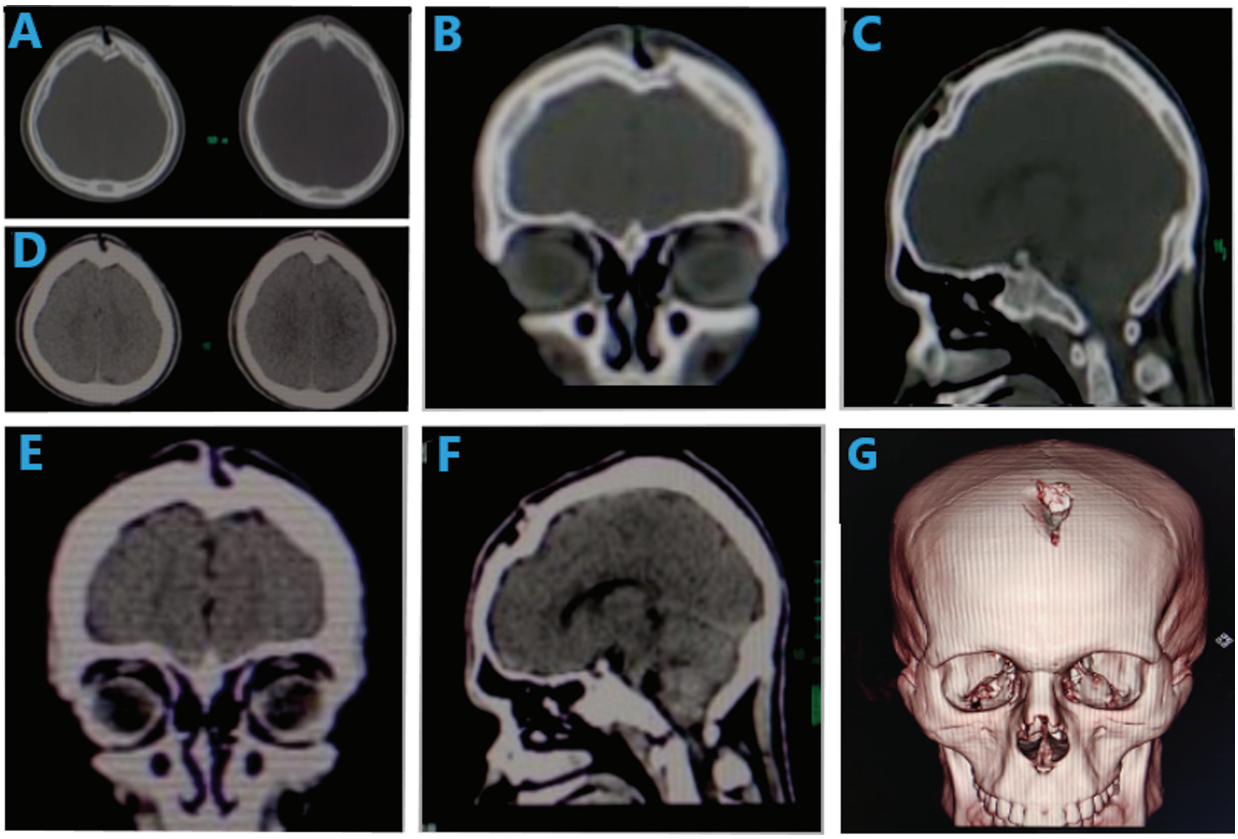

Fig. 5 Computed tomography (CT) of the brain, bone window: (**A**) axial cut, (**B**) coronal cut, and (**C**) sagittal cut; a midline frontal depressed fracture with no pneumocephalus. CT of the brain, brain window: (**D**) axial cut, (**E**) coronal cut, and (**F**) sagittal cut; there is no localized hematoma. (**G**) Three-dimensional (3D) reconstruction showing the accurate location and extension of the fracture.

