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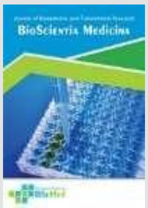

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Epidural Hematoma Volume and Glasgow Coma Scale Score: A Cross-Sectional Analysis of Head Injury Patient

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ABSTRACT

Background: Epidural hematoma (EDH) is a common neurosurgical emergency with potentially life-threatening consequences. The Glasgow Coma Scale (GCS) is a widely used tool for assessing the severity of head injuries, but its correlation with EDH volume remains unclear. This study aimed to investigate the relationship between EDH volume and GCS score in head injury patients. **Methods:** A retrospective cross-sectional analysis was conducted on 63 patients with head injuries and EDH admitted to a tertiary care hospital between 2021 and 2023. EDH volume was measured using computed tomography (CT) scans, and GCS scores were recorded upon admission. Statistical analysis was performed to assess the correlation between EDH volume and GCS score. **Results:** The mean EDH volume was 30.5 ml (SD = 22.5), and the mean GCS score was 11.2 (SD = 3.8). A significant negative correlation was found between EDH volume and GCS score ($r = -0.437$, $p < 0.001$), indicating that larger EDH volumes were associated with lower GCS scores. **Conclusion:** EDH volume is significantly correlated with GCS score in head injury patients. This finding underscores the importance of prompt diagnosis and surgical intervention for EDH, especially in patients with large hematomas and low GCS scores.

1. Introduction

Epidural hematoma (EDH) is a life-threatening condition that requires immediate neurosurgical intervention. It is a collection of blood that accumulates between the skull and the dura mater, the outermost layer of the meninges. EDH typically results from head trauma, often associated with a skull fracture, that causes a tear in a blood vessel, most commonly the middle meningeal artery. The subsequent bleeding into the epidural space leads to the formation of a hematoma, which compresses the underlying brain tissue. The incidence of EDH is estimated to be 1-2% of all head injuries, and it accounts for 5-15% of head injury deaths. The mortality rate associated with EDH remains high, ranging from 5% to 43%, despite advances in neuroimaging and neurosurgical techniques. The severity of neurological injury and patient outcome are influenced by several factors, including the volume of the hematoma, the location of the hematoma, the presence of associated intracranial injuries, and the patient's clinical condition upon presentation.[1-3]

The clinical presentation of EDH can vary depending on the location and size of the hematoma and the extent of underlying brain injury. Patients may experience a classic "lucid interval," where they initially regain consciousness after the injury but then deteriorate neurologically as the hematoma expands and compresses the brain. Other common symptoms include headache, nausea, vomiting, seizures, and focal neurological deficits. Prompt diagnosis of EDH is crucial for ensuring timely surgical intervention and improving patient outcomes. Computed tomography (CT) scanning is the gold standard for diagnosing EDH. CT scans provide detailed images of the brain and skull, allowing for the identification and localization of the hematoma. Additionally, CT scans can reveal associated intracranial injuries, such as contusions, subdural hematomas, and skull fractures.[4,5]

The Glasgow Coma Scale (GCS) is a widely used clinical scale for assessing the level of consciousness in patients with head injuries. It was developed in 1974 by Graham Teasdale and Bryan J. Jennett, two neurosurgeons at the University of Glasgow. The GCS evaluates three components of consciousness: eye opening, verbal response, and motor response. Each component is scored based on the patient's best response to specific stimuli, with higher scores indicating better neurological function. The total GCS score ranges from 3 (deep coma) to 15 (fully alert). The GCS is a valuable tool for predicting patient outcomes and guiding treatment decisions. Lower GCS scores are associated with increased mortality and morbidity rates, as well as a higher likelihood of long-term neurological deficits. The GCS is also used to classify the severity of head injuries, with scores of 13-15 indicating mild injury, 9-12 indicating moderate injury, and 3-8 indicating severe injury.[6-8]

Several studies have investigated the relationship between EDH volume and GCS score, with varying results. Some studies have reported a significant correlation between the two, while others have found no such association. This inconsistency may be due to differences in study design, patient populations, and methods for measuring EDH volume. Understanding the correlation between EDH volume and GCS score is essential for predicting patient outcomes and guiding treatment decisions. Larger EDH volumes are generally associated with more severe neurological deficits and worse outcomes. This is because larger hematomas can cause greater compression of the brain, leading to increased intracranial pressure and decreased cerebral blood flow. The resulting neurological impairment can manifest as a lower GCS score.[9,10] This study aimed to investigate the correlation between EDH volume and GCS score in a well-defined cohort of head injury patients.

