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Depressed Skull Fractures Overlying Dural Venous Sinuses: Management Strategies and Outcomes

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ABSTRACT

Keyword: Depressed skull fracture, dural venous sinus, superior sagittal sinus, neurosurgical trauma, surgical vs. conservative management, intracranial pressure, venous thrombosis

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Background: Depressed skull fractures involving the dural venous sinuses represent a complex neurosurgical emergency, These fractures carry a significant risk of complications such as venous sinus thrombosis, intracranial hemorrhage, and neurological deterioration, making their management particularly challenging. **Objective**: To compare the clinical outcomes of surgical versus conservative management in patients with depressed skull fractures overlying the cerebral venous sinuses. **Methodology**: , 40 patients with depressed skull fractures involving dural venous sinuses were enrolled.patients were treated either surgically or conservatively. with follow-up extending up to 6 months to assess neurological recovery and complications. **Results**: Among the 40 patients, 22 (55%) underwent surgical intervention, while 18 (45%) were managed conservatively. The mean hospital stay was 4.88 ± 1.73 days, and the average follow-up period was 6.98 ± 2.98 months. Overall, 80% of patients achieved good recovery, while 20% experienced mild disability. Surgical management was significantly associated with a higher incidence of mild disability ($p = 0.005$). **Conclusion**: Both surgical and conservative management can be effective in treating depressed skull fractures involving dural venous sinuses. However, conservative treatment may be associated with better functional outcomes in selected patients without neurological deficits or extensive fracture involvement.

INTRODUCTION

Depressed skull fractures are a significant subset of traumatic brain injuries (TBI), most frequently resulting from high-energy impacts such as vehicular collisions, falls from height, and assaults [1]. These fractures are characterized by inward displacement of the skull bone, often leading to compression or laceration of underlying brain structures. When a depressed fracture overlies a dural venous sinus—such as the superior sagittal, transverse, or sigmoid sinus—the clinical situation becomes more complex due to the heightened risk of life-threatening complications, including venous sinus thrombosis, intracranial hemorrhage, air embolism, and dural tears [2].

The management of depressed skull fractures involving dural venous sinuses presents a significant clinical dilemma. On one hand, surgical intervention is often considered necessary to relieve intracranial pressure, prevent venous congestion, and reduce the risk of long-term neurological deficits. Surgical procedures may include craniotomy and careful elevation or removal of the depressed bone fragments, especially when the fracture causes direct compression or injury to the venous sinus. However, surgical manipulation of these structures is fraught with risk. The thin-

walled venous sinuses are vulnerable to uncontrollable bleeding when injured, which can lead to catastrophic hemorrhage, hemodynamic instability, and even death. Additionally, surgery in this region may result in postoperative complications such as infection, venous infarction, or persistent thrombosis [3,4].

Conversely, conservative management may be favored in cases where the fracture is minimally depressed, there is no evidence of venous sinus obstruction, and the patient exhibits no neurological deficits. This approach relies on close radiological monitoring, supportive care, and management of symptoms such as headache or seizure. The primary advantage of conservative treatment lies in its avoidance of surgical risks; however, delaying or avoiding surgery inappropriately could result in missed opportunities to prevent complications such as sinus thrombosis or progressive neurological deterioration [5].

Despite advancements in imaging and surgical techniques, clear guidelines for managing depressed skull fractures overlying venous sinuses remain lacking. Clinicians must often weigh the benefits of surgical decompression against the potential for severe intraoperative complications, making individualized decision-making crucial. This diagnostic and therapeutic challenge underscores the need for further research into patient outcomes based on treatment modality. [6]

This study aims to investigate and compare the outcomes of surgical versus conservative management in patients with depressed skull fractures involving dural venous sinuses, with the goal of providing evidence-based guidance for optimal treatment strategies.

PATIENTS AND METHODS

This prospective observational study was conducted over a 12-month period, from April 2023 to April 2024, at Aswan university hospital neurosurgical department and included patients diagnosed with depressed skull fractures overlying dural venous sinuses. The primary aim was to evaluate and compare the clinical outcomes of surgical versus conservative management in this specific patient population.

