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Original Article

Factors determining the requirement of surgical intervention and prognosis in cases of traumatic bifrontal contusions: A prospective observational study

Raj Ratan[1], Sandeep Mohindra[2], Manjul Tripathi[2], Raghav Singla[3], Rajeev Chauhan[4]

[1]Department of Neurosurgery, Army Hospital Research and Referral, Delhi, [2]Department of Neurosurgery, Post Graduate Institute of Medical Education and Research, Chandigarh, [3]Department of Neurosurgery, All India Institute of Medical Sciences, Delhi, [4]Department of Anaesthesia and Intensive Care, Post Graduate Institute of Medical Education and Research, Chandigarh, India.

E-mail: *Raj Ratan - drrajratan8060k@gmail.com; Sandeep Mohindra - sandeepmohindra@gmail.com; Manjul Tripathi - drmanjultripathi@gmail.com; Raghav Singla - dr.raghavsingla@gmail.com; Rajeev Chauhan - dr.rajeevchauhan@gmail.com

***Corresponding author:**
Raj Ratan,
Department of Neurosurgery,
Army Hospital Research and
Referral, Delhi, India.

drrajratan8060k@gmail.com

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ABSTRACT

Background: Traumatic brain injury, being a notorious cause of mortality and morbidity across the globe, presents with a variety of lesions. One of the distinct patterns of injury is characterized by contusions of both frontal lobes, labeled "traumatic bifrontal contusions" (TBCs). TBC is often associated with the presence of significant edema and mass effect leading to rapid clinical deterioration after a usually benign presentation at the time of first evaluation. Formulating a management plan in a patient with TBC is often more difficult than in a patient with a major intracranial hematoma.

Methods: A prospective observational study with aims and objectives to identify predictors of an unfavorable outcome, analysis of the evolution of TBC, evaluation of the specific indications for surgery, and determination of the prognosis. All head trauma patients harboring bifrontal contusions were included in the study. Patients with other associated operable injuries involving blunt trauma abdomen and orthopedic injuries, counter-coupe injuries, and obvious open fractures noted over calvaria were excluded from the study. Glasgow coma scale (GCS) was recorded during the first assessment, followed by non-contrast computerized tomography (NCCT) Head.

Results: A total of 53 patients satisfying inclusion and exclusion criteria were included in the study. The average GCS score recorded before surgical intervention was 9. The mean and median best motor response noted was M5. The interval from the time of injury to the first NCCT of the brain at the study hospital ranged from 3 h to 163 h, averaging 17.66 h. The median category w.r.t Marshall's CT classification observed was "*Diffuse Injury IV.*" The volume of the contusions in each scan was estimated, and the average anterior cranial fossa volume observed was 125 mL. "*Upfront surgery*" ("*Bifrontal decompressive craniectomy*" or "*unilateral Fronto-Temporo-Parietal [FTP] decompressive hemicraniectomy*") was carried out on the day of admission based on the findings on the first NCCT brain. About 49% of patients at presentation needed surgical intervention as per existing protocols. The duration of observation for patients who were initially observed but eventually had to undergo surgery ranged from 1 to 5 days, with an average observation period of 2 days. The duration of observation in those who did not subsequently need surgery ranged from 7 to 10 days, with an average duration of 9 days.

Conclusion: What leads to the poorly predictable, delayed, and rapid deterioration that sets TBCs apart from other traumatic brain injuries is still unclear. Our study finds that having a low threshold for repeat CT imaging of the patient led to earlier identification of progression, and a low threshold for surgical intervention led to favorable outcomes.

Keywords: Traumatic bifrontal contusion, Upfront surgery, Rapid clinical deterioration