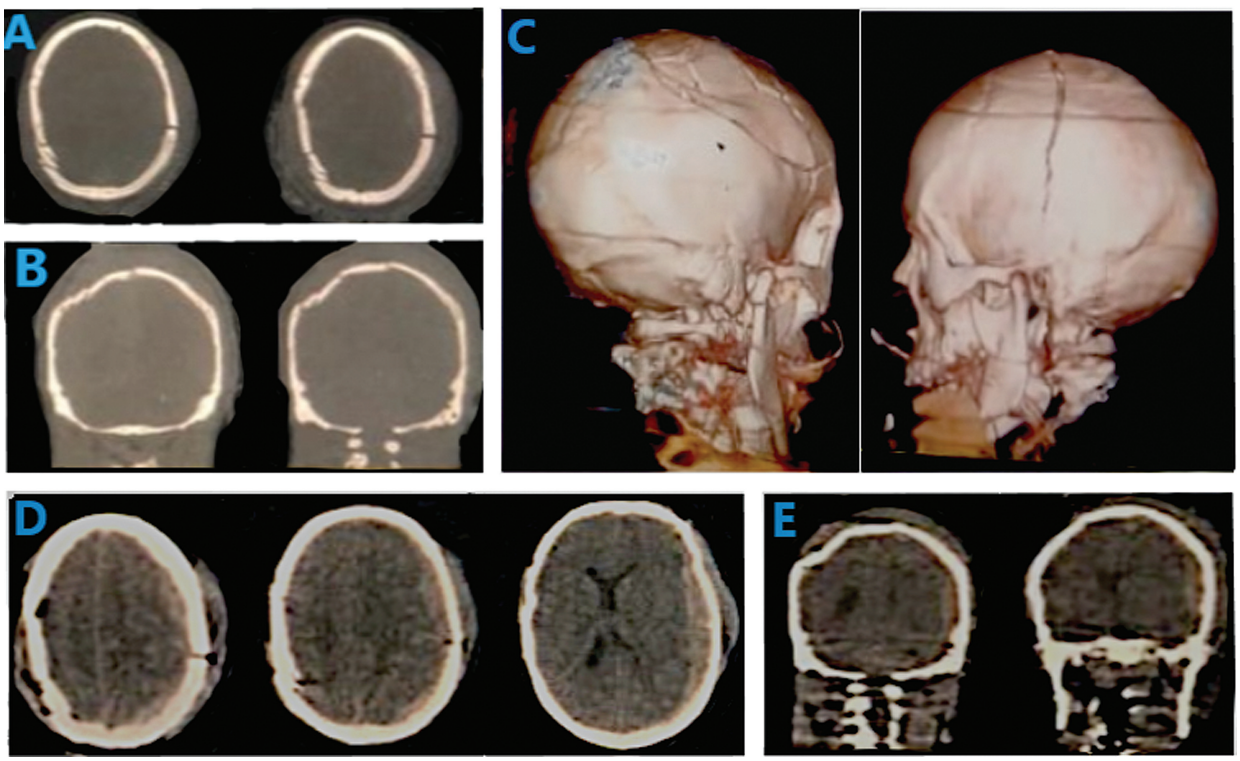

Fig. 6 Computed tomography (CT) of the brain, bone window: (**A**) axial cut, (**B**) coronal cut, and (**C**) three-dimensional (3D) reconstruction; an extensive right parietal off-midline depressed fracture with extensive fissure fracture crossing the other side. CT of the brain, brain window: (**D**) axial cut and (**E**) coronal cut; there is left acute subdural hematoma with extensive brain edema.

Table 1 Summarizes clinical data of patients

	Total number of patients ($N = 34$), *n* (%)
Age	
≤18 y	19 (56)
≤12 y	12
12–18 y	7
>18 y	15 (44)
Sex	
Males	27 (79.4)
Females	7 (20.6)
Mode of trauma	
Isolated head trauma	26 (76.5)
Sharp object, e.g., fan blade	6
Blunt object, e.g., brick, stone, or heavy object	20
Fall from height	1 (3)
Road traffic accident	7 (20.5)
GCS on admission	
15/15	29 (85)
13–15 (mild head injury)	1 (3)
9–12 (moderate head injury)	2 (6)
3–8 (severe head injury)	2 (6)

Abbreviation: GCS, Glasgow Coma Scale.

