CT Evaluation of Post-traumatic Extradural Hemorrhage Volume: Correlation with Brain Parenchymal Changes and Clinical Outcomes

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Abstract

Introduction: Traumatic brain injury (TBI) lead significant morbidity and mortality with common causes including motor vehicle accidents, falls, assaults and sports injuries.

Materials & Methods: A prospective observational study was conducted at Jubilee Mission Medical College, Kerala over 18 months including 50 patients with CT-confirmed EDH. Data were analysed to assess their impact of EDH volume on brain parenchymal changes and treatment decisions. Statistical analyses included descriptive statistics, correlation coefficients, unpaired t-tests, ANOVA and chi-square tests

Results: In the study, 70% of the patients were male averaging 45 years old and 70% of injuries resulted from motor vehicle accidents. Larger volumes of EDH are linked to midline shift (16.5cc), cerebral edema (17.5cc), cerebral herniation (18cc) and basal cistern compression (20cc). Conservative management was the predominant approach with 45 cases (90%) treated conservatively compared to 5 cases receiving surgical intervention. EDH volume showed moderate sensitivity (73.3%) and high specificity (80.0%) meaning that approximately 80% of patients with large EDH volumes were accurately identified as needing surgical treatment with high positive predictive value (PPV) of 97.1% and low negative predictive value (NPV) of 25.0%.

Conclusions: Larger EDH volumes correlate with more severe clinical outcomes, influencing the need for surgical intervention. However, the predictive capacity of EDH volume alone is limited, suggesting the need for a comprehensive approach including advanced imaging..

Key words: Extradural hemorrhage volume, Traumatic Brain Injury, Outcome

Introduction

Traumatic brain injury (TBI) stands out among prevalent neurological issues and represents a significant public health burden1. In developing countries, the incidence of TBI is typically higher such as 160 per 100,000 people in India and 344 per 100,000 in Asia compared to developed countries. It is anticipated that by 2030, TBI will surpass many diseases as a leading cause of death and disability[2]. Rapid urbanization and motorization has led to a significant rise in trauma-related deaths. Head injuries are now a leading cause of mortality, particularly among young adults under 45. Common causes of TBIs include falls, motor vehicle accidents, assaults, sports injuries, and blast injuries in military contexts. Poor road infrastructure and traffic environment, Lack of safety measures and pedestrian safety, mixed traffic and increasing motorized vehicles and Unsafe driving behaviors and invalid or fake driving licenses contributes to road crashes.

By 2020, trauma is projected to become the fifth leading cause of mortality and third leading cause of disease burden in India, with 11% of non-communicable disease deaths attributed to trauma and 78% of injury deaths due to head injuries.[3]

TBIs vary significantly in severity from mild concussions which often result in temporary cognitive and physical symptoms to moderate and severe TBIs, which may cause prolonged unconsciousness, significant cognitive impairments and potentially lifelong disabilities. The effects of TBIs can manifest immediately or develop over time, making early diagnosis and intervention crucial for effective management[4]

The economic impact of TBIs is considerable, as they require substantial resources for initial medical care, rehabilitation, long-term support, and lost productivity. Treating TBIs

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necessitates a multidisciplinary approach involving neurologists, neurosurgeons, rehabilitation specialists, psychologists, and other healthcare providers [5]

Risk factors for patients with EDH are advanced age, intradural lesions, temporal location, increased hematoma volume, rapid clinical progression, pupillary abnormalities, increased intracranial pressure (ICP) and low Glasgow coma scale (GCS)6. But others found the most significant factors associated with unfavourable outcome were higher age, lower GCS, and higher EDH volume[7].