INTRODUCTION

Traumatic brain injury (TBI), being a notorious cause of mortality and morbidity across the globe, presents with a variety of lesions. Traumatic damage to brain parenchyma in the form of contusions has been seen with increasing frequency.[6] One of the distinct patterns of injury is characterized by contusions of both frontal lobes, labeled "Traumatic Bifrontal Contusions" (TBCs). An awake patient with ominously contused bilateral frontal lobes on imaging constitutes a challenging clinical scenario. The challenge here lies in breaking the path to late neurological deterioration. TBC is often associated with the presence of significant edema and mass effect leading to rapid clinical deterioration after a usually benign presentation at the time of first evaluation. This clinical picture may evolve to demonstrate the "talk and die" course of events.[8] The late deterioration that occurs in TBC is mostly due to the close anatomic relation of these contusions with the midline structures, causing rostrocaudal displacement of the brain and terminating in central herniation.[10] Early warning signs of TBI fail to manifest in these cases, and thus, the presentation of patients to a neurosurgical center occurs in a delayed fashion with signs of deterioration. Moreover, the basifrontal lobe, by virtue of its electrophysiological characteristics, possesses epileptogenic potential, thereby posing an additional risk of seizures and consequent sudden deterioration.[12] Formulating a management plan in a patient with TBC is often more difficult than in a patient with a major intracranial hematoma (ICH). The absence of any forewarning lateralizing signs, as seen in other lobar ICHs, and the patient's good early neurological status leads to decreased vigilance. In the absence of clear guidelines and indications for early surgical decompression, the patient suffers the risk of abrupt worsening that is known to occur in other such large lesions involving the frontal lobes. Literature on the natural progression of these lesions is scant, and a clear, comprehensive guideline for TBC remains to be developed. The objectives of our study include the identification of predictors of an unfavorable outcome, analysis of the evolution of TBC, evaluation of the specific indications for surgery, and determination of the prognosis.

MATERIALS AND METHODS

The study has been approved by the Institutional Ethical Committee vide reference no INT/IEC/2020/SPL-1466 dt 18 Nov 2020. The study design and protocol have been elaborated in the flowchart in Figure 1. Radiological assessment of the patients was done by the neurosurgical team in coordination with the radiologist on duty [Figure 2]. The volume of bifrontal contusion was calculated by ABC/2 technique (where A = maximum diameter in cm inclusive of both hyperdense and hypodense areas, B = diameter 90° to maximum diameter in cm involving both hyperdense and hypodense area, C = total number of 1 cm axial slices). Figure 3 demonstrates the radiology of one illustrative case of TBC in this study.

RESULTS

A total of 53 patients satisfying inclusion and exclusion criteria were included in the study. The study population consisted of 48 (90.6%) males and 05 (9.4%) females with ages ranging from 18 to 50 years (average age 37.2 years). The causes of TBI were road traffic accidents (RTA) in 38 (71.7%), fall from height in 12 (22.6%), assault in 2, and other mode of injury in one patient. The initial post-resuscitation Glasgow coma scale (GCS) score ranged from 4 to 15 and averaged 10. The mean and median best motor response noted was M5. The severity of TBI across the patient population according to admission GCS is depicted in Figure 4. The average GCS score recorded before surgical intervention was 9. Initial pupillary assessment revealed normal-sized reactive pupils in nearly half the study population [Table 1].

The interval from the time of injury to the first non-contrast computerized tomography (NCCT) of the brain at the study hospital ranged from 3 h to 163 h, averaging 17.66 h. The longest interval for the first NCCT Head was 163 h in one patient as the patient could not be attended at a medical establishment with CT scan facilities before being attended at the study hospital. Marshall's CT classification for TBI was utilized for radiological characterization of the bifrontal contusions, and the category-wise distribution in the study population is noted in Table 2. The median category observed was "*Diffuse Injury IV*."

The approximate volume of anterior cranial fossa (ACF) estimated in the study population ranged from 110 mL to 140 mL, with an average volume of 125 mL among the 53 patients. The volume of the contusions in each scan was estimated.

With regard to the management, the study population has been divided into three distinct groups:

(i) Upfront surgery comprising of either "*Bifrontal decompressive craniectomy*" or "*unilateral FTP decompressive hemicraniectomy*"
(ii) Observation followed by surgery ("*Bifrontal decompressive craniectomy*" or "*unilateral FTP decompressive hemicraniectomy*")
(iii) Observation alone (No surgery done).

"*Upfront surgery*" was carried out on the day of admission based on the findings on the first NCCT brain. About 49% of patients at presentation needed surgical intervention as per existing protocols. The criteria for surgery were as follows:-

(i) The presence of large-volume bifrontal contusions with the findings of poor GCS
(ii) Presence of frontal horn distortion, suprasellar cistern effacement, and significant mass effect.

