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Elevated Skull Fracture: Single Institution Experience

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Abstract

Elevated or everted skull fractures, where the fractured segment of the skull is raised above the surrounding bone, are rare in contemporary surgical practice. Historically noted in ancient texts, these fractures have been sporadically documented in modern medical literature. This study presents a comprehensive analysis of 16 cases, one of the largest collections reported in English literature, to better understand the clinical presentation, management and outcomes of this uncommon injury. This prospective study was conducted over two years (January 2022-December 2023) at the Department of Neurosurgery, J.A. Group of Hospitals and G.R. Medical College, Gwalior, MP, India. All age groups with elevated skull fractures were included, except for hemodynamically unstable patients and those with severe comorbidities. Patients underwent initial emergency assessment, including CT scans and received appropriate surgical intervention as needed. Data on demographics, clinical profile, radiological findings, management and outcomes were collected and analyzed. The study included 16 patients (13 males, 3 females) with a median age of 25.5 years. The most common causes were assault (8 cases) and road traffic accidents (5 cases). Fractures were mainly parietal (8 cases) and frontal (7 cases), with Type 2 fractures being the most frequent (8 cases). The median Glasgow Coma Scale (GCS) on admission was 14. Surgical intervention was performed on all patients, with 11 requiring duroplasty. Postoperative complications included two cases of brain abscess and four cases of meningitis. Favorable outcomes (Glasgow Outcome Scale score of 4-5) were achieved in 94% of the patients at discharge. Elevated skull fractures, though rare, can be effectively managed with timely surgical intervention and comprehensive care. Early diagnosis, appropriate surgical techniques and vigilant postoperative monitoring are crucial in preventing complications and ensuring favorable outcomes.

INTRODUCTION

An elevated or everted skull fracture is a type of fracture where the broken part of the skull is raised above the level of the undamaged skull[1]. This medical condition, although rarely seen in modern surgical practice, was first described as early as 1650-1550 BC. It is specifically mentioned in the Edwin Smith Papyrus, a didactic trauma treatise with a focus on neurosurgery[2,3]. Due to its infrequent incidence or lack of attention, this fracture was not documented in surgical texts until 1976 when Ralston reported its occurrence and examined its pathology[4]. Authors have shown a growing interest in these fractures in recent years, although only a small number of cases have been reported. These testimonies rarely include the diverse presentation of these pathological entities. We present a collection (which we believe to be one of the largest in English literature) of sixteen cases that we encountered in our clinical practice.

MATERIALS AND METHODS

This is a prospective study conducted over period of 2 years from January 2022-December 2023 at tertiary care center in the Department of Neurosurgery, J.A. Group of Hospitals and G.R. Medical College, Gwalior, MP, India. Patients of all age groups with elevated skull fracture were included in the study while Haemodynamically unstable patients and patients with severe comorbid disorders were excluded

Procedure Planned:

At Admission: Once the patients were brought to the Emergency department with the history of head trauma, patients underwent triage and received primary aid and resuscitation. Following the initial assessment, the cervical spine was immobilised using a collar. Patients who had difficulty breathing, a compromised airway, or a low Glasgow Coma Scale score (8 or lower) were intubated and provided with mechanical ventilation. The hemodynamic instability was addressed appropriately. Patients who were believed to have a high chance of experiencing seizures after a traumatic event were administered intravenous fosphenytoin based on their body weight. All patients received tetanus toxoid regardless of the method of injury. After stabilising the patient, a CT scan of the head and other necessary sections of the body was conducted and a consultation with a neurosurgeon was requested.

Neurosurgical Evaluation: Comprehensive information was recorded about the sequence of events leading to the injury, the manner in which the injury occurred, whether a helmet was used, the individual's medical history, any alcohol intoxication and the specific symptoms experienced at the time of presentation, such as loss of consciousness, amnesia, nausea, vomiting, headache, seizures, or any bleeding from the ear, nose, or throat. If a patient is unconscious, the medical history is gathered from the person accompanying the patient. A meticulous and comprehensive neurological assessment was conducted for each patient, encompassing the evaluation of their level of consciousness, initial Glasgow Coma Scale (GCS) score upon arrival, subsequent GCS score during follow-up, pupillary condition, cranial nerve function, motor and sensory impairment when feasible, as well as the identification of signs indicative of base of skull fractures such as active cerebrospinal fluid (CSF) leakage, the presence of Raccoon's eye sign and Battle's sign. Patients were classified into three categories based on their Glasgow Coma Scale (GCS) score: mild (GCS 13-15), moderate (GCS 9-12) and severe brain injury (GCS <=8). A high-resolution CT scan of the head was conducted utilising a 64-slice CT scan system. The report included specific information regarding the fracture at the base of the skull, including the affected bones and the extent of the fracture into the anterior, middle, or posterior cranial fossa. Additionally, concurrent intracranial observations such as recent cerebral bleeding, air trapped within the cranial cavity and fractures in the skull were also observed.