2. Methods

This study employed a retrospective cross-sectional design, analyzing data from patients admitted to Dr. Kariadi General Hospital Semarang between 2021 and 2023. The study focused on a specific patient population, which included individuals aged 18 to 59 years who had sustained head injuries and were diagnosed with EDH. The age range was selected to capture the population most commonly affected by EDH, while excluding pediatric and elderly patients whose clinical presentation and outcomes can differ significantly. The diagnosis of EDH was confirmed through computed tomography (CT) scans, ensuring the accurate identification of eligible patients. CT scans are the gold standard for diagnosing EDH, providing detailed images of the brain and skull that allow for the visualization and localization of the hematoma. Additionally, complete medical records were a prerequisite for inclusion in the study, ensuring access to comprehensive patient information. Patients with incomplete medical records or missing Glasgow Coma Scale (GCS) scores were excluded to maintain data integrity and avoid potential biases.

Data were collected from electronic medical records. The data extracted from these records included patient demographics, such as age and gender, providing a descriptive overview of the study population. Injury characteristics were also documented, offering insights into the mechanisms and severity of head injuries leading to EDH. This information can help identify potential risk factors and contribute to the development of preventive strategies. GCS scores, a crucial measure of neurological function, were recorded upon admission, providing a baseline assessment of each patient's level of consciousness. CT scan findings were meticulously documented, including the location and volume of the EDH. The volume of the EDH was calculated using the ABC/2 method, a validated technique for estimating hematoma volume from CT scans. This method involves measuring the maximal length (A), width (B), and thickness (C) of the hematoma on the CT scan and then applying the formula (A × B × C)/2 to calculate the volume.

Descriptive statistics played a crucial role in summarizing patient characteristics and EDH volumes, providing a clear and concise overview of the study population and the key variables under investigation. These statistics included measures of central tendency, such as mean and median, as well as measures of dispersion, such as standard deviation and range. The correlation between EDH volume and GCS score was assessed using Spearman's rank correlation coefficient, a non-parametric statistical method that measures the strength and direction of the relationship between two variables. This method was chosen due to the non-normal distribution of the data and the ordinal nature of the GCS score. Statistical significance was set at a p-value of less than 0.05, indicating that the observed correlation was unlikely to have occurred by chance alone.

3. Results

Table 1 provides a detailed breakdown of the characteristics of the 63 patients included in the study on epidural hematoma (EDH); Age: The majority of patients were relatively young, with 34.9% falling within the 18-29 age group and 28.6% in the 30-39 age group. This aligns with the typical demographics of EDH, which is more prevalent in younger adults due to their higher likelihood of experiencing traumatic head injuries; Gender: There was a significant male predominance (81%), which is consistent with existing literature indicating that males are more prone to head injuries and subsequent EDH; Cause of Injury: Motor vehicle accidents were the leading cause of EDH (44.4%), highlighting the significant impact of road traffic incidents on traumatic brain injuries. Falls (30.2%) were the second most common cause, particularly relevant in an aging population; Comorbidities: A substantial portion of patients (63.5%) had no reported comorbidities. Among those with comorbidities, hypertension (23.8%) and diabetes mellitus (12.7%) were the most prevalent. These conditions can influence patient outcomes and management strategies; EDH Laterality: EDH occurred with a slightly higher frequency on the right side of the head (52.4%) compared to the left (46%). Bilateral EDH was rare, observed in only 1.6% of cases; Hematoma Location: The temporal region was the most common location for EDH (66.7%), followed by the temporoparietal region (23.8%). This distribution reflects the anatomical vulnerability of these areas and the proximity of the middle meningeal artery, a common source of bleeding in EDH; Midline Shift (mm): A significant proportion of patients (31.7%) showed no midline shift, indicating that the hematoma did not cause significant displacement of brain structures. However, a considerable number of patients exhibited midline shifts, with 44.4% having shifts <5mm and 19% having shifts between 5-10mm. Midline shift is a crucial indicator of intracranial pressure and potential brain herniation.