Eligibility Criteria

Inclusion criteria: Patients of any age or gender presenting with depressed skull fractures involving one or more dural venous sinuses (e.g., superior sagittal, transverse, or sigmoid sinuses).

Exclusion criteria: Patients with depressed skull fractures not involving venous sinuses, or those with prior neurosurgical interventions that could confound outcome measures.

These criteria ensured a homogeneous study population, allowing for focused analysis of treatment outcomes in fractures specifically affecting venous sinuses.

Clinical and Radiological Evaluation

All eligible patients underwent a comprehensive baseline evaluation, which included:

Clinical assessment: Medical history, physical examination, and detailed neurological evaluation.

Imaging studies:

Plain skull X-rays and non-contrast CT scans to assess fracture location, depth, and bone displacement. 3D CT reconstructions for preoperative planning and anatomical clarity.

Magnetic Resonance Venography (MRV) to assess dural venous sinus patency and detect thrombosis or stenosis.

Fundus examination to evaluate signs of papilledema or raised intracranial pressure.

Laboratory Investigations

Routine pre-treatment laboratory tests included:

Complete Blood Count (CBC), Coagulation profile, Renal function tests, Blood grouping and cross-matching (especially relevant for surgical candidates)

Treatment Modalities

Surgical Management

Patients selected for surgery had significant fracture depression, neurological deficits, or radiological evidence of sinus compromise as more and significant depression as significant neurological deficit. Preoperative imaging guided the surgical approach. The operative procedure involved:

- Elevation of depressed bone fragments.
- Inspection and, if needed, repair of the venous sinus walls.
- Haemostasis management, particularly in cases of sinus laceration or active bleeding. We used surgicel and gelfoam sponge, in addition to hitching the dura close to the sinus to prevent recollection of haemorrhage. Some cases required direct repair of the sinus with stitches.

Conservative Management

Patients with minor fractures, no neurological deficits, and no radiological evidence of sinus obstruction were managed conservatively. Treatment included:

- Close clinical monitoring and observation.
- Symptomatic management (e.g., analgesics, anti-edema therapy).
- Serial imaging, including repeat MRV and fundus examinations, to monitor for delayed complications such as venous thrombosis or intracranial hypertension.

Follow-Up Protocol

All patients were followed up during hospitalization and after discharge for a period of at least 3–6 months. Follow-up assessments included:

Clinical and neurological evaluations.

CT brain scans before discharge and at 6–8 weeks post-treatment, or earlier if new symptoms developed.

Additional imaging or interventions were carried out based on clinical findings during follow-up.

Ethical Considerations

Informed consent was obtained from all patients or their legal guardians, where applicable. The study protocol received approval from the institution's scientific and ethical review board, and all procedures complied with ethical standards for clinical research and patient care.

Statistical Analysis

Data were entered and analysed using IBM SPSS Statistics software (version XX). Descriptive statistics were used to summarize demographic data and injury characteristics. Comparative analyses between the surgical and conservative groups were performed using:

Chi-square test or Fisher's exact test for categorical variables.

Independent sample t-tests for continuous variables.

A p-value < 0.05 was considered statistically significant.

RESULTS

A total of **40 patients** with depressed skull fractures overlying the dural venous sinuses were enrolled in the study and managed either **surgically (n = 22, 55%)** or **conservatively (n = 18, 45%)**.

Demographics and Injury Characteristics

Patient ages ranged from **12 to 56 years**, with a mean age of **26.28 ± 8.93 years**. The majority of patients (**72.5%**) were between **21 and 40 years** old, and **males constituted 87.5%** of the study population (Table 1).