Table 2 Summarizes radiological and operative data of patients

	Total number of patients ($N = 34$), *n* (%)
Location of fracture	
Frontal bone	19 (56)
Parietal bones	9 (26.4)
Occipital bone	6 (17.6)
Related venous sinuses to the fractures	
Superior sagittal sinus (SSS)	28 (82.4)
Anterior one-third	17 (50)
Middle one-third	7 (20.6)
Posterior one-third	4 (11.8)
Transverse sinuses	6 (17.6)
Associated localized hematoma	
Yes	18 (52.9)
No	16 (47.1)
Associated localized pneumocephalus	
Yes	20 (58.8)
No	14 (41.2)
Status of the sinus intraoperatively	
Intact	17 (50)
Tear	17 (50
Easily controlled	15
Difficult to be controlled (sinus ligated)	2

Table 3 Univariate logistic regression for prediction of tear

		Tear		Intact		*p*-value
		Count	%	Count	%	
Mode of trauma	IHT	10	38.5	16	61.5	0.034
	FFH + RTA	7	87.5	1	12.5	
GCS on admission	15/15	12	41.4	17	58.6	0.999
	Other than 15/15	5	100.0	0	0.0	
Location of fracture	Midline	5	31.3	11	68.8	0.044
	Off-midline	12	66.7	6	33.3	
Associated hematomas	Yes	16	88.9	2	11.1	<0.001
	No	1	6.3	15	93.8	
Associated pneumocephalus	Yes	15	75.0	5	25.0	0.002
	No	2	14.3	12	85.7	

Abbreviations: FFH, fall from height; GCS, Glasgow Coma Scale; IHT, isolated head trauma; RTA, road traffic accident.

following surgery is 1.7%[4] and increases up to 11.6% in VS injuries related to penetrating head injuries in wars.[30] A study in 1992 reported a mortality rate of 41% due to sinus injury after head trauma; however, it did not mention the GCS in those patients, and only 54% of patients in the study had a brain CT done.[6] The cause of mortality is not only profuse bleeding but also severe head injury.[4,31] Kim et al reported a mortality rate of 15% (3 of 20 cases) and all of them had severe head injury with a GCS score of $\leq$8 on admission.[4] Abdel-Aziz and Ragaee et al reported a mortality rate of 22.73% (5 of 22 cases); two of them presented with GCS score of $\leq$8.[7] In our study, the mortality rate was 5.8% (2 of 34 cases), and the two patients who died had a severe head injury and a GCS score of $\leq$8.

The SSS was distinguished as the most commonly involved VS in relation to CDF in many clinical studies[4–8,13,23,30] including our study in 28 patients (82.4%). In line with the reported age group with a high incidence of head injury,[5,23] the mean age in our study was 19.85 years. Consistent with many studies,[7,8,13,23] most of our patients were males (27, 79.4%), and IHT was the most common cause of CDF (26, 76.5%). This pattern is consistent with typical causes of injuries such as being hit by heavy or sharp objects during street fights, injuries from a heavy object falling over them, or young children being hit in their heads by a fan blade. All of these could explain why the highest incidence of injury was observed in the SSS.

Conservative treatment was the first option for CDF for many years,[1,6,30,32] making this traumatic pathology "untouchable"; however, a rising evidence in literature for complication happened for many cases like those with open and closed depressed fractures over the VS that present earlier or in delayed fashion with sinus thrombosis and different symptoms of intracranial hypertension, which was improved after surgery,[9–17] additionally; delayed abcess formation was reported after CDF after months,[5,33,34] and nonimprovement of visual deterioration due to thrombosis in the posterior one-third of the SSS was also reported.[13] These made the surgical option more favorable than the conservative option for many patients, especially in experienced tertiary neurotrauma centers.[3,4,7,8,19,23–25]

Surgical elevation would alleviate sinus compression and intracranial hypertension, and this was proved in postoperative MRV.[9,10,16,32] Additionally, MRV done in the cases in which a tear was repaired with Gelfoam or a piece of muscle and compression revealed the patency of the VS.[24]

Massive blood loss due to a complete tear of the sinus is a less common possibility and should be expected in patients with a GCS of $\leq$8, especially in the presence of associated hematomas especially acute subdural hematoma and severe brain edema, in cases with longitudinal fissure parallel to the sinus even without associated hematoma,[4] or in cases with fissure fracture crossing over the sinus like case[5].