The Glasgow Coma Scale (GCS) is commonly used to categorize the severity of TBI based on eye opening, verbal response, and motor function. Mild TBIs, often referred to as concussions result in GCS scores of 13-15 and typically require monitoring and rest. Moderate TBIs, with GCS scores of [9-12], indicate more significant impairment and may require medical intervention. Severe TBIs, presenting with GCS scores of [3-8], involve profound neurological deficits and often necessitate urgent medical attention, including surgical intervention.[8]

In cases where patients are unconscious, conducting thorough neurological examinations can be challenging. With the advent of Computed Tomography (CT) scans are crucial in these situations, as they help identify and evaluate neuroparenchymal injuries, providing essential information for grading the severity of brain injury and determining the need for surgical intervention. CT imaging is preferred in emergency situations due to its speed, cost-effectiveness, and suitability for critical patients. However, CT scans also have limitations, including the potential for radiation exposure and reduced sensitivity in detecting subtle brain injuries.[9]

Magnetic Resonance Imaging (MRI) is highly effective in detecting neuroparenchymal injuries in traumatic brain injury (TBI) patients, particularly after the initial hours post-injury. MRI is superior in identifying diffuse axonal injuries, small haemorrhagic contusions, and subtle neuronal damage that CT scans may miss.10 While CT is crucial for rapid initial assessment due to its speed and availability, MRI is preferred for comprehensive evaluation during the subacute and chronic phases.

Accurate CT-based quantification of epidural hematoma (EDH) volumes is vital for assessing their impact, guiding management decisions, and improving outcomes for TBI patients.[11]

The study primarily aims to quantify the volume of extradural haemorrhage in patients with traumatic head injuries and assess the resulting brain parenchymal changes. A secondary objective is to correlate the volume of the extradural hematoma with its impact on immediate clinical decision-making.

MATERIALS AND METHODS

The study, conducted in the Department of Radiodiagnosis at Jubilee Mission Medical College, Trissur, Kerala, employed a prospective observational design over 18 months, from October 8, 2022 to February 10, 2024.

This study includes a minimum sample size of 50 traumatic head injury patients with CT-confirmed EDH alone or with associated cerebral lesions, provided that the extradural haemorrhage is the main lesion.

CT-128 slice MDCT scanner GE Optima 660. Self-made Performa will be used for data collection which includes age, gender and mode of injury, CT findings and immediate clinical management.

The volume of blood in extradural haemorrhage is calculated and the associated brain parenchymal changes due to which are analysed along with the immediate clinical management of the patient. Initial CT scans obtained within 24hrs after sustaining the head injury were used.

Head injury patients without extradural haemorrhage, Non-traumatic causes, CT brain taken beyond 72hrs excluded and long term outcome were excluded.

RESULTS

Total 50 cases were included in the study.

1.GENDER DISTRIBUTION:

Males constitute a significantly larger portion (35cases) compared to females. (Table 1)

Table 1: Gender distribution

	Count	Percentage
Male	**35**	**70.00%**
Female	15	30.00%

2.AGE DISTRIBUTION

The mean age of the patients is approximately 45 years. (Figure 1)

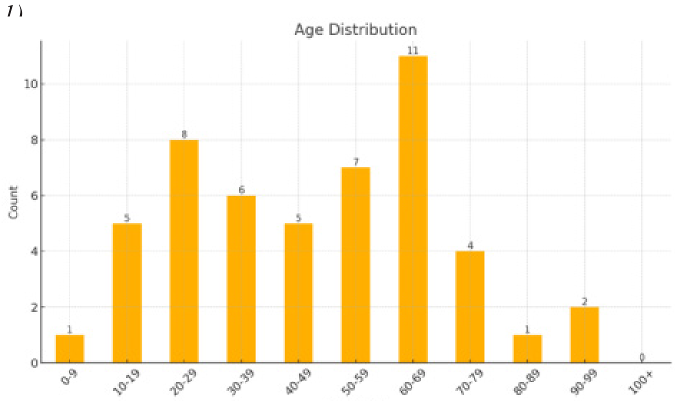

Figure 1 : Age distribution

3.MODE OF INJURY DISTRIBUTION

Majority of injuries (70%) were caused by motor vehicle collisions while falls accounted for the remaining 30%. (Figure 2)

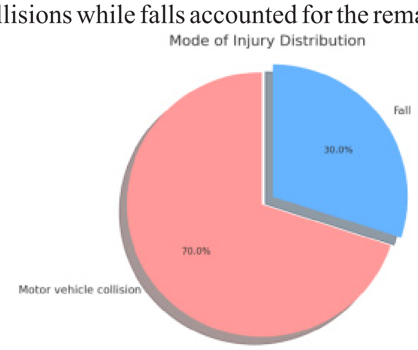

Figure 2: Mode of injury distribution

4.DISTRIBUTION OF PATIENTS ACCORDING TO CT FINDINGS

Skull fractures (56%) is the most common CT finding followed closely by SDH in 27 patients (54%) and cerebral edema in 25 patients (50%). (figure 3).