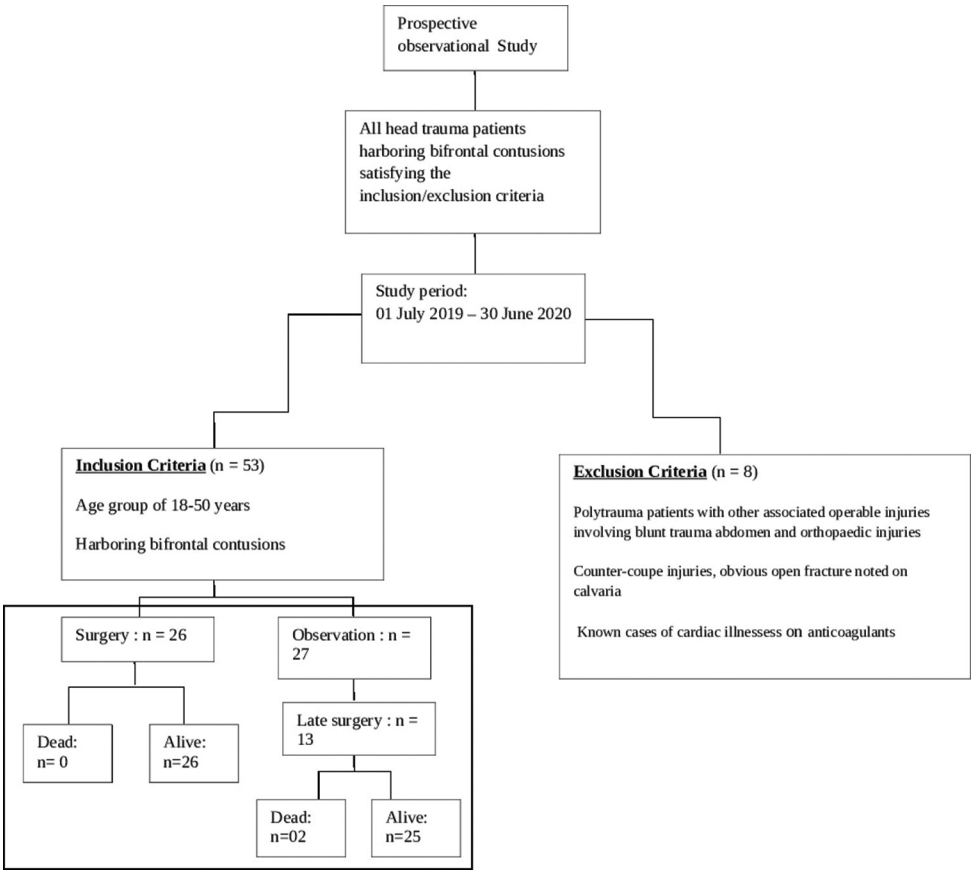

Figure 1: Study design and protocol.

These patients underwent decompressive craniectomy with or without evacuation of hematomas/contusions. In most patients undergoing contusectomy, falx was not divided. Two patients who would otherwise have been candidates for upfront surgical decompression were in an unfit state for surgery and succumbed to their injuries. In the rest, a CT of the brain was done on each day following admission so as to assess for radiological deterioration. Medical management involved hyperosmolar therapy with mannitol in patients who demonstrated mass effect on imaging while being neurologically as well as hemodynamically stable [Figure 5]. In case of clinical and/or radiological deterioration, patients were taken up for surgical decompression. After the fourth NCCT, twelve patients showed an improving trend in the clinicoradiological parameters. In these patients, further, daily CT imaging was continued for a total duration of 9 days. Having exhibited progressive improvement in their GCS and evidence of radiological resolution of TBC, these 12 patients were subsequently discharged [Table 3].

The duration of observation for patients who were *initially observed but eventually had to undergo surgery* ranged from 1 to 5 days, with an average observation period of 2 days. The duration of observation in those who did not subsequently need surgery ranged from 7 to 10 days, with an average duration of 9 days. Table 4 depicts the distribution of patients among the clinical categories described, and Table 5 depicts the volume of bifrontal contusions across the different patient groups.