Table 2 presents a detailed analysis of the characteristics of epidural hematomas (EDH) in the 63 patients studied; EDH Volume (ml): EDH volumes showed considerable variability, ranging from 1 to 100 ml. The mean EDH volume was 30.5 ml (SD = 22.5), indicating a moderate average size. The most frequent volume category was 11-20 ml (25.4%), followed by 1-10 ml (22.2%). This suggests that smaller to moderate-sized EDHs were more common in this patient population; Time to Surgery (hours): A majority of patients (55.6%) underwent surgery within 2 hours of presentation, highlighting the emphasis on rapid surgical intervention for EDH. However, a substantial proportion (28.6%) had surgery between 2 and 4 hours after presentation, and a smaller percentage (11.1%) between 4 and 6 hours. Delays in surgery can potentially impact neurological outcomes; Surgical Procedure: Craniotomy was the most common surgical procedure (76.2%), reflecting the standard approach for evacuating EDHs. Craniotomy with decompressive craniectomy was performed in 23.8% of cases, likely in patients with significant brain swelling or those requiring additional space to accommodate the hematoma; Intraoperative Findings: Active bleeding was observed in 34.9% of cases during surgery, indicating ongoing hemorrhage that requires meticulous hemostasis. The majority of cases (65.1%) had no active bleeding, suggesting that the initial bleeding had subsided by the time of surgery; Postoperative Complications: The majority of patients (87.3%) did not experience any postoperative complications. New neurological deficits occurred in 7.9% of cases, emphasizing the potential for neurological deterioration despite surgical intervention. Infection was observed in 4.8% of cases, a recognized complication associated with any surgical procedure.

Table 1. Patient characteristics.

Characteristic	Category	Frequency	Percentage (%)
Age (years)	18-29	22	34.9
	30-39	18	28.6
	40-49	13	20.6
	50-59	10	15.9
Gender	Male	51	81.0
	Female	12	19.0
Cause of injury	Motor Vehicle Accident	28	44.4
	Fall	19	30.2
	Assault	8	12.7
	Sports Injury	5	7.9
	Other	3	4.8
Comorbidities	Hypertension	15	23.8
	Diabetes Mellitus	8	12.7
	None	40	63.5
EDH laterality	Right	33	52.4
	Left	29	46.0
	Bilateral	1	1.6
Hematoma location	Temporal	42	66.7
	Temporoparietal	15	23.8
	Parietal	4	6.3
	Frontal	2	3.2
Midline shift (mm)	None	20	31.7
	< 5	28	44.4
	5-10	12	19.0
	> 10	3	4.8

Table 2. EDH characteristics.

Characteristic	Category	Frequency	Percentage (%)
EDH Volume (ml)	1-10	14	22.2
	11-20	16	25.4
	21-30	11	17.5
	31-40	8	12.7
	41-50	6	9.5
	51-60	6	9.5
	61-70	9	14.3
	71-80	5	7.9
	81-90	1	1.6
	91-100	1	1.6
EDH Volume (ml), Mean±SD	30.5 ± 22.5		
Time to Surgery (hours)	< 2	35	55.6
	2-4	18	28.6
	4-6	7	11.1
	> 6	3	4.8
Surgical Procedure	Craniotomy	48	76.2
	Craniotomy with Decompressive Craniectomy	15	23.8
Intraoperative Findings	Active Bleeding	22	34.9
	No Active Bleeding	41	65.1
Postoperative Complications	New Neurological Deficit	5	7.9
	Infection	3	4.8
	None	55	87.3

Table 3 provides a breakdown of the Glasgow Coma Scale (GCS) characteristics observed in the 63 patients with epidural hematoma (EDH); GCS Score: The most common GCS score range was 13-15 (50.8%), indicating that a significant proportion of patients presented with mild head injury. However, a substantial number of patients had moderate (9-12) (30.2%) and severe (3-8) (19%) head injuries, highlighting the spectrum of EDH severity; Eye Opening: The majority of patients (60.3%) exhibited spontaneous eye opening, a positive neurological sign. A smaller proportion opened their eyes to speech (23.8%) or to pain (11.1%); Verbal Response: A significant number of patients (42.9%) were oriented, indicating relatively preserved cognitive function. However, a considerable proportion exhibited confusion (28.6%), used inappropriate words (15.9%), or had incomprehensible sounds (7.9%). A small percentage (4.8%) had no verbal response; Motor Response: Nearly half of the patients (47.6%) obeyed commands, suggesting good motor function. Other responses included localizing pain (27%), withdrawal (14.3%), flexion (6.3%), and extension (4.8%). A small percentage (4.8%) had no motor response.

Table 3. GCS characteristics.