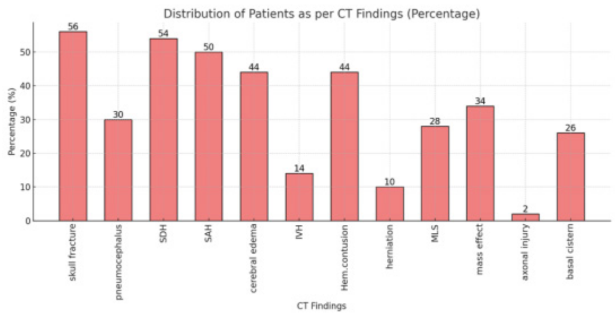

Figure 3: Distribution of patients according to CT findings

5.DISTRIBUTION ACCORDING TO EDH THICKNESS AND VOLUME

The mean EDH thickness among patients is 10.56 mm with a standard deviation of 5.78 mm. Meanwhile, the mean EDH volume is 13.00 cc with a standard deviation of 7.89 cc. (Table 2).

This variability in both thickness and volume underscores the diverse nature of EDH presentations among patients.

Table 2: Distribution of patients according to EDH thickness and EDH volume

	Mean ± SD
EDH thickness (mm)	**10.56 ± 5.78**
EDH volume (cc)	13.00 ± 7.89

6.ASSOCIATION OF EDH VOLUME WITH VARIOUS CEREBRAL PARENCHYMAL CHANGES

Various cerebral parenchymal changes analysed including cerebral edema, cerebral herniation, MLS, mass effect and effects on basal cistern.

The analysis shows that larger epidural hematoma (EDH) volumes are linked to more severe cerebral conditions. Specifically, the mean EDH volume is higher in cases with cerebral edema (17.5 cc vs. 10.5 cc), herniation (18 cc vs.[11] cc), and midline shift (MLS) (16.5 cc vs. 12 cc) compared to cases without these conditions. Mass effect also shows a slightly higher EDH volume (15 cc vs. 13 cc). For basal cistern status, the mean EDH volumes are distributed as follows: Normal (12.5 cc), Compressed (20 cc) and partially effaced (16 cc) and fully effaced (15 cc).

These findings suggest that larger EDH volumes correlate with more severe clinical outcomes.

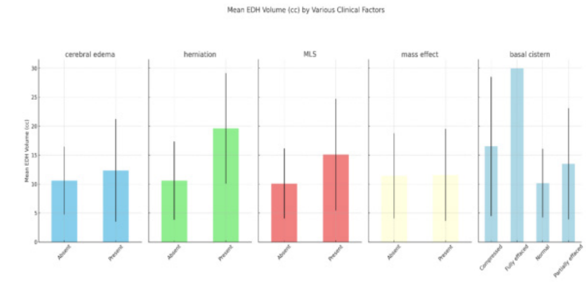

Figure 4: Relation of EDH (Epidural Hematoma) volume with various cerebral parenchymal changes

7.DISTRIBUTION OF PATIENTS ACCORDING TO THE OUTCOME

There is predominance of conservative management (45 cases) followed by surgical intervention (5 cases). (Table 3).

Table 3: Distribution of patients according to the outcome

Outcome	**No.**	**Percentage**
(n=50)	**%**	**70.00%**
Conservative treatment	45	90.0
Surgical treatment	5	10.0

8.COMPARING EDH THICKNESS AND VOLUME ACROSS DIFFERENT OUTCOMES

EDH thickness (in mm) was significantly higher in the surgical treatment group (19.00±5.78) compared to the conservative treatment group (9.62±5.02), with a p-value of <0.0001 (very significant).