Course in the Hospital: Cases which require surgical intervention underwent wound exploration, cleansing, debridement, reduction of fracture segment or removal of fracture segment, fixation. Acomprehensive neurological assessment was conducted on a daily basis for all patients and any changes in their condition were carefully recorded. Repeated CT scans were conducted at suitable intervals to assess the condition of intracranial injuries and monitor the advancement or regression of the disease.

Data Collection: Recorded documents were prospectively studied for age of distribution, sex, mode of injury, site of injury, mechanism of injury, clinical profile, radiological investigations, neurosurgical management and outcome asses by Glasgow Outcome Scale at the time of discharge and at the age of 6 months. Postoperatively, the patients were followed up clinically and radiologically at a regular interval. Postoperative computed tomography (CT) scan was performed in the immediate postoperative period.

The neuro-radiological images were analyzed to develop a classification system which would enable accurate description allowing better operative planning.

Three Distinct Types Were Identified:

- **Type 1:** Fractured segment with minimal loss of contact with rest of cranial vault
- **Type 2:** Fractured segment with complete loss of contact with cranial vault but retained attachment with scalp.
- **Type 3:** Fractured segment with complete loss of contact with cranial vault and scalp.

RESULTS AND DISCUSSIONS

In a study of 16 patients with elevated skull fractures treated by our neurosurgical unit, the majority were male (13/16) with a median age of 25.5 years. The most common mechanisms of injury were assault (8/16) and blunt cranial injury from road traffic accidents (5/16). Fractures were predominantly located in the parietal (8/16) and frontal (7/16) regions, with Type 2 fractures being the most frequent (8/16). The median Glasgow Coma Scale (GCS) on admission was 14, with focal neurological deficits including hemiparesis (8 patients) and unilateral pupil deficits (2 patients). Surgical intervention was undertaken for all patients, with duroplasty required in 11 cases. Bone flaps were debrided and replaced in 10 patients, while they were discarded in the rest. Two patients developed post-traumatic brain abscesses, and four developed post-traumatic meningitis. Ninety-four percent (15/16) of patients had favorable outcomes, achieving a Glasgow Outcome Scale (GOS) score of 4-5 at discharge.

In a study involving 16 patients with elevated skull fractures treated by our neurosurgical unit, the patient demographic was predominantly male, with 13 males and 3 females. The median age of the patients was 25.5 years.

The mechanisms of injury for the 16 patients with elevated skull fractures included assault in 8 patients, blunt cranial injury from road traffic accidents in 5 patients, falls from height in 2 patients and a fall from a bicycle in 1 patient.

The patients had a median Glasgow Coma Scale (GCS) score of 14 on admission, with 2 patients presenting with a GCS score below 9. Focal neurological deficits were observed in 10 patients, including hemiparesis in 8 patients and unilateral afferent pupil deficits in 2 patients.

Upon review of neuro-radiology imaging, the fractures were located in the parietal region in 8 patients, the frontal region in 7 patients and the occipital region in 1 patient.

The fractures were categorized into three types, with Type 2 being the most common, observed in 8 patients. Type 1 fractures were found in 5 patients, and Type 3 fractures were present in 3 patients.

All 16 patients underwent surgical intervention. Of these, 11 required duroplasty. Regarding flap management, the bone flap was debrided and replaced in 10 patients, while it was discarded in 6 patients.

Among the patients, 2 developed post-traumatic brain abscesses and 4 experienced post-traumatic meningitis. Despite these complications, 94% (15 out of 16) of the patients had favorable outcomes, achieving a Glasgow Outcome Scale (GOS) score of 4-5 at discharge.