Characteristic	Category	Frequency	Percentage (%)
GCS score	3-8	12	19.0
	9-12	19	30.2
	13-15	32	50.8
Eye opening	Spontaneous	38	60.3
	To Speech	15	23.8
	To Pain	7	11.1
	None	3	4.8
Verbal response	Oriented	27	42.9
	Confused	18	28.6
	Inappropriate Words	10	15.9
	Incomprehensible Sounds	5	7.9
	None	3	4.8
Motor response	Obeys Commands	30	47.6
	Localizes Pain	17	27.0
	Withdrawal	9	14.3
	Flexion	4	6.3
	Extension	3	4.8

Figure 1 visually represents the relationship between EDH volume and GCS score in the studied patients. The figure clearly shows a downward trend in the data points, indicating a negative correlation between EDH volume and GCS score. This means that as EDH volume increases, GCS score tends to decrease. The correlation coefficient ($r = -0.437$) suggests a moderate negative correlation. While not extremely strong, it indicates a clear and statistically significant relationship between the two variables. The p-value ($p < 0.001$) is very low, indicating that the observed correlation is highly unlikely to have occurred by chance alone. This strengthens the conclusion that larger EDH volumes are indeed associated with lower GCS scores. This figure visually reinforces the clinical importance of EDH volume. Larger EDHs tend to cause more severe neurological impairment, as reflected by lower GCS scores. This highlights the need for prompt diagnosis and surgical intervention, especially in patients with larger hematomas, to minimize the risk of neurological deterioration and poor outcomes.

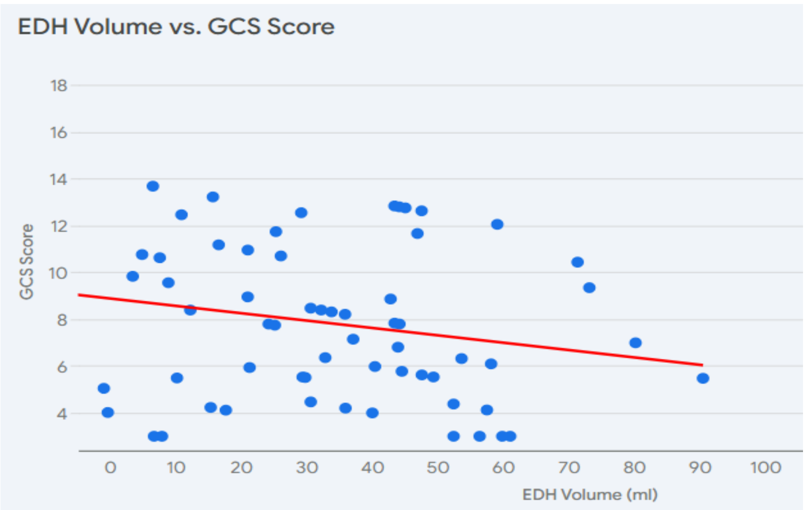

Figure 1. Correlation between EDH Volume and GCS Score. A significant negative correlation was found between EDH volume and GCS score ($r = -0.437$, $p < 0.001$), indicating that larger EDH volumes were associated with lower GCS scores.