Many methods for dealing with intraoperative VS injury are mentioned in the literature. These include the use of Gelfoam or muscle graft followed by compression over cottonoid, hitch stitches over Gelfoam to tent the dura to the bone adjacent to the sinus (►**Fig. 7A**), bilateral crossing hitch stitches over Gelfoam (►**Fig. 7B**), direct repair of the sinus through simple sutures if there is any loss of dural wall and this can be reinforced by a piece of Gelfoam or temporalis muscle or pericranium flap, flipping of part of the dura over the injured sinus over a piece of Gelfoam, use of a Fogarty catheter to be inflated for temporary control of bleeding, use of autologous venous graft or artificial sinus prosthesis for repair of the defect, and finally ligation of the sinus, which can be done only in the anterior one-third of the SSS.[1,3,4,9,24]

Patients presenting after IHT ($p = 0.034$) with off-midline fractures ($p = 0.044$) with the presence of localized hematoma ($p < 0.001$) are more likely to have a tear in the VS, especially a side tear. A side tear is easier to control than a top tear in the SSS. It is usually repaired with Gelfoam or muscle graft followed by compression over cottonoid, or hitch stitches over Gelfoam tenting the dura to the adjacent bone (►**Fig. 7A**).

A top tear in the SSS, which is more common in midline fractures, is usually associated with extensive high-flow

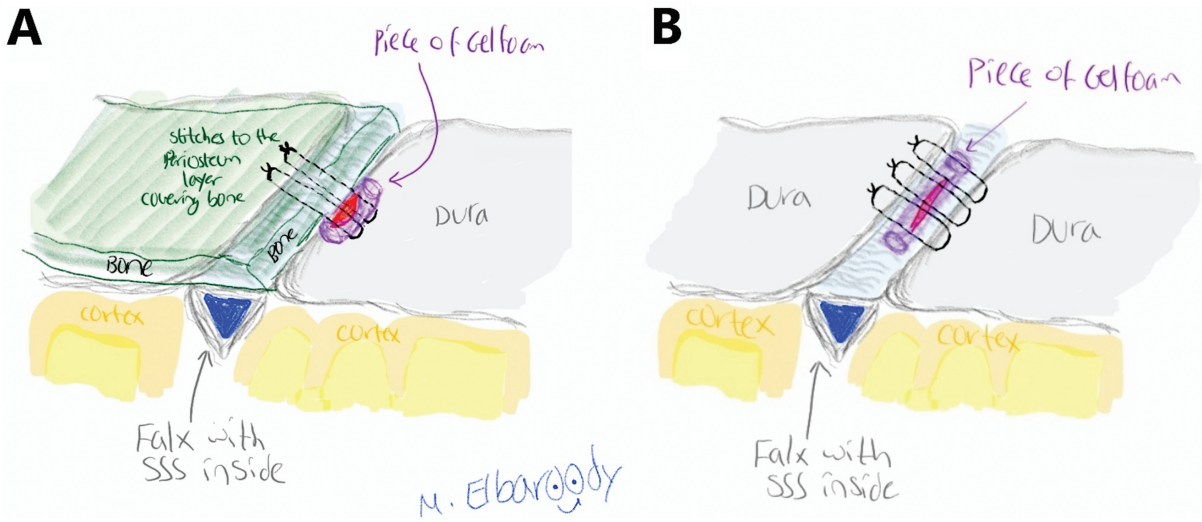

Fig. 7 Illustration showing two methods of control of bleeding. (**A**) Hitch stitches over Gelfoam to tent the dura to the bone adjacent to the sinus. (**B**) Bilateral crossing hitch stitches over Gelfoam.