DISCUSSION

TBC is a common cerebral injury that may not appear very serious at the outset but has a tendency to evolve in a poorly predictable manner and abruptly turn life-threatening if not managed in a timely fashion. The primary finding of the present study is that the clinicoradiological course of patients with isolated TBC varies from that described in the literature for traumatic cerebral contusions elsewhere in the brain. Contusions, rather than extra-axial ICHs, have been increasingly known to occur in recent times, with rising numbers of low-velocity injuries in the developed world.[6] The predominant etiology for the TBCs in our study has been the infamous RTA. The average GCS at admission was in the moderate head injury range (GCS 9–13). There is no scientifically proven "best method" for surgical management of these lesions. Most studies have used the logically obvious choice of bifrontal craniectomy to manage these bifrontal lesions.[11] Evacuation of contusions was shown to be vital for improving outcomes, while decompression by craniotomy

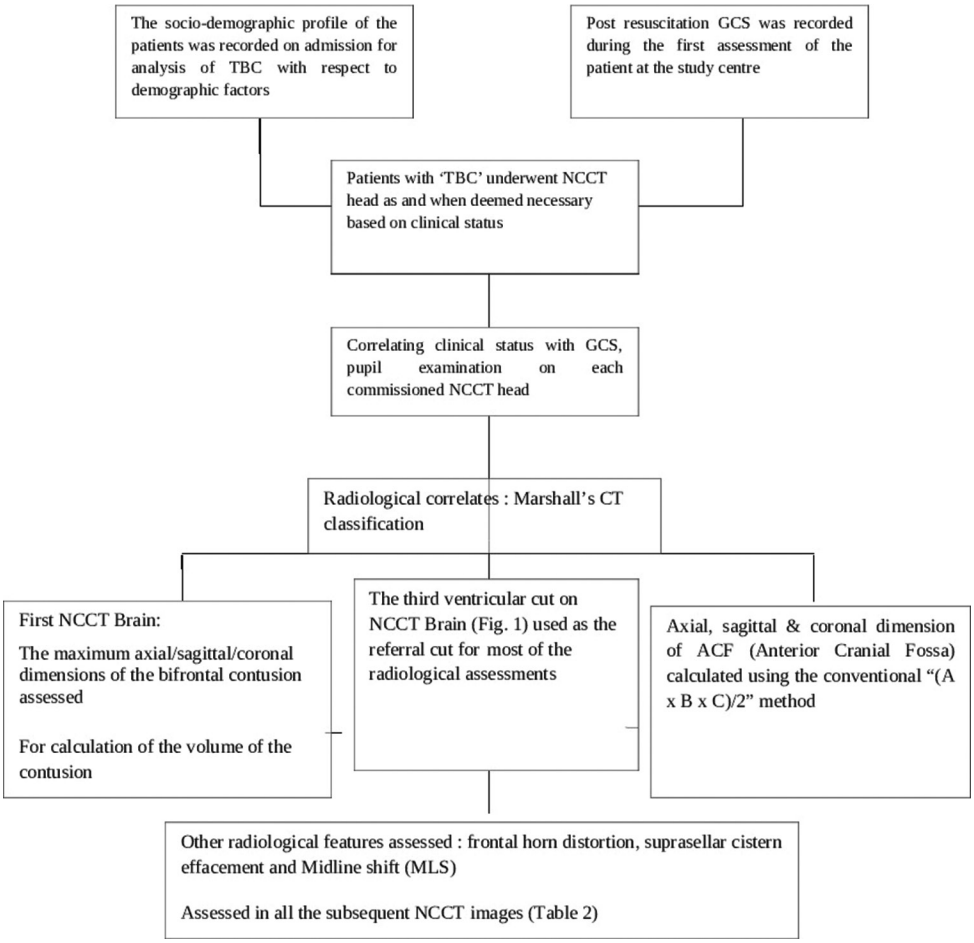

Figure 2: Radiological assessment. TBC: Traumatic bifrontal contusion, GCS: Glasgow coma scale, NCCT: Non contrast computed tomography, ACF: Anterior cranial fossa.