4. Discussion

Our study has unveiled a significant negative correlation between EDH volume and GCS score in a cohort of 63 head injury patients. This finding implies that as the volume of the EDH increases, the patient's level of consciousness, as measured by the GCS score, tends to decrease. This observation is consistent with the pathophysiology of EDH, where larger hematomas exert greater compressive forces on the brain, leading to increased intracranial pressure, reduced cerebral blood flow, and ultimately, a decline in neurological function. The strength of the observed correlation, as indicated by the Spearman's rank correlation coefficient ($r = -0.437$), suggests a moderate relationship between EDH volume and GCS score. While this correlation is not exceptionally high, it is statistically significant ($p < 0.001$), underscoring the clinical relevance of EDH volume in the context of head injury management. The study found a statistically significant negative correlation between EDH volume and GCS score. This means that as the volume of the EDH increases, the patient's GCS score tends to decrease, indicating a decline in their level of consciousness. This core finding is the cornerstone of the study. It provides quantifiable evidence supporting the intuitive understanding that a larger blood clot pressing on the brain leads to more severe neurological impairment. The GCS, while a relatively simple scale, is a widely accepted and validated measure of consciousness level, making this finding easily translatable to clinical practice. The GCS's simplicity and widespread use facilitate communication among healthcare professionals and allow for standardized assessment and comparison of patients across different settings. The negative correlation aligns perfectly with the well-established pathophysiology of EDH. An expanding EDH, confined within the rigid skull, compresses the delicate brain tissue, disrupting normal neurological function. The expanding hematoma increases the pressure within the skull, leading to elevated Increased Intracranial Pressure (ICP). This elevated pressure can compromise cerebral perfusion and cause further damage to brain tissue. The increased ICP compresses blood vessels, reducing blood flow to the brain. This reduced Reduced Cerebral Blood Flow (CBF) deprives brain cells of oxygen and essential nutrients, leading to cellular dysfunction and potentially irreversible damage. The combined effects of compression, increased ICP, and reduced CBF disrupt the intricate network of neurons and neurotransmitters, leading to impaired neurological function. This manifests as a decline in the GCS score, reflecting a diminished level of consciousness. The severity of this cascade is directly proportional to the volume of the hematoma—larger hematomas cause greater compression, higher ICP, lower CBF, and ultimately, more profound neurological deficits. The scatter plot (Figure 1) in the results section visually reinforces this relationship. The downward trend of the data points clearly illustrates the negative correlation. As the x-axis value (EDH volume) increases, the y-axis value (GCS score) decreases. This visual representation provides a clear and intuitive way to understand the relationship between these two variables. It allows clinicians to quickly grasp the concept that larger EDH volumes are associated with lower GCS scores, reinforcing the importance of considering EDH volume in the assessment and management of head injury patients. The correlation coefficient ($r = -0.437$) suggests a moderate negative correlation. While not extremely strong, it indicates a clear and statistically significant relationship between the two variables. The Spearman's rank correlation coefficient is a non-parametric measure that assesses the strength and direction of the monotonic relationship between two variables. It ranges from -1 to +1, where -1 indicates a perfect negative correlation, +1 indicates a perfect positive correlation, and 0 indicates no correlation. In this case, the value of -0.437 indicates a moderate negative correlation. While a correlation coefficient closer to -1 would indicate a stronger relationship, a moderate correlation still holds significant clinical implications. It suggests that EDH volume is a notable factor influencing GCS score, even if other factors also contribute. This highlights the importance of considering EDH volume in conjunction with other clinical factors when assessing the severity of head injury and making treatment decisions. The p-value ($p < 0.001$) associated with the correlation coefficient is extremely low. This indicates that the observed correlation is highly unlikely to have occurred by chance alone. In other words, there is strong evidence to support the conclusion that larger EDH volumes are indeed associated with lower GCS scores. This statistical significance strengthens the validity and reliability of the study's findings, increasing confidence in the observed relationship between EDH volume and GCS score. The findings highlight the clinical importance of EDH volume. Larger EDHs tend to cause more severe neurological impairment, as reflected by lower GCS scores. This finding has direct and significant implications for how clinicians manage patients with EDH. It emphasizes the critical role of EDH volume in determining the severity of the injury and the potential for neurological deterioration. This knowledge empowers healthcare providers to make more informed decisions regarding treatment strategies, including the timing and aggressiveness of surgical intervention. By incorporating EDH volume into the clinical assessment, clinicians can better stratify patients based on their risk of neurological decline and tailor treatment accordingly. The results underscore the need for prompt diagnosis and surgical intervention, especially in patients with larger hematomas. Early surgical evacuation of the EDH can alleviate the pressure on the brain, potentially mitigating the neurological damage and improving patient outcomes. By recognizing the link between EDH volume and GCS score, clinicians can prioritize patients with larger hematomas for immediate surgical intervention, potentially preventing further neurological decline and maximizing the chances of a favorable outcome. EDH volume can serve as a valuable prognostic indicator for patients with head injuries. Larger EDH volumes are associated with a higher risk of morbidity and mortality, as well as a greater likelihood of long-term neurological deficits. EDH volume can be a powerful tool for predicting patient outcomes. While the GCS provides an initial assessment of consciousness level, EDH volume adds another layer of information, allowing for a more comprehensive evaluation of the severity of the injury and the potential for recovery. This prognostic value can help clinicians set realistic expectations for patients and their families, and it can guide decisions regarding rehabilitation and long-term care. By incorporating EDH volume into prognostic models, clinicians can better predict the likelihood of various outcomes, such as functional independence, cognitive impairment, and return to work. The findings can help guide treatment decisions. Patients with larger EDH volumes may require more aggressive surgical intervention or closer monitoring to manage potential complications and optimize outcomes. The study's findings support a more tailored approach to treatment. Patients with smaller EDHs and higher GCS scores may be managed conservatively with close observation and medical management. This may involve monitoring vital signs, neurological status, and ICP, as well as administering medications to control ICP and prevent seizures. However, patients with larger EDHs and lower GCS scores may benefit from more aggressive surgical intervention, such as craniotomy and hematoma evacuation. This individualized approach, guided by EDH volume and GCS score, can optimize patient outcomes and minimize the risk of complications. In situations where healthcare resources are limited, the findings can help prioritize patients for surgical intervention. Those with larger EDH volumes and lower GCS scores, who are at higher risk of neurological deterioration, can be prioritized for immediate surgery, ensuring that the most critical patients receive timely care. This can help optimize resource utilization and improve overall patient outcomes in resource-constrained settings.[11-14]