EDH volume (in cc) was also significantly higher in the surgical treatment group (27.60±10.06) compared to the conservative treatment group (11.38±5.77), with a p-value of <0.0001 (very significant). (table 4, figure 5)

Table 4: Comparing EDH thickness and EDH volume across different outcomes

Outcome	**EDH thickness in mm**	**EDH volume in cc**
Conservative treatment	**9.62 ± 5.02**	**11.38 ± 5.77**
Surgical treatment	19.00 ± 5.78	27.60 ± 10.06
p-value1	0.0001*	0.0001*

*1Unpaired t-test, *Significant*

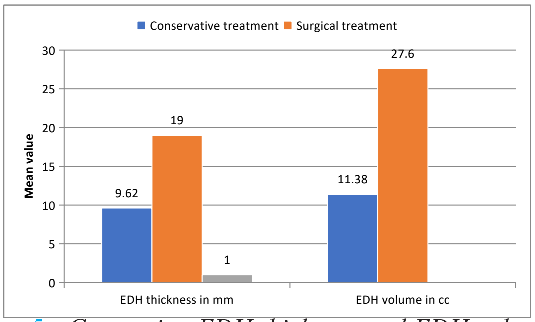

Figure 5 : Comparing EDH thickness and EDH volume across different outcomes

9.ASSOCIATION OF CT FINDINGS WITH CLINICAL MANAGEMENT

Only SDH was significantly associated with clinical management (p -value = 0.03), with patients having SDH more likely to be treated surgically than those without SDH.
No significant association with clinical management was found for other CT findings (p-values range from 0.08 to 0.84) (figure 6)

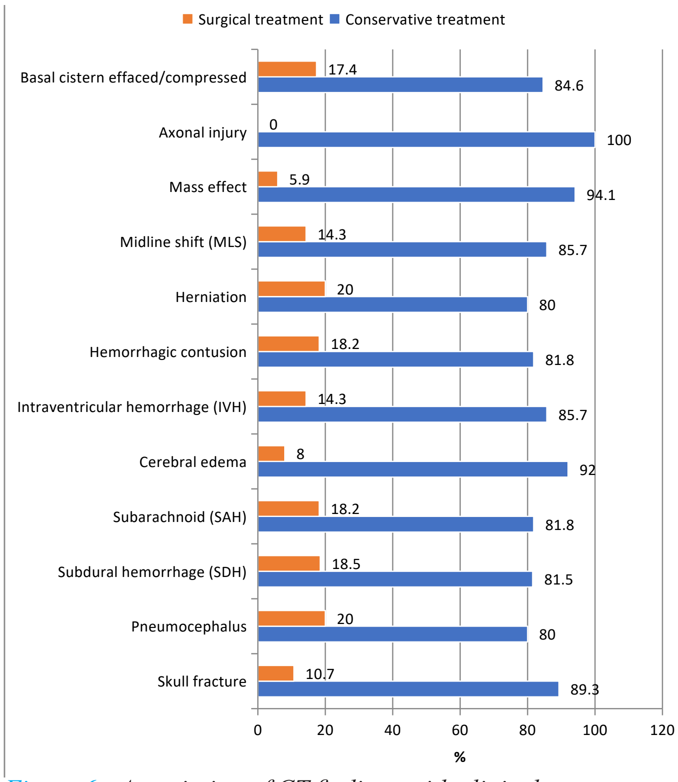

Figure 6 : Association of CT findings with clinical management

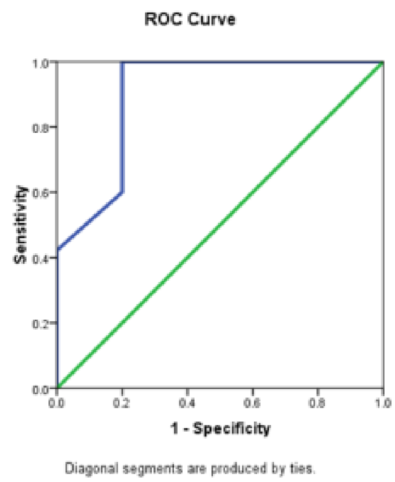

Figure 7: ROC curve showing sensitivity and specificity of EDH volume in decision making for conservative treatment from surgical treatment

10.PREDICTIVE VALUE OF EDH VOLUME IN DECISION-MAKING FOR CONSERVATIVE VERSUS SURGICAL TREATMENT

AUC (Area Under the Curve) = 0.90, p-value = 0.003*, indicating that the relationship between EDH volume and clinical management is statistically significant.
Moderate sensitivity (73.3%) indicates that about 73% of patients with small EDH volumes (< 15cc) were correctly classified as candidates for conservative treatment.
The specificity is high (80.0%) indicating that about 80% of patients with large EDH volumes (≥ 15cc) were correctly classified as candidates for surgical treatment.