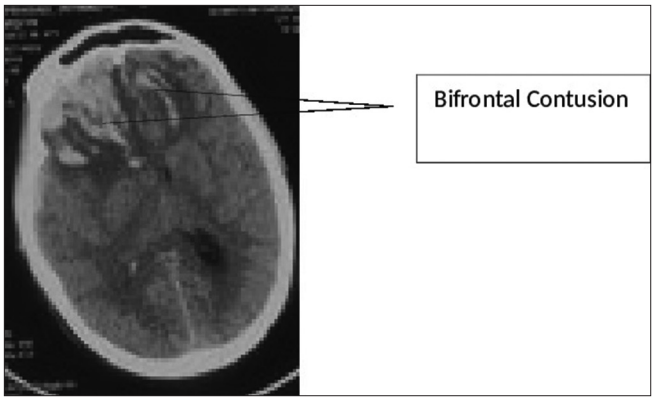

Figure 3: Radiology traumatic bifrontal contusion.

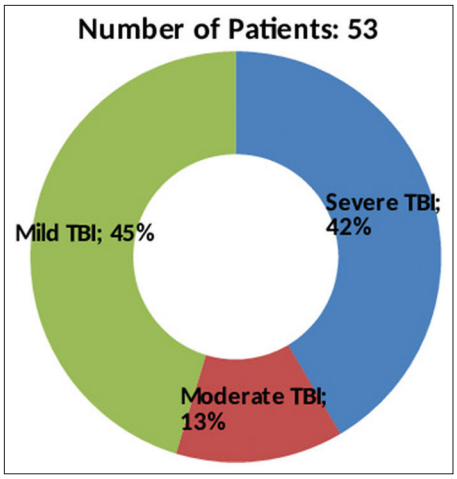

Figure 4: Severity of traumatic brain injury (TBI).

alone was seen to be associated with increased mortality in the Indian series of TBCs by Sarma *et al*.[9]

To do or not to do: Early versus delayed deterioration

The first challenge of decision-making was surmounted fairly easily in the "upfront surgery" group. The remainder of the patients admitted for observation with relatively better initial clinical and radiological pictures (i.e., nearly half the study population) mandated the development of a foolproof algorithm for management. The rate of clinical deterioration

Table 1: Initial pupillary assessment.

Pupillary Reaction	No. of Patients
Normal reaction to light in bilateral pupils	24
Anisocoria	4
Sluggish reaction to light in bilateral pupils	17
Mid dilated non reaction to light in bilateral pupils	7
Dilated and fixed reaction to light in bilateral pupils	1

Table 2: Marshall's Computed Tomography (CT) classification for the study protocol.

Category	Definition	No of Patients (Percentage)
Diffuse Injury I	No visible intracranial pathology seen on CT scan	NIL
Diffuse Injury II	Cisterns are present with <= 5 mm midline shift; no high or mixed density lesions > 25 ml	13 (24%)
Diffuse Injury III	Cisterns compressed with <= 5 mm midline shift; no high or mixed density lesions > 25 ml	07 (13%)
Diffuse Injury IV	Midline shift >5mm; no high or mixed density lesions > 25 ml	29 (54%)
Evacuated mass lesion	Any lesion surgically evacuated	04 (9%)
Non-evacuated mass lesion	High or mixed density lesions > 25 ml not surgically evacuated	NIL

Table 3: Computed Tomography (CT) characteristics.

CT Characteristics	No of Patients			
	First CT scan	Second CT scan	Third CT scan	Fourth CT scan
Frontal horn distortion	27 (50.9%)	10 (18.9%)	02 (3.7%)	01(1.9%)
Suprasellar cistern effacement	19 (35.8%)	05 (9.4%)	02 (3.7%)	NIL
Midline shift	23 (43.4%)	07 (13.2%)	02 (3.7%)	NIL
None of the above findings	16 (30.2%)	17 (32.1%)	14 (26.4%)	13 (24.5%)

Table 4: Distribution of patients as per management protocol.

Protocol	No. of Patients	
Upfront surgery	26 (49.1%)	Bifrontal Decompressive Craniectomy : 24
		Unilateral Fronto-Tempero-Parietal (FTP) Decompressive Hemicraniectomy : 02
Observation followed by surgery	13 (24.5%)	Bifrontal Decompressive Craniectomy : 12
		Unilateral Fronto-Tempero-Parietal (FTP) Decompressive Hemicraniectomy : 01
Observation (No need for surgery)	14 (26.4%)	Includes mortality- 02 patients

seen in our study population stands in contrast to existing worldwide literature studying the progression of traumatic cerebral contusions in certain pertinent aspects. A fourth (24.5%) of our TBC patients admitted for observation went on to require surgery. Nine out of these 13 patients deteriorated

Table 5: Volume of bifrontal contusion detected as per management protocol.