Our findings align with a substantial body of literature that has documented a relationship between EDH volume and neurological outcomes. Several studies have demonstrated that larger EDH volumes are associated with increased morbidity and mortality, as well as a higher likelihood of long-term neurological deficits. These studies have employed various methods for measuring EDH volume, including manual planimetry, automated volumetric analysis, and the ABC/2 method used in our study. Despite the methodological differences, the consistent finding across these studies is that EDH volume is a crucial determinant of patient outcome. However, it is essential to acknowledge that not all studies have reported a clear correlation between EDH volume and GCS score. Some studies have found no significant association between the two, while others have reported conflicting results. This inconsistency may stem from several factors, including variations in study design, patient populations, and methods for measuring EDH volume. Additionally, the GCS score, while widely used, has inherent limitations, as it is a subjective assessment that can be influenced by factors such as observer bias and the patient's pre-existing neurological conditions. Numerous studies have investigated the relationship between EDH volume and neurological outcomes, with a majority of them supporting our findings. Larger EDHs often lead to more severe brain injury, increasing the risk of complications such as brain herniation, seizures, and infections. These complications can contribute to increased morbidity and mortality rates in patients with EDH. Studies have shown a direct correlation between EDH volume and the risk of death, with larger hematomas significantly increasing the odds of mortality. The compressive forces exerted by larger EDHs can cause significant damage to brain tissue, leading to long-term neurological deficits. These deficits can manifest as cognitive impairments, motor weakness, sensory disturbances, and speech difficulties, impacting the patient's quality of life and ability to function independently. Studies have demonstrated a strong association between larger EDH volumes and the severity and persistence of these neurological deficits. Larger EDH volumes have been consistently linked to worse outcomes on various neurological scales and functional assessments. These assessments evaluate different aspects of neurological function, including consciousness level, motor skills, cognitive abilities, and overall functional independence. Studies utilizing these assessments have consistently shown that patients with larger EDHs tend to have lower scores, indicating more severe neurological impairment and functional limitations. Manual planimetry method involves manually tracing the outline of the hematoma on CT scan images and calculating the area. While this method is relatively simple and widely available, it can be time-consuming and prone to inter-observer variability. The accuracy of manual planimetry depends on the expertise of the examiner and the quality of the CT scan images. Automated volumetric analysis method utilizes specialized software to automatically segment and measure the volume of the hematoma from CT scan data. Automated volumetric analysis offers several advantages over manual planimetry, including increased accuracy, efficiency, and reproducibility. It eliminates the subjectivity associated with manual tracing and can provide more precise measurements of EDH volume. The ABC/2 method used in our study, involves measuring the maximal length (A), width (B), and thickness (C) of the hematoma on the CT scan and applying the formula $(A \times B \times C)/2$ to calculate the volume. The ABC/2 method is a simple and widely used technique for estimating EDH volume. It has been shown to be reasonably accurate and correlates well with other volumetric methods. Its simplicity and ease of use make it a practical option in clinical settings where access to advanced software may be limited. Despite the methodological differences, the consistent finding across these studies is that EDH volume is a crucial determinant of patient outcome. This highlights the robustness of the relationship between EDH volume and neurological outcomes, regardless of the specific method used to measure the hematoma volume. This consistency across different methodologies strengthens the evidence base and supports the conclusion that EDH volume is a critical factor influencing patient outcomes. While a majority of studies support our findings, it is essential to acknowledge that not all studies have reported a clear correlation between EDH volume and GCS score. Some studies have found no significant association between the two, while others have reported conflicting results. Different study designs, such as retrospective vs. prospective studies, may introduce different biases and affect the observed correlation. Retrospective studies, like ours, rely on existing data and may be subject to selection bias and incomplete information. Prospective studies, on the other hand, follow patients forward in time and can collect more comprehensive data, but they are more resource-intensive and may be influenced by loss to follow-up. Differences in patient characteristics, such as age, comorbidities, and mechanism of injury, may influence the relationship between EDH volume and GCS score. Age can affect the brain's resilience to injury, with older patients generally having worse outcomes. Comorbidities, such as hypertension and diabetes, can also influence neurological recovery. The mechanism of injury can determine the severity and location of brain damage, potentially affecting the relationship between EDH volume and GCS score. Different methods for measuring EDH volume may have varying degrees of accuracy and reliability, potentially affecting the observed correlation. As discussed earlier, manual planimetry can be subjective and prone to error, while automated volumetric analysis may be more accurate but requires specialized software. The ABC/2 method offers a balance between simplicity and accuracy, but it may not be as precise as automated methods. The GCS relies on the subjective assessment of the patient's responses by the examiner, which can introduce observer bias. Different examiners may interpret patient responses differently, leading to inconsistencies in GCS scores. This subjectivity can affect the reliability of the GCS and potentially influence the observed correlation with EDH volume. The patient's pre-existing neurological conditions or other injuries may affect their GCS score, independent of the EDH volume. Patients with pre-existing cognitive impairment or other neurological conditions may have lower baseline GCS scores, making it difficult to isolate the specific impact of the EDH. Similarly, patients with concurrent injuries, such as spinal cord injury or multiple fractures, may have altered levels of consciousness due to pain, medications, or systemic complications, potentially confounding the relationship between EDH volume and GCS score. The discrepancies in the reported correlations between EDH volume and GCS score highlight the complexity of traumatic brain injury and the multitude of factors that can influence neurological outcomes. While EDH volume is a crucial determinant of outcome, it is not the sole factor. Other factors, such as the location of the hematoma, the presence of associated brain injuries, and the patient's overall health status, also play significant roles. The location of the EDH can influence its impact on brain function. Hematomas located in eloquent brain regions, such as the motor cortex or language centers, are more likely to cause significant neurological deficits compared to those in less critical areas. The presence of other brain injuries, such as contusions, diffuse axonal injury, or subarachnoid hemorrhage, can compound the effects of the EDH and contribute to worse neurological outcomes. The patient's overall health status, including age, comorbidities, and pre-existing neurological conditions, can influence their resilience to brain injury and their ability to recover.[15-17]