The PPV is high (97.1%) indicating that nearly all patients who received surgical treatment had an EDH volume ≥ 15cc.
The NPV is low (25.0%), indicating that only about 25% of patients who received conservative treatment had an EDH volume < 15cc.
(Figure 7, Table 5)

Table 9: Predictive value of EDH volume in decision-making for conservative treatment versus surgical treatment

EDH volume	**Conservative treatment**		**Surgical treatment**		**Total**	
	No.	**%**	**No.**	**%**	**No.**	**%**
<15 cc	33	66.0	1	2.0	34	68.0
≥15 cc	12	24.0	4	8.0	16	32.0
Total	45	90.0	5	10.0	50	100.0
Predictive values, %						
AUC, p-value	0.90, 0.003*					
Sensitivity	73.3					
Specificity	80.0					
PPV	97.1					
NPV	25.0					

%ages from total number of cases

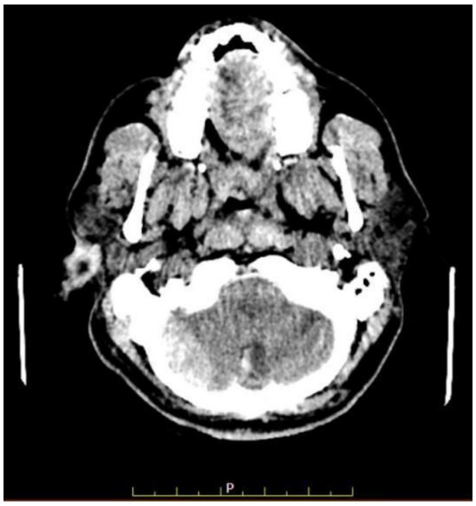

FIGURE 8: Axial CT cut showing EDH along right occipital convexity causing mass effect on cerebellum.

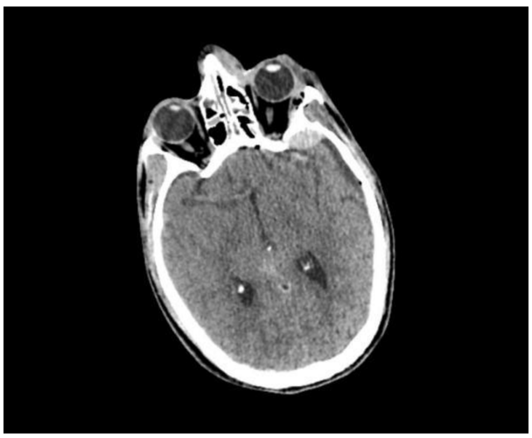

FIGURE 9: CT Axial cut showing EDH along basitemporal convexity with fracture of temporal bone.

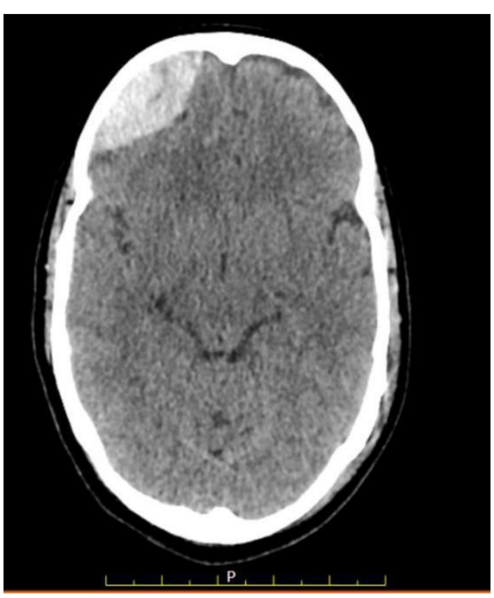

FIGURE 10: Axial CT cut showing EDH along right frontal convexity causing mass effect.