Management Protocol	Bifrontal Contusion Volume Range	Average Volume of Bifrontal Contusion	Remarks
Upfront Surgery	~32 – 94 ml	~53 ml	-
Observation followed by Surgery	1st NCCT Brain: ~12 – 38 ml	1st NCCT Brain: ~24 ml	-
	Operative NCCT Brain: ~27 – 60 ml	Operative NCCT Brain: ~43 ml	
Observation (No need for surgery)	1st NCCT Brain: ~9 – 19 ml	1st NCCT Brain: ~14 ml	02 patients in this group expired while being observed
	Last NCCT Brain (prior to discharge from hospital): ~8 – 16 ml	Last NCCT Brain (prior to discharge from hospital): ~12 ml	

NCCT: Non Contrast Computed Tomography

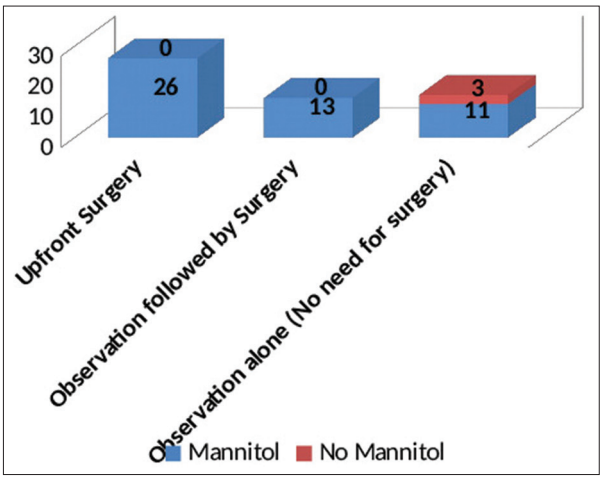

Figure 5: Hyperosmolar therapy.

within 48 h of admission and underwent surgery. Alahmadi *et al*.,[2] in a series of 98 patients, studied the progression of traumatic cerebral contusions and concluded that 19% required operative intervention. When surgeries for evacuation of extra-axial hematomas alone and surgical placement of intracranial pressure (ICP) monitors were excluded, only four patients required surgical decompression for the contusions *per se*. Narayan *et al*.[7] and Chang *et al*.,[4] in their studies of patients with traumatic cerebral contusions/hematomas, reported an operative decompression rate of 8.9% (of 56 cases) and 8.7% (of 115 cases), respectively. Although a higher rate of progression of injuries was documented by all of these studies, the rate of requirement of surgery was significantly lower than that observed in our series. This difference makes TBCs stand out from other forms of traumatic contusions.

Blossoming of contusions: An unknown phenomenon

An important factor pointed out in the literature that contributes to significant progression is contusion size. Contusion size

at presentation, in itself, appears to determine immediate management. Attempts have been made to delineate a cutoff size below which contusions may not require surgery. The mean contusion volume at which patients were taken for upfront decompressive craniectomy in our study was 43 mL. The ratio between volumes of bifrontal contusion to volume of ACF ranged from 0.067 to 0.721, with a mean ratio of 0.289. The smallest bifrontal contusion was 6.7% of the volume of ACF, and the largest bifrontal contusion involved 72.1% of the volume of ACF. Associated intracranial injuries, besides the contused frontal brain itself, also play a very significant role in determining the management path. In the study by Peterson and Chesnut [8], which only took severe TBC (with volumes over 30 mL) into consideration, half of the patients progressed to require surgery. This underlined the importance of the presence of associated trauma, including subdural hematoma and perilesional edema. The edema volume has not been calculated separately in our series. Nevertheless, the wide range of ~32–94 mL contusion volume seen in 49.1% of patients who required a decompressive craniectomy showed that lower volumes, when aggravated by surrounding edema, cause rapid clinical deterioration. Sarma *et al*.[2] report worsening of cerebral edema around the contusion as the commonest cause of deterioration in their series on TBC. Patients with delayed deterioration showed significant worsening of edema and an increase in the size of contusions, also known as "blossoming of contusions," which happen in a time-bound fashion 3–4 days following injury.