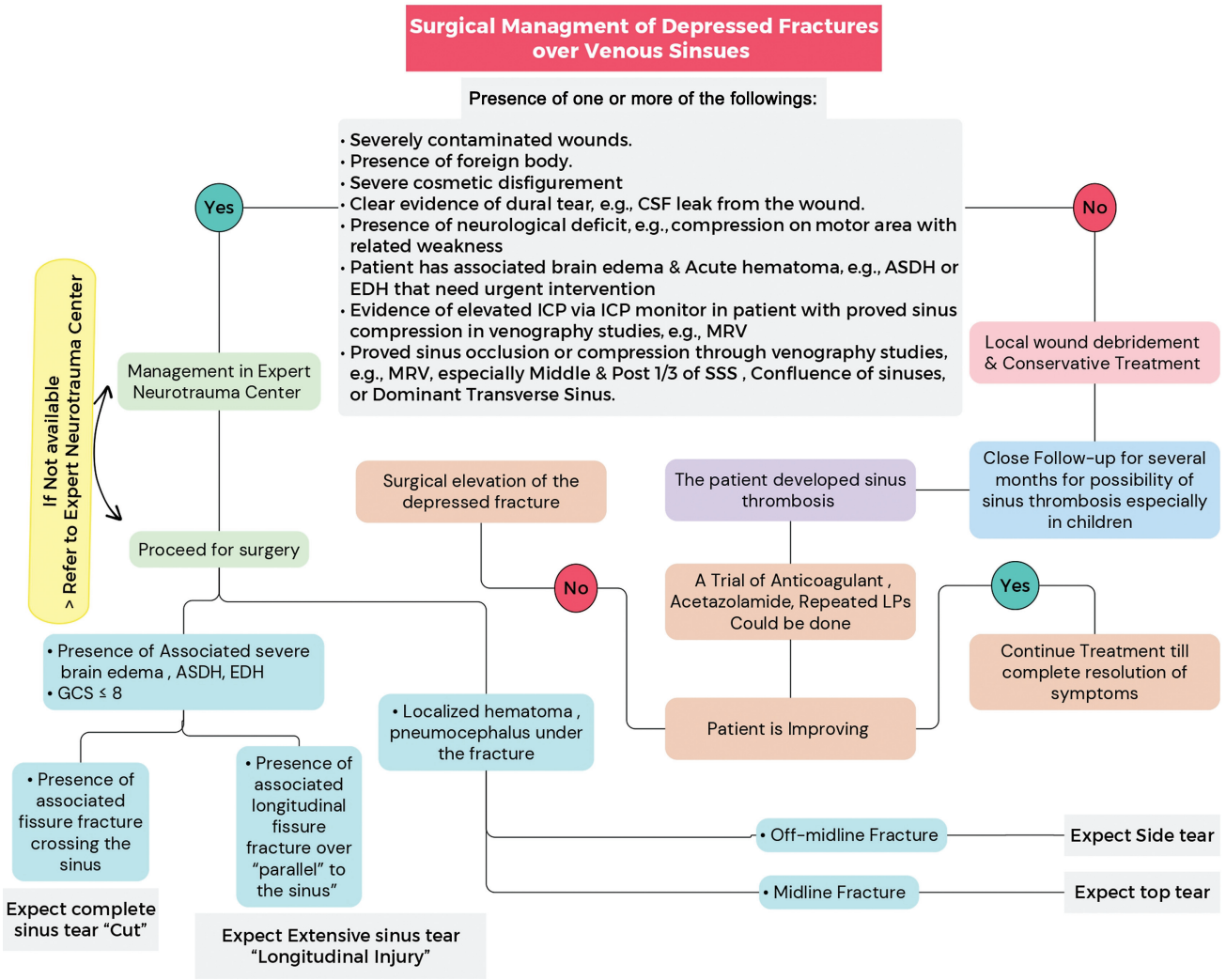

Fig. 8 A suggested algorithm for the management of compound depressed fractures over venous sinuses. ASDH, acute subdural hematoma; CSF, cerebrospinal fluid; EDH, epidural hematoma; GCS, Glasgow Coma Scale; ICP, intracranial pressure; LP, lumbar puncture; MRV, magnetic resonance venography; SSS, superior sagittal sinus.

bleeding after elevation of the depressed segment. Effective control is typically achieved with the use of Gelfoam and compression over cottonoid, and then gradually doing bilateral crossing hitch stitches over Gelfoam to cover the whole length (►**Fig. 7B**). We recommend performing a craniotomy around the depressed segment in those cases.

In our cases in which the transverse sinus was involved, all of them had small lacerations that were stopped with the use of Gelfoam and compression over cottonoid. However, in case of a tear, we used hitch stitches to tent the dura to the adjacent bone (►**Fig. 7A**) or bilateral hitch stitches. In the two cases with complete tear in the SSS, surgery was inevitable due to other associated indications and poor GCS score; however, sinus ligation was mandatory to stop the bleeding.

Good neurosurgeons know how to operate depressed fractures over the VSs and how to deal with intraoperative sinus injury, better ones know when to operate those cases, and the best neurosurgeons know when not to operate. Based on the literature and our experience, we came up with an algorithm for the management of CDF over the VS and this also includes the conservative option (►**Fig. 8**).