DISCUSSION

Traumatic brain injury (TBI) disproportionately affects different demographics. In our study of 50 patients, 70% were male and 30% female. Lafta et al. (2023) and Hagos et al. (2022) reported similar trends with 88.6% and 75% male patients, respectively[12, 13]. Our study's mean patient age was 45 years, with the highest incidence in the 60 to 69 age group. Bener et al. (2010) also noted peak TBI cases in those over 65 years [14].

In our study, motor vehicle collisions were the leading cause of injuries (70%), with falls accounting for 30%. Similar findings were reported by Lafta et al. (2023), where road traffic accidents were the primary cause of TBI (37.1%) followed by falls (23.9%) [12].

Skull fractures were present in 56% of our patients, aligning with Faried et al. (2019) who found fractures in 36% of cases[15]. Subdural hematoma (SDH), cerebral edema, hemorrhagic contusions, and subarachnoid hemorrhage (SAH) were also common. Lee et al. (2017) noted SDH as a strong predictor of poor outcomes, while Hafiz et al. (2011) and Allison et al. (2017) highlighted cerebral edema and hemorrhagic contusions, respectively[16,17,18]. Axonal injury and brain herniation, though less common, were severe complications (Hafiz et al.,2011; Wu et al., 2021) [17,18].

Epidural Hematoma (EDH) is critical in traumatic brain injury management. The mean thickness of EDH was 10.56 mm, with a standard deviation of 5.78 mm. In comparison, Lee et al. (2017) reported that in a study of 50 cases, hematoma thickness varied from 15 to 40 mm, with an average thickness of 26.3 ± 6.6 mm [16]. The mean EDH volume was 13.00 cc, with a standard deviation of 7.89 cc. Our findings indicate that larger EDH volumes are generally linked with more severe clinical presentations, such as cerebral herniations, midline shift (MLS), mass effect, and increased basal cistern compression.

In our study, conservative management was the predominant approach with 45 cases treated conservatively compared to 5 cases that required surgical intervention. The EDH thickness (19.00 mm ± 5.78 mm) and volume (27.60 cc ± 10.06 cc) were significantly higher in the surgical treatment group than in the conservative treatment group. Flaherty et al. (2014) also found that patients who underwent surgery had significantly greater mean initial EDH thickness and volume compared to those who were only observed. Specifically, their study reported mean initial EDH thickness and volume of 15.5 mm and 35 ml in the surgery group, compared to 8.0 mm and 8.6 ml in the observation group [20].

In our study, only the presence of subdural hematomas (SDH) was significantly associated with clinical management (p-value = 0.03) indicating that patients with SDH were more likely to undergo surgical treatment compared to those without SDH. No significant associations were found between clinical management and other CT findings, with p-values ranging from 0.08 to 0.84.

Lee et al. (2017) also reported that the presence of SDH is much more sensitive for predicting poor outcomes than other types of traumatic brain injury (TBI) and is more indicative of poor outcomes than a low Glasgow Coma Scale (GCS) score (3 to 8) [16].

Our study demonstrated moderate sensitivity (73.3%) and high specificity (80.0%). This means that around 80% of patients with large EDH volumes (≥ 15cc) were accurately identified as needing surgical treatment. Additionally, the high positive predictive value (PPV) of 97.1% indicates that nearly all patients who underwent surgery had EDH volumes of 15cc or more. However, the low negative predictive value (NPV) of 25.0% shows that only about 25% of patients who were treated conservatively had EDH volumes less than 15cc which is in line with findings from a retrospective prognostic study by Ferdi Stefiyan et al. (2023). [21]

CONCLUSION

The study highlights the crucial role of EDH volume and associated brain parenchymal changes in determining the severity and clinical outcomes of TBI.

It confirms that larger EDH volumes are linked to more severe clinical conditions such as cerebral herniation, midline shift, and basal cistern compression/effacement, reinforcing the value of EDH volume as a key parameter in TBI assessment and management.

Most patients were managed conservatively with surgical intervention reserved for cases exhibiting larger EDH volumes and more severe CT findings. This management strategy is consistent with current clinical guidelines, which advocate for personalized treatment based on injury severity and imaging results.

The data also suggested that while EDH volume has predictive value in treatment decisions, its effectiveness is limited, indicating the need for a multifaceted approach in clinical decision-making.

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