The average GCS at presentation in our series was 10. Over 45% of patients presented with mild head injury (GCS ≥ 13), and of these, 54% of patients deteriorated within 48 h of admission and had to undergo decompressive craniectomy. The distribution of patients across the categories of mild, moderate, and severe head injury was similar to the study populations of other series, including Zhaofeng *et al*.[13] and Gao *et al*.[5] These numbers substantiate the finding that a high proportion of TBC primarily presents as mild-to-moderate head injury clinically. This relatively preserved GCS demonstrates the relatively minor impact (even large) TBCs have on the patient's consciousness until late in the clinical course. The frontal region may be more tolerant to enlarging lesions than seen in other regions. Deterioration in the particularly ominous appearing ones has been noted up to 9 days following injury.[10] Keeping this possibility in mind, the patients in the conservatively managed group were discharged after noting a reassuring clinical and radiological picture after about nine days of hospital stay. When TBC patients did deteriorate clinically, they did so in a rapid fashion. On the other hand, deterioration in contusions in regions other than the frontal lobes is often heralded by a slower decline in consciousness (generally over hours).

Predictive markers of deterioration

It is important to consider the two aspects of deterioration in these traumatic lesions: clinical deterioration and radiographic progression. No specific study has ever analyzed the link or difference in timing between the two. Peterson and Chesnut[8] mention an average time to clinical deterioration of 4.5 days after injury. Other series[4,7,9] have concluded that the vast majority of bifrontal contusions progress in the first 48 h. While most studies have accepted radiographic progression as a reflection of clinical deterioration, the impetus must be laid on timely recognition of clinical deterioration in the form of worsening sensorium, which is then augmented with a radiological assessment. In our protocol, a drop in GCS by 1–2 points was set as a marker of clinical deterioration, which was further substantiated with a fresh NCCT brain. This presumably explains the shorter recorded time to deterioration in our study (average 1.53 days). Events other than just contusion expansion may harbinger clinical deterioration, such as the progression of edema or other mechanisms of secondary brain injury. Radiological worsening has to be viewed in light of the findings of various studies, which demonstrate that the majority (about 75%) of traumatic cerebral contusions show radiological progression with time.[1]

An important objective of this study was to evaluate specific indications for surgical intervention. Adequate analgesia, sedation, institution of hyperosmolar therapy, and correction of coagulation dysfunction must be immediately undertaken on admission. In cases where surgery is indicated, a decompressive craniectomy is the most useful among available methods to control ICP. The selection of the surgical time is critical, considering the rapid development of central brain herniation and the poor prognosis associated with it. The fate of the patient is decided by the duration for which the effects of central herniation persist. It is apparent in our study that early surgical intervention has resulted in a good prognosis for patients. Brain Trauma Foundation guidelines[3] have recommended bifrontal decompressive craniectomy as a treatment option for patients with diffuse, intractable posttraumatic cerebral edema with resultant intracranial hypertension with poor GCS. Peterson and Chesnut[8] rightly mention that despite the encouraging results observed with decompressive craniectomy, surgical decompression shall not be extended to patients who have not deteriorated. In our study, of the 12 patients to whom observation and best medical management was the chosen management, all were discharged on antiepileptic drugs with a GOS of 5 after an average hospital stay of 9 days.

CONCLUSION

What leads to the poorly predictable, delayed, and rapid deterioration that sets TBCs apart from other traumatic brain

injuries is still unclear. During the admission period, even a small drop in GCS (1–2 points) is of paramount importance in these cases. Our study finds that having a low threshold for repeat CT imaging of the patient led to earlier identification of progression, and a low threshold for surgical intervention led to a favorable outcome. Further studies are needed to develop a uniform, systematic approach to patients with TBCs.

Ethical approval

The author(s) declare that they have taken the ethical approval from IEC vide reference no INT/IEC/2020/SPL-1466 dated 18 November 2020.

Declaration of patient consent

Patients' consent not required as patients' identities were not disclosed or compromised.

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Nil.

Conflicts of interest

There are no conflicts of interest.

Use of artificial intelligence (AI)-assisted technology for manuscript preparation

The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

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