Sometimes surgery is mandatory in patients with complete tears due to associated pathology and poor GCS, while the conservative option is a wise decision if taken in the right patient by an expert neurotrauma surgeon. No one disagrees that if traumatic pathology would be managed without surgery, this should be done. However, it is not as simple as it looks because sinus thrombosis with intracranial hypertension is a major concern like massive bleeding.

In experienced tertiary neurotrauma centers with skilled teams, achieving optimal outcomes for patients with CDF over the VS requires meticulous studying of the preoperative images, good preparation, wise surgical steps, presence of several plans to deal with the VS injury, and close postoperative follow-up to manage the expected complications.

Conclusion

In experienced tertiary neurotrauma centers, CDFs over the VSs should be surgically elevated in most cases. Bleeding from the sinus can be controlled in most cases, and complete tear of the sinus with massive bleeding is a less common possibility and usually associated with severe head injury. If expert opinion favors the conservative approach, then close follow-up for months is recommended due to the high possibility of sinus thrombosis and intracranial hypertension, especially in children.

Authors' Contributions

M.E. contributed to the concepts, design, definition of intellectual content, literature search, manuscript preparation, manuscript editing, and manuscript review. A.A.M., A.A.M.E., H.A. helped in the design, definition of intellectual content, literature search, manuscript preparation, manuscript editing, and manuscript review. K.S., A.A.M., M.A. were involved in data collection and manuscript preparation. All the authors approved the manuscript before submission.

Ethical Approval

This study was approved by the research ethics committee of the Faculty of Medicine at Cairo University (N129-2023).

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Conflict of Interest

None declared.

References

1 LeFeuvre D, Taylor A, Peter JC. Compound depressed skull fractures involving a venous sinus. Surg Neurol 2004;62(02): 121–125, discussion 125–126
2 Miller JD, Jennett WB. Complications of depressed skull fracture. Lancet 1968;2(7576):991–995
3 Behera SK, Senapati SB, Mishra SS, Das S. Management of superior sagittal sinus injury encountered in traumatic head injury patients: analysis of 15 cases. Asian J Neurosurg 2015;10(01): 17–20
4 Kim Y-S, Jung S-H, Lim D-H, Kim T-S, Kim J-H, Lee J-K. Traumatic dural venous sinus injury. Korean J Neurotrauma 2015;11(02): 118–123
5 Abdelaal MA, Saro ASEM, Fadl KN, Abdelrahman AM. Management of compound depressed fractures over major cranial venous sinuses. Egypt J Hosp Med 2021;83:1177–1182
6 Meier U, Gärtner F, Knopf W, Klötzer R, Wolf O. The traumatic dural sinus injury: a clinical study. Acta Neurochir (Wien) 1992; 119(1–4):91–93
7 Abdel-Aziz KI, Ragaee MA. Compound depressed fracture over dural venous sinuses: experience of 22 surgically treated cases. Med J Cairo Univ 2019;87:2587–2591
8 Özer FD, Yurt A, Sucu HK, Tektaş S Depressed fractures over cranial venous sinus. J Emerg Med 2005;29(02):137–139
9 Yadav YR, Parihar V, Sinha M, Jain N. Simple depressed skull fracture causing posterior third superior sagittal sinus occlusion and elevated intracranial pressure. Neurol India 2009;57(06): 830–831
10 Yokota H, Eguchi T, Nobayashi M, Nishioka T, Nishimura F, Nikaido Y. Persistent intracranial hypertension caused by superior sagittal sinus stenosis following depressed skull fracture. Case report and review of the literature. J Neurosurg 2006;104(05): 849–852
11 Donovan DJ. Simple depressed skull fracture causing sagittal sinus stenosis and increased intracranial pressure: case report and review of the literature. Surg Neurol 2005;63(04):380–383, discussion 383–384
12 Fuentes S, Metellus P, Levrier O, Adetchessi T, Dufour H, Grisoli F. Depressed skull fracture overlying the superior sagittal sinus causing benign intracranial hypertension. Description of two cases and review of the literature. Br J Neurosurg 2005;19(05): 438–442
13 Elshanawany A, Ragab M. Delayed neurological deterioration after depressed fracture over superior sagittal sinus: our experience with 13 patients. J Neurol Surg A Cent Eur Neurosurg 2020; 81(04):324–329
14 Uzan M, Çiplak N, Dashti SGR, Bozkus H, Erdinçler P, Akman C. Depressed skull fracture overlying the superior sagittal sinus as a cause of benign intracranial hypertension. Case report. J Neurosurg 1998;88(03):598–600
15 Binder DK, Sarkissian V, Schmidt MH, Pitts LH. Resolution of intracranial hypertension after elevation of depressed cranial fracture over the superior sagittal sinus: case report. Neurosurgery 2004;55(04):986