The **most common mechanism of injury** was **direct trauma (37.5%)**, followed by **falls from height (32.5%)** and **road traffic accidents (30%)**. The **superior sagittal sinus** was the most frequently involved site (**67.5%**), followed by the **confluence of sinuses (25%)**, **right transverse sinus (5%)**, and **left transverse sinus (2.5%)**. **Compound fractures** were observed in **65%** of patients.

Neurological Status and Imaging Findings

At presentation, **90%** of patients had **intact motor function**, while **10%** exhibited some degree of paresis. **MR venography (MRV)** was positive in **7 patients (17.5%)**, indicating venous sinus involvement or thrombosis. **Fundoscopic examination** showed signs of increased intracranial pressure (e.g., papilledema) in **21 patients (52.5%)**.

Cranio-cerebral lesions were identified in **40%** of the cases, including:

- **Epidural hematomas (20%)**
- **Cerebral contusions (10%)**
- **Orbital fractures (10%)**

All patients (100%) had CT-confirmed skull fractures (Table 2).

Treatment Outcomes

The **mean hospital stay** was **4.88 ± 1.73 days**, and the **average follow-up period** was **6.98 ± 2.98 months**. There was **no significant difference** between the surgical and conservative groups in terms of **Glasgow Coma Scale (GCS)** at admission ($p = 0.175$), **hospital stay duration** ($p = 0.367$), or **follow-up duration** ($p = 0.087$) (Table 3).

Clinical Outcomes and Group Comparisons

Overall, **80%** of patients achieved **good recovery**, while **20%** experienced **mild disability**. Notably, **all conservatively managed patients (100%)** had good recovery, whereas **36.4% of the surgical group** had mild residual disability—a **statistically significant difference** (**$p = 0.005$**) (Table 4).

Further analysis revealed:

- A significantly higher proportion of **fractures at the confluence of sinuses** in the **conservative group** (**$p = 0.017$**).
- A significantly greater incidence of **epidural hematomas** and **orbital fractures** in the **surgical group** (**$p = 0.001$**).

These findings suggest that patients undergoing surgery more frequently had complex fractures with associated cranio-cerebral injuries, potentially contributing to less favorable functional outcomes.

Table (1): Distribution of the studied patients regarding clinical assessment.

		Studied patients (N= 40)	
		N	**%**
Mode of trauma	**Direct trauma**	15	37.5%
	Fall from height	13	32.5%
	Road traffic accident	12	30.0%
Pre-treatment Neurological status	**Intact motor power**	36	90.0%
	Paresis	4	10.0%
Fracture location	**Confluence of Sinuses**	10	25.0%
	Left Transverse Sinus	1	2.5%
	Right Transverse Sinus	2	5.0%
	Superior Sagittal Sinus	27	67.5%
Fracture type	**Compound**	26	65.0%
	Simple	14	35.0%

Table (2): Fundus examination and investigations in the studied cases.

		Studied patients (N= 40)	
		N	**%**
Magnetic resonance venography (MRV)	**Negative**	33	82.5%
	Positive	7	17.5%
Fundus examination	**Negative**	19	47.5%
	Positive	21	52.5%
CT Scan Brain	**Positive**	40	100.0%
Associated cranio-cerebral Lesions	**None**	24	60.0%
	Epidural hematoma	8	20.0%
	Contusion	4	10.0%
	Orbital Fracture	4	10.0%

Table (3): Comparison between the two treatment modalities regarding GCS, hospital stay and follow up period.

	Conservative (N= 18)	**Surgical (N= 22)**	**Test value**	**P-value**
	Mean± SD	**Mean± SD**		
Admission GCS	13.78± 0.81	14.14± 0.83	Z_{MWU}= 1.355	0.175 (NS)
Hospital stay (days)	5.17± 1.82	4.64± 1.65	Z_{MWU}= 0.903	0.367 (NS)
Follow up period (months)	7.67± 2.22	6.41± 2.28	T= 1.754	0.087 (NS)

Table (4): Comparison between the two treatment modalities regarding Neurological outcome.