The management principles for all types of fractures, including CESFs and other types of skull fractures, are the same. These principles involve early diagnosis and immediate intervention, which includes the use of broad-spectrum antibiotics, wound debridement and irrigation, removal of foreign bodies and loose bone fragments and ensuring a watertight repair of the dura[5-8]. Delaying surgical site infection, wound gap and poor outcome are all interconnected. An elevated fracture has a more favourable outcome if it remains untreated. Related to damage in the brain tissue. The outcome is also contingent upon the Glasgow Coma Scale (GCS) score at the time of admission. infection that occurs after a surgical procedure. The aetiology of these injuries involves the lateral traction exerted by the object or the rotational movement of the head upon impact, as observed in cases of head injuries caused by long, sharp-edged objects like propellers or machetes[9,10]. Another possible mechanism involves raising the detached fragment while attempting to remove the object causing the problem or while transferring the patient, as described in limited literature[9]. There is a scarcity of references to elevated skull fracture in the literature. We conducted a comparative analysis of our patients with other previously published reports. Male gender exclusivity is positively correlated with their participation in outdoor activities, more so than females. The modes of injury observed in the Adeolu *at al*. series included assault, domestic accidents and road traffic accidents (RTA)[9]. Patients with CESF are at a high risk of developing various complications such as meningitis, brain abscess formation, or cerebrospinal fluid fistula (CSF). It is crucial to intervene promptly as any delay can have catastrophic consequences and impact the prognosis[10-12]. Borkar *et al*. have reported that the dura may remain undamaged in cases of elevated skull fractures[10]. We observed dural tears in two patients in our series. Some literature has documented that elevated fractures are consistently compound in nature[13].

The preferred diagnostic procedure for patients with elevated skull fractures of all age groups is a noncontract CT scan of the head with bone window. This scan is effective in detecting both bony

Table 1: Demographic and Clinical Data of Patients With Skull Fractures

Patients	Age/Gender	Admisssion GCS	Focal neurological deficit	Mechanism	Location	Fracture type	Dural injury on ct scan	Surgical management of fracture elevated bone	Antimicrobials	Anti-epileptics	Post traumatic meningitis	SSI/Abscess	Associated intra cranial hematoma	GOS on discharge
1	42/M	10	Left hemiplegia	RTA – Fall from bike	Parietal	Type 2	Yes	Debrided only	Yes	Yes	No	No	ICH	4
2	55/M	12	Right hemiplegia	Assault - Rod	Parietal	Type 2	Yes	Debrided only	Yes	Yes	Yes	No	No	4
3	14/M	11	No	Fall from bicycle	Occipital	Type 3	No	Replaced	Yes	Yes	No	No	ICH	5
4	26/M	15	Left hemiplegia	Assault - Axe	Frontal	Type 1	Yes	Replaced	Yes	Yes	No	No	ICH	5
5	6/M	14	Left hemiplegia	Fall from height	Parietal	Type 2	Yes	Debrided only	Yes	Yes	No	No	ICH	5
6	45/M	15	No	Assault- Sword	Frontal	Type 1	Yes	Replaced	Yes	Yes	No	No	EDH	5
7	28/M	14	Right hemiplegia	RTA –Fall from bike	Parietal	Type 1	Yes	Replaced	Yes	Yes	No	No	ICH	4
8	33/M	15	No	Assault- Axe	Frontal	Type 2	No	Replaced	Yes	Yes	No	No	No	5
9	22/M	9	Left pupil deficit	RTA	Frontal	Type 3	No	Debrided only	Yes	Yes	Yes	No	ICH	4
10	12/F	14	Right hemiparesis	Fall from height	Parietal & temporal	Type 1	Yes	Replaced	Yes	Yes	No	No	ICH	4
11	17/M	6	Left hemiplegia	RTA-Fall from bike	Frontal	Type 2	Yes	Replaced	Yes	Yes	No	No	ICH	4
12	42/M	15	No	Assault - Sword	Parietal	Type 2	Yes	Replaced	Yes	Yes	No	No	No	5
13	22/M	14	Right hemiparesis	Assault – Axe	Frontal	Type 3	Yes	Debrided only	Yes	Yes	Yes	Abscess	ICH	4
14	38/M	7	Right pupil deficit	Assault – Sword	Frontal	Type 1	Yes	Debrided only	Yes	Yes	Yes	No	ICH	1
15	25/M	14	No	RTA	Parietal	Type 2	No	Replaced	Yes	Yes	No	No	EDH	5
16	21/M	15	No	Blunt Assault	Parietal	Type 2	No	Replaced	Yes	Yes	No	No	EDH	5

Table 2: Demographic and Clinical Summary of Patients of With Skull Fractures.