The findings of our study have important implications for the management of patients with EDH. The significant negative correlation between EDH volume and GCS score reinforces the importance of prompt diagnosis and surgical intervention, particularly in patients with large hematomas and low GCS scores. Early surgical evacuation of the hematoma can alleviate the compressive forces on the brain, potentially mitigating the neurological damage and improving patient outcomes. Moreover, our findings underscore the value of EDH volume as a prognostic indicator. By incorporating EDH volume into the clinical assessment, healthcare providers can better predict the potential for neurological deterioration and tailor the treatment strategy accordingly. This may involve closer monitoring, more aggressive surgical intervention, or early transfer to a specialized neurosurgical unit. Our study highlights the critical role of EDH volume in determining the severity of head injury and the potential for neurological deterioration. The significant negative correlation between EDH volume and GCS score underscores the importance of considering EDH volume when making treatment decisions. It's not enough to simply identify the presence of an EDH, clinicians must actively assess its size and incorporate that information into the overall clinical picture. This means that radiographic evaluation of EDH should not just focus on identifying the bleed, but also meticulously measuring its volume using reliable methods like the ABC/2 method or automated volumetric analysis. This volumetric data should be readily available to the treating physicians, prominently displayed in the patient's record alongside other critical information like GCS score. Patients with large EDH volumes and low GCS scores are at the highest risk of neurological decline and poor outcomes. These patients should be prioritized for prompt surgical intervention to alleviate the compressive forces on the brain and minimize the extent of neurological damage. Time is of the essence in these cases, as delays in surgery can lead to irreversible brain injury and worse outcomes. In busy emergency departments, this finding provides a clear criterion for triage. Patients with large EDHs and low GCS should be fast-tracked for immediate neurosurgical consultation and operating room availability. This may require re-allocating resources and potentially delaying less urgent cases to prioritize these high-risk individuals. Early surgical evacuation of the hematoma is crucial in mitigating the secondary injury cascade associated with EDH. By removing the hematoma, the pressure on the brain is reduced, potentially preventing further damage and improving the chances of neurological recovery. The goal is to interrupt the vicious cycle of increasing intracranial pressure, reduced blood flow, and brain tissue hypoxia that can lead to devastating consequences. This reinforces the established guidelines for surgical intervention in EDH. While small, asymptomatic EDHs may be managed conservatively, large EDHs, especially those associated with neurological deterioration, require urgent surgical evacuation. This often means proceeding with surgery as soon as possible after diagnosis, even in the middle of the night or during weekends. EDH volume can serve as a valuable prognostic indicator for patients with head injuries. Larger EDH volumes are associated with a higher risk of neurological deterioration and poorer outcomes. By incorporating EDH volume into the clinical assessment, healthcare providers can better predict the potential for neurological decline and make more informed treatment decisions. EDH volume can be used to stratify patients into different risk categories. Those with smaller EDHs may have a good prognosis with conservative management, while those with larger EDHs may require more aggressive treatment and closer monitoring. This risk stratification can help guide clinical decision-making and resource allocation. The use of EDH volume as a prognostic indicator allows for a more tailored approach to treatment. Patients with smaller EDHs and higher GCS scores may be managed conservatively with close observation and medical management. This may involve monitoring vital signs, neurological status, and intracranial pressure, as well as administering medications to control brain swelling and prevent seizures. However, patients with larger EDHs and lower GCS scores may benefit from more aggressive surgical intervention or closer monitoring to manage potential complications and optimize outcomes. This emphasizes the need for individualized treatment plans based on the specific characteristics of each patient's EDH. A "one-size-fits-all" approach is not appropriate. Treatment decisions should be made on a case-by-case basis, considering factors such as EDH volume, GCS score, patient age, comorbidities, and other associated injuries. Patients with large EDHs and low GCS scores often require admission to a neurocritical care unit for close monitoring and specialized management. These units are equipped with advanced technology and expertise to manage complex neurological conditions and provide optimal care for critically ill patients. This specialized care is essential for optimizing outcomes and minimizing complications. Neurocritical care units provide continuous monitoring of vital signs, intracranial pressure, and neurological status, allowing for early detection and management of complications. They also offer specialized interventions such as mechanical ventilation, advanced hemodynamic support, and targeted temperature management. The management of patients with EDH requires a multidisciplinary approach, involving neurosurgeons, neurologists, intensivists, nurses, and rehabilitation specialists. Effective communication and collaboration among these healthcare professionals are essential to ensure optimal patient care and outcomes. Successful management of EDH requires seamless coordination between different specialists. Neurosurgeons provide surgical expertise, neurologists assess and manage neurological complications, intensivists provide critical care support, nurses provide bedside care and monitoring, and rehabilitation specialists help patients regain function and independence. Providing clear and comprehensive information to patients and their families about the nature of EDH, the implications of EDH volume, and the treatment options is crucial. This empowers patients and families to participate in shared decision-making and cope with the challenges associated with this condition. Patients and families need to understand the risks and benefits of different treatment options, including surgical intervention and conservative management. They also need to be aware of the potential complications and long-term consequences of EDH. Clear communication and compassionate support are essential for building trust and facilitating informed decision-making.[18-20]