		Conservative (N= 18)		**Surgical (N= 22)**		**Test value**	**P-value**
		No.	**%**	**No.**	**%**		
Outcome	**Good Recovery**	18	100.0%	14	63.6%	X^2= 8.182	**0.005^{FET} (HS)**
	Mild Disability	0	0.0%	8	36.4%		

P value >0.05: Not significant (NS), P value <0.05 is significant (S), p<0.01 is highly significant (HS).

SD: standard deviation, IQR: Interquartile range, X^2: Chi- Square test, FET: Fischer Exact Test,

CASE PRESENTATIONS

Case 1:

A 35-year-old male patient sustained injuries from a fall from height, presenting with a GCS score of 15 and symptoms of blurred vision. He had no history of seizures. Preoperative CT imaging identified a compound depressed fracture at the left transverse sinus. Given the involvement of the venous sinus, surgical repair was necessitated. During surgery, the fracture fragments were elevated, and the venous sinus injury was repaired using simple stitches. The postoperative period was uneventful, with the patient retaining a GCS of 15, no neurological deficits, and improved vision. Postoperative CT scans confirmed the effectiveness of the surgical repair and the intact venous sinus.

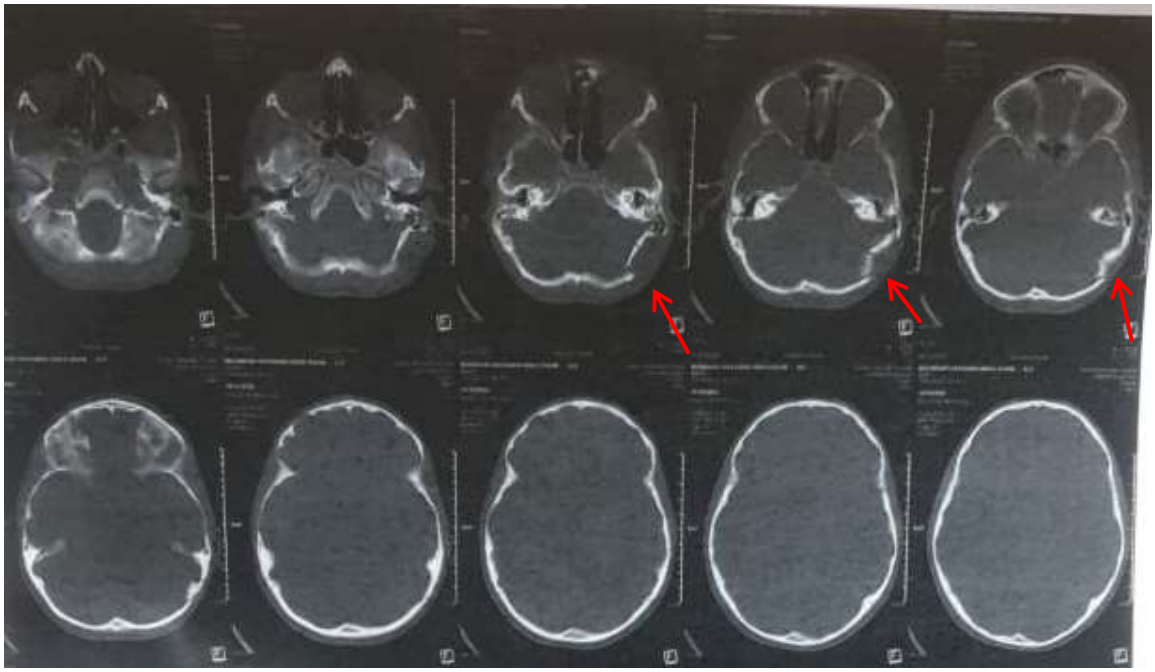

Figure 1 : CT bone window axial cuts showing left basal occipital depressed fracture , red arrow showing location of depressed fracture.