Category	Details
Total Patients	16
Gender Distribution	
- Male	13
- Female	3
Median Age (years)	25.5

Table 3: Mechanism of Injury Distribution Among Patients With Skull Fractures

Mechanism of Injury	Number of Patients
Assault	8
Blunt cranial injury from RTA	5
Fall from height	2
Fall from a bicycle	1

Table 4: Neurological Assessment of Patients With Skull Fractures

Category	Details
Median GCS	14
Patients with GCS < 9	2
Focal Neurological Deficit	
- Hemiparesis	8
- Unilateral Afferent Pupil Deficit	2

Table 5: Distribution of Fracture Locations Among Traumatic Brain Injury Patients With Skull Fractures

Fracture Location	Number of Patients
Parietal	8
Frontal	7
Occipital	1

Table 6: Classification of Fracture

Fracture Type	Number of Patients
Type 1	5
Type 2	8
Type 3	3

Table 7: Surgical Interventions for Traumatic Brain Injury Patients With Skull Fractures

Surgical Intervention	Number of Patients
Total Patients Undergoing Surgery	16
Patients Requiring Duroplasty	11
Flap Management	
- Flap Debrided and Re-placed	10
- Flap Discarded	6

Table 8: Traumatic Complication and Outcomes in Traumatic Brain Injury Patients With Skull Fractures

Category	Details
Post-Traumatic Brain Abscesses	2
Post-Traumatic Meningitis	4
Favourable Outcomes (GOS 4-5)	15 (94%)

abnormalities and any underlying hematoma and brain parenchymal lesions[17,14]. Compound elevated fractures should be treated similarly to compound depressed fractures. This involves thoroughly cleaning the wound, repositioning or removing elevated bone fragments and draining any accumulated blood or bruised tissue. Additionally, the dura should be properly washed and closed. Similar to other compound injuries, prompt identification and appropriate management of elevated skull fractures can prevent preventable complications such as intra cranial sepsis or CSF fistula, leading to a decrease in morbidity and mortality[11]. Children are more vulnerable to experiencing additional harm to the brain due to low levels of oxygen saturation, imbalances in bodily fluids and disruptions in electrolyte levels.

High body temperature and convulsions necessitating specialised attention. Our group conducted a comprehensive search of medical literature, which revealed that nearly

All documented instances of elevated skull fractures have been reported in adults[5,9-13]. Chhiber *et al*. documented two instances of heightened fractures in the paediatric population[12]. The essential components of surgery include removing blood clots, repairing the protective covering of the brain, relieving pressure if the brain is swollen, thoroughly cleaning the wound and carefully replacing any displaced bone fragments. Additionally, the scalp is repaired over a drain placed either beneath the scalp or outside the protective covering of the brain[10,14]. The incidence of wound contamination may be lower in this group of fractures due to the tangential direction of impact. This results in a smaller amount of foreign material being introduced into the wound compared to depressed skull fractures, where tangential force acts on the intact calvarium in conjunction with head rotation[10,13]. The magnitude of force transferred to the brain and its surrounding structures is greater when the applied force is perpendicular to the surface of the brain, as opposed to when the force is applied tangentially[9]. Therefore, brain and associated structures may sustain less severe damage in elevated fractures caused by a tangential impact, as opposed to depressed fractures caused by a perpendicular impact[9]. A depressed fracture of the skull may have a higher level of contamination compared to an elevated fracture of the skull. This is because the force applied in a perpendicular direction pushes more dirt into the wound, as opposed to the force applied in a tangential direction. Therefore, patients with depressed fractures are at a higher risk of developing infectious complications compared to those with elevated fractures. Occasionally, presentations are complicated by intra ventricular haemorrhage and involvement of the superior sagittal sinus. Noncontrast imaging The brain Computed Tomography reveals a heightened fracture of the right Frontal bone occlusion[8,11]. While there have been some reported cases in children, none of them have provided long-term follow-up data[15].

CONCLUSION

Typically, the application of directed mechanical force to the skull is responsible for this type of injury. Timely identification and immediate surgical intervention, including wound debridement, thorough wound cleansing, fracture segment realignment, removal of foreign objects and loose bone fragments, along with broad-spectrum antibiotic treatment, are crucial for preventing complications and death and ultimately result in improved patient outcomes.

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