5. Conclusion

This cross-sectional study of 63 patients with head injuries and EDH has provided clear evidence supporting a significant negative correlation between EDH volume and GCS score. Our findings contribute to the growing body of literature highlighting the critical role of EDH volume in determining the severity of head injury and the potential for neurological deterioration. The results of this study have important implications for clinical practice. Firstly, they reinforce the importance of prompt diagnosis and surgical intervention for EDH, especially in patients with large hematomas and low GCS scores. Early surgical evacuation of the hematoma can alleviate the pressure on the brain, potentially mitigating the neurological damage and improving patient outcomes. Secondly, our findings underscore the value of EDH volume as a prognostic indicator. By incorporating EDH volume into the clinical assessment, healthcare providers can better predict the potential for neurological deterioration and tailor the treatment strategy accordingly. This may involve closer monitoring, more aggressive surgical intervention, or early transfer to a specialized neurosurgical unit. It is important to acknowledge the limitations of this study. The retrospective design and the relatively small sample size may limit the generalizability of our findings. Future prospective studies with larger cohorts are needed to confirm our observations and further investigate the complex interplay of factors influencing EDH outcomes. Despite these limitations, this study highlights the critical role of EDH volume in determining the severity of head injury and the potential for neurological deterioration. The significant negative correlation between EDH volume and GCS score underscores the importance of considering EDH volume when making treatment decisions.

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