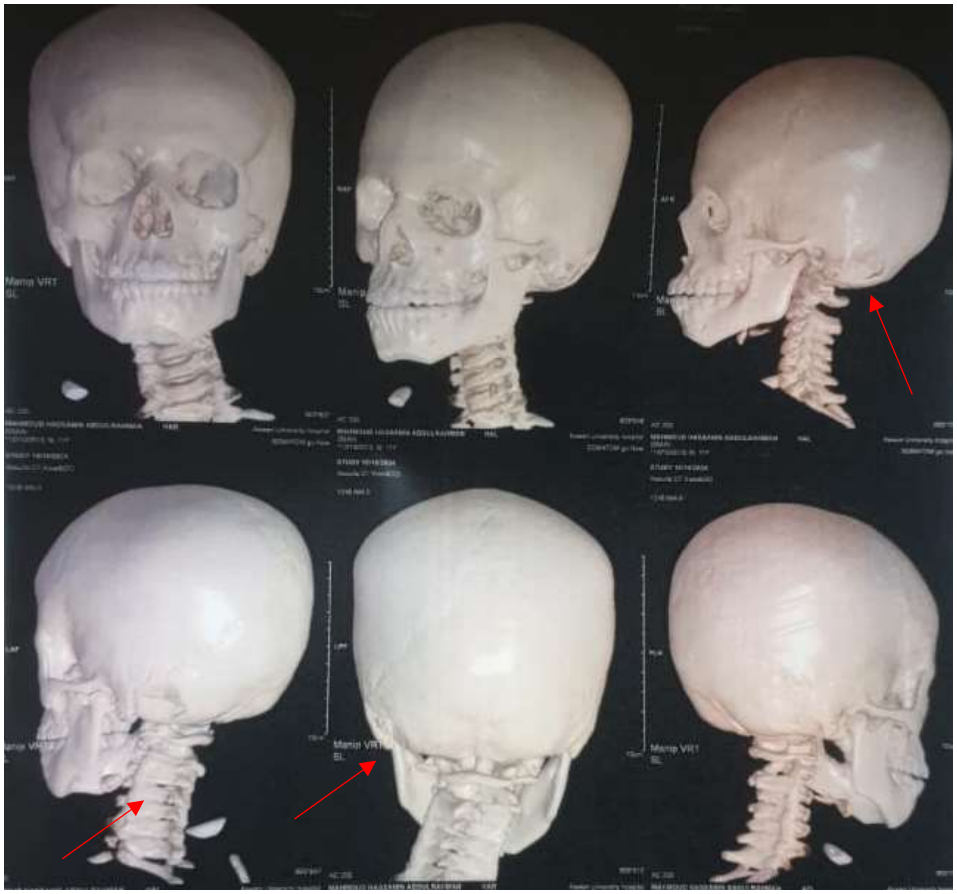

Figure 2: 3D reconstruction of CT showing cosmetic disfigurement and external appearance of the fracture. Red arrow showing location of the fracture