16 du Plessis JJ. Depressed skull fracture involving the superior sagittal sinus as a cause of persistent raised intracranial pressure: a case report. J Trauma 1993;34(02):290–292
17 Zabalo San Juan G, Vázquez Míguez A, Zazpe Cenoz I, et al. Intracranial hypertension caused by superior sagittal sinus stenosis secondary to a depressed skull fracture: case report and review of the literature. Neurocirugia (Astur Engl Ed) 2019;30(05):243–249
18 Sundaram PK, Jain PK. Visual failure and sinus thrombosis following depressed skull fracture: management with single session lumboperitoneal shunt and sinus decompression -case report. Br J Neurosurg 2020;34(02):219–223
19 Sheng H-S, Shen F, Lin J, et al. Traumatic open depressed cranial fracture causing occlusion of posterior superior sagittal sinus: case report. Medicine (Baltimore) 2017;96(22):e7055
20 Wang WH, Lin JM, Luo F, Hu LS, Li J, Huang W. Early diagnosis and management of cerebral venous flow obstruction secondary to transsinus fracture after traumatic brain injury. J Clin Neurol 2013;9(04):259–268
21 Bullock MR, Chesnut R, Ghajar J, et al; Surgical Management of Traumatic Brain Injury Author Group. Surgical management of depressed cranial fractures. Neurosurgery 2006;58(03):S56–S60, discussions Si-iv
22 Stein SC. The evolution of modern treatment for depressed skull fractures. World Neurosurg 2019;121:186–192
23 Aziz MM, Molla S, Abdelrahiem HA, Dawood OM. Depressed skull fractures overlying dural venous sinuses: management modalities and review of literature. Turk Neurosurg 2019;29(06): 856–863
24 Tripathi AK, Kansal S, Murthy K, Kumar A, Baid A. Is the elevation of depressed Calveria over superior sagittal sinus (SSS): (no men land) rightly contraindicated. IP Ind J Anat Sur Head Neck Brain 2016;2:32–34
25 Mathew JE, Sharma A. Bizarre depressed skull fracture by a tile fragment in a young child, causing superior sagittal sinus injury. Surg Neurol Int 2010;1:52
26 Braakman R. Depressed skull fracture: data, treatment, and follow-up in 225 consecutive cases. J Neurol Neurosurg Psychiatry 1972;35(03):395–402
27 Chan YH. Biostatistics 102: quantitative data—parametric & non-parametric tests. Singapore Med J 2003;44(08):391–396
28 Chan YH. Biostatistics 103: qualitative data - tests of independence. Singapore Med J 2003;44(10):498–503
29 Chan YH. Biostatistics 202: logistic regression analysis. Singapore Med J 2004;45(04):149–153
30 Meirowsky AM. Wounds of dural sinuses. J Neurosurg 1953;10 (05):496–514
31 Unnithan AK. A brief review of dural venous sinus injury with a short case series. Egypt J Neurol Psychiatr Neurosurg 2022; 58:146
32 Meltzer H, LoSasso B, Sobo EJ. Depressed occipital skull fracture with associated sagittal sinus occlusion. J Trauma 2000;49(05): 981
33 Geisler FH, Rodriguez E, Manson PN. Traumatic skull and facial fractures. In: Ellenbogen RG, Abdulrauf SI, Sekhar LN, eds. Principles of Neurological Surgery. 3rd ed. Philadelphia, PA: W. B. Saunders; 2012:365–393
34 Antunes Á, Franciscatto A, Modkovski R, De Ávila T. Depressed skull fracture. In: Kalangu KKN, Kato Y, Dechambenoit G, eds. Essential Practice of Neurosurgery. Nagoya:Access Publishing;2009:716–723