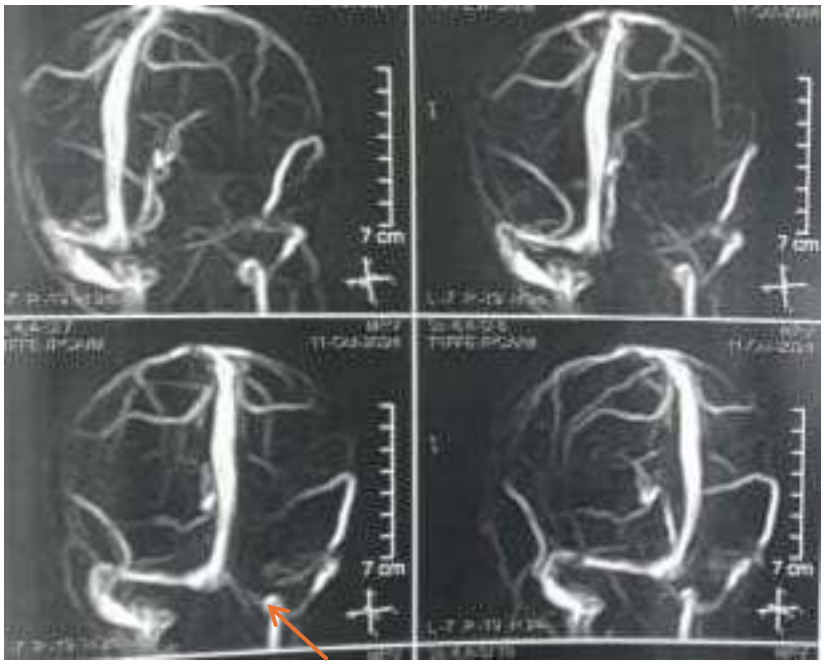

Figure 3: MR venography showing occlusion of left transverse sinus , orange arrows showing occlusion of left transverse sinus .

Case 2:

A 19-year-old male patient was admitted following an assault. He presented with a Glasgow Coma Scale (GCS) score of 15, indicating full consciousness, and displayed no neurological deficits or seizures. The preoperative CT scan revealed a compound depressed fracture over the superior sagittal sinus. Preoperative MRV venography was done to show partial occlusion of SSS. Surgical intervention was undertaken to address the fracture. Intraoperatively, it was confirmed that the superior sagittal sinus was intact. Postoperative assessments showed the patient remained fully conscious with a GCS of 15, and no neurological deficits were noted. The postoperative CT images validated the successful surgical outcome, confirming the realignment of the fracture without additional complications.

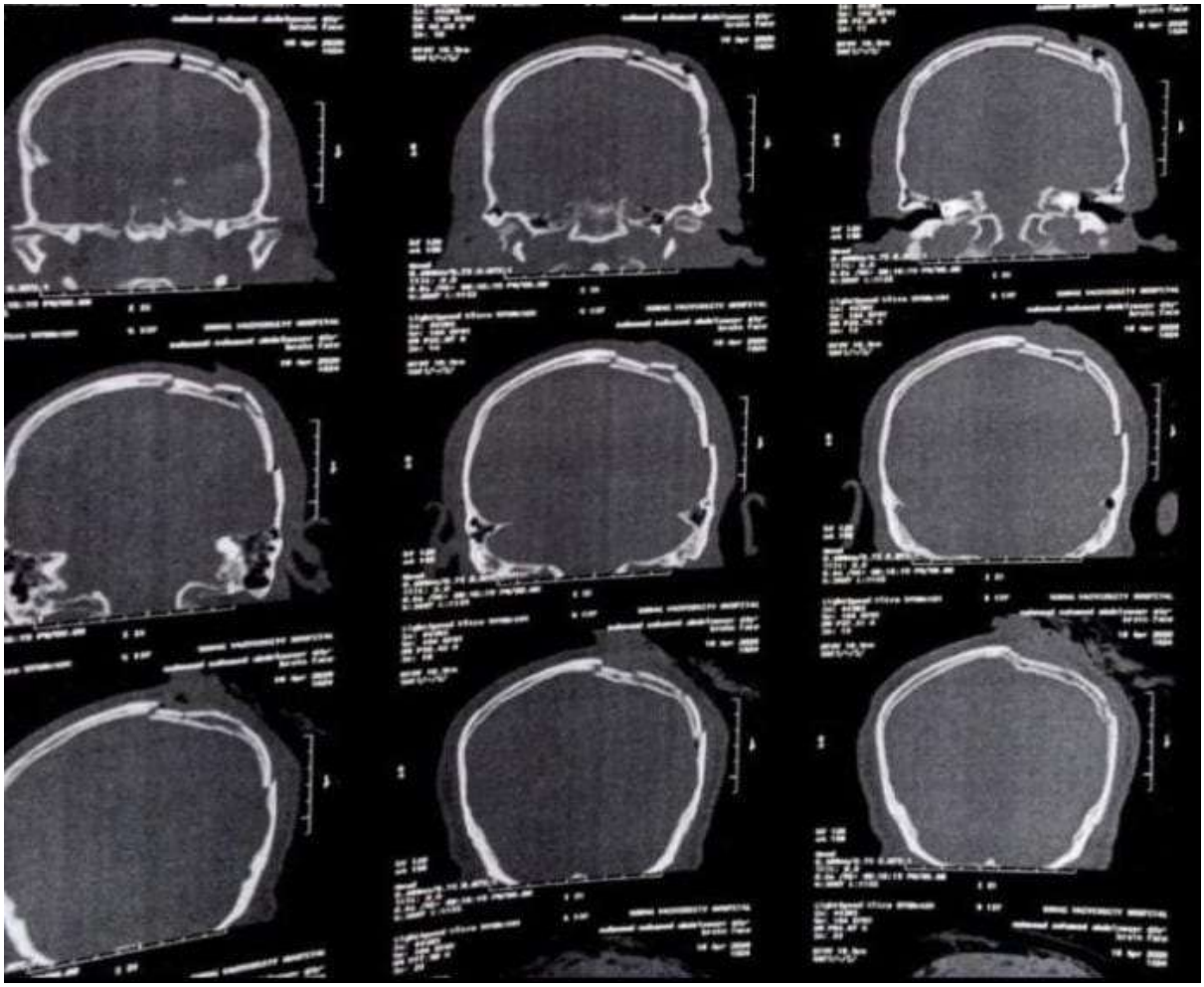

Figure 4: CT coronal cuts showing left parasagittal parietal depressed fracture

Figure 5: MR venography showing parietal occlusion of anterior third of superior sagittal sinus

DISCUSSION

Overview and Clinical Significance

Depressed skull fractures overlying the dural venous sinuses (DVS) represent a particularly high-risk subset of traumatic brain injuries due to their anatomical proximity to critical cerebral venous drainage pathways. The superior sagittal sinus (SSS), confluence of sinuses, and transverse sinuses are essential for maintaining cerebral venous outflow, and disruption of these structures may lead to venous sinus thrombosis (VST), intracranial hypertension, hemorrhage, or cerebral edema. Timely diagnosis and a well-considered treatment strategy are essential to mitigate both immediate and delayed neurological complications.

This study aimed to clarify the clinical dilemma surrounding the choice between **surgical versus conservative management** in these cases, highlighting the outcomes and risks associated with each approach.

Surgical Versus Conservative Management: A Therapeutic Dilemma

The decision between surgical and conservative treatment remains a subject of ongoing debate, with no universally accepted guidelines due to the rarity and complexity of these injuries. In our cohort, 55% of patients were managed surgically and 45% conservatively, underscoring the tailored nature of treatment based on fracture characteristics, sinus involvement, neurological status, and risk of complications.

Surgical intervention is generally favored in the presence of:

- Significant fracture depression,
- Overt venous sinus compression or laceration,
- Associated intracranial hematomas,
- Progressive neurological deficits.

Conversely, conservative treatment is typically reserved for:

- Non-depressed or minimally depressed fractures,
- Absence of neurological compromise,
- Stable imaging findings without evidence of venous thrombosis or hemorrhage.

Our findings demonstrated that both groups had favorable outcomes overall; however, **mild disability was significantly more frequent in the surgical group (36.4%)**, whereas all patients in the conservative group achieved full recovery. These results mirror prior observations by Wilson et al. [9], who noted that while surgery can be lifesaving, it may be associated with minor but persistent neurological deficits likely attributable to surgical manipulation near critical venous structures.

Fracture Location and Associated Injuries

Fracture location played a pivotal role in both treatment selection and clinical outcomes. The **SSS** was the most affected sinus (67.5%), followed by the **confluence of sinuses** and **transverse sinuses**. This distribution aligns with anatomical vulnerability, as the SSS spans the midline and is more exposed to direct trauma.

A substantial proportion (40%) of patients had **associated cranio-cerebral lesions**, including epidural hematomas, contusions, and orbital fractures—more common in the surgically managed group. These findings are supported by Zhang et al. [10], who emphasized that skull fractures involving midline venous sinuses tend to be more severe and often necessitate surgical decompression due to a higher risk of mass effect or bleeding.

Interestingly, our study also found that **fractures at the confluence of sinuses** were more likely to be managed conservatively, consistent with Singh et al. [7], who reported that unless complicated by hematomas or neurological deterioration, such fractures can be successfully observed without operative intervention.

Role of Imaging in Guiding Management

Imaging is indispensable in the evaluation of depressed fractures involving the DVS. CT and 3D CT were critical for fracture characterization, while MRV provided insights into **venous sinus patency and thrombosis**. In our study, **17.5% of patients** demonstrated VST, and **over half (52.5%)** showed signs of increased intracranial pressure (ICP) on fundus examination.

The diagnostic value of MRV and CT venography has been underscored by Thomas et al[11], who emphasized their role in identifying early thrombotic complications or venous compression, which may not be apparent on conventional CT. In cases with thrombosis or worsening ICP, surgical decompression may be required to restore venous outflow and prevent deterioration. However, our findings confirm that in selected patients with stable neurological exams and imaging, **conservative management can prevent progression to thrombosis or herniation**, supporting the conclusions of Evans et al. [4].

Surgical Risk and Functional Recovery

Despite the theoretical benefits of surgery in relieving venous compression and correcting deformity, it is not without risk. The **higher incidence of mild disability** in surgically treated patients may be attributed to:

- Greater fracture severity (e.g., compound or comminuted fractures),
- Presence of associated lesions,
- Surgical manipulation near vital venous channels.

These outcomes echo the conclusions of Harris et al.[5] , who observed that even technically successful surgery may lead to transient or permanent neurological deficits, especially when venous flow is disrupted intraoperatively.

Furthermore, Patel et al. [8] highlighted that **post-surgical venous insufficiency**, whether transient or persistent, can impair recovery even if structural decompression is achieved. Therefore, surgical candidacy must be determined not only by radiological findings but also by patient-specific risk factors and functional baseline.

Long-Term Outcomes and Complications

The overall outcome in this study was favorable, with **80% of patients achieving good recovery**. Importantly, **no major delayed complications** (e.g., progressive VST, worsening ICP) were observed in the conservatively treated group during follow-up. Routine **post-discharge imaging**—particularly MRV and CT at 6–8 weeks—proved instrumental in ensuring neurological recovery and identifying potential complications early.

However, the **risk of delayed venous insufficiency** or **chronic intracranial hypertension** cannot be entirely excluded. Evans et al. [4] cautioned that patients with sinus involvement may still develop subtle cognitive or visual symptoms later on, emphasizing the need for **long-term neurological monitoring**, especially for conservatively managed patients.

Clinical Implications

This study reinforces the principle that **individualized treatment planning** is essential in managing depressed skull fractures overlying dural venous sinuses. While **surgical intervention** remains the cornerstone in severe or complicated cases, our findings validate that **conservative management is a safe and effective alternative** in select patients without neurological compromise or significant fracture depression.

Given the potential risks associated with surgery—including venous sinus injury, postoperative disability, and longer recovery—**early identification of surgical indications** and **careful follow-up in conservatively managed cases** are both critical to optimizing outcomes.

CONCLUSION

This study demonstrates that both surgical and conservative management strategies can be effective for treating depressed skull fractures overlying the dural venous sinuses, provided that patient selection is carefully guided by clinical and radiological findings. **Conservative management is associated with fewer complications and better functional outcomes** in patients without significant neurological deficits or extensive fractures. **Surgical intervention remains essential in more severe cases**, though it carries a higher risk of mild disability, highlighting the need to minimize intraoperative trauma and preserve venous integrity.

Overall, our findings underscore the importance of an individualized, imaging-guided approach to management. Further large-scale, long-term studies are needed to refine clinical guidelines and better define the optimal treatment pathway for this challenging and potentially high-risk injury pattern.

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