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Research Article

Impact of Time from Injury to Surgery on Postoperative Functional Recovery in Large Volume Traumatic Extradural Hematomas

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Abstract

Background In traumatic brain injury (TBI) patients, the time from trauma to cranial surgery is always of great concern to patients and neurosurgeons.

Patients and Methods A retrospective study conducted on 93 TBI patients presented with Glasgow Coma Scale from 4 to 13 and were operated for large volume ($\geq 40\ cm^3$) extradural hematoma (EDH) from July 2020 to December 2022. Surgery was done either within 6 hours following trauma (group A) or later than 6 hours (group B). We evaluated the impact of time from injury to surgery on postoperative clinical recovery, survival, and hospital stay.

Results Fifty patients (53.8%) were operated upon within 6 hours after trauma and 43 patients (46.2%) had operations later than 6 hours. No significant difference was found between the two study groups regarding any of the preoperative clinical or radiological factors except for the mean time from injury to surgery ($p < 0.001$). Delayed surgery > 6 hours was significantly associated with higher postoperative mortality ($p = 0.014$). Hospital stay was significantly shorter in patients operated $\leq$ 6 hours ($p = 0.006$). Patients operated $\leq$ 6 hours showed significantly favorable functional recovery both at discharge ($p = 0.010$) and after 1 month of follow-up ($p = 0.023$).

Conclusion Timely surgical intervention for large volume traumatic EDH is the gold standard. Early surgery "within 6 hours from trauma" not only can save patients' life but also is significantly associated with postoperative favorable clinical recovery, low morbidity, and short hospital stay.

Keywords
- extradural hematoma
- head injury
- surgical evacuation
- time from injury to surgery
- postoperative recovery

Introduction

Head injury is a major health problem with high risk of morbidity and mortality.[1,2] Among intracranial hematomas, extradural hematoma (EDH) assumes the greatest importance as it can be easily diagnosed and treated. For large volume EDH, craniotomy and hematoma evacuation is the only way to save patients' life from a potentially fatal benign lesion.[3,4]

Various factors can be of prognostic value in patients with traumatic EDH including: age, the Glasgow Coma Scale (GCS), pupillary abnormalities, hematoma volume, midline shift (MLS), time from injury to surgery, and secondary brain insult (hypotension, hypertension, or hypoxia).[5,6] In computed tomography (CT) scans, associated intracranial lesions such as subdural hematoma (SDH), intracerebral hematoma (ICH), subarachnoid hemorrhage (SAH), or cerebral contusion may result in an increased mortality rate.[7,8]

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In the daily neurotrauma practice, the time from injury to surgery is of great concern to patients and neurosurgeons; however, in literature there remains little data evaluating the association. Hence, we carried out this retrospective study to evaluate the impact of time from injury to surgery on postoperative functional recovery in traumatic brain injury (TBI) patients, operated for large volume EDH.

Patients and Methods

Study Design and Patients' Population

A retrospective observational study, conducted on TBI patients who underwent craniotomy and evacuation of acute large volume EDH in our institution in the period from July 2020 to December 2022. This study was approved by the local ethical scientific committee of our institution (IRB approval number: 4-2023.NEUS 4-1). Head injury patients of either sex with no age restrictions who presented with GCS score (4–13) and had acute EDH with volume $\geq$ 40 cm^3 on brain CT scan were included in our study. We excluded patients with (1) GCS score 14 or 15, (2) GCS score 3 with bilateral dilated fixed pupils, (3) concomitant posttraumatic intracranial hemorrhagic lesions (SDH, ICH, SAH, or cerebral contusion), and (4) associated other significant systemic injury that affected the hospital course. In regards to the time interval from head injury to EDH evacuation, operations were done either within the first 6 hours after trauma (group A) or later than 6 hours (group B).

Data Collection

Demographic, clinical, and radiographic data were collected from patients' medical records of our department including data on and during the period of admission and then follow-up data during the first month after discharge. Preoperative data included: age; sex; mechanism of trauma including road traffic accident (RTA), fall from height (FFH), or assault; GCS on admission; clinical signs (pupillary responses and contralateral hemiparesis); coagulopathy; EDH side, location, volume, and maximum thickness; degree of MLS; concomitant intracranial lesions; and time from trauma to the beginning of surgery.

Postoperative data included: GCS after surgery and at discharge, neurological deficits, findings in follow-up CT scans, operative-related complications, hospital course, and discharge outcome.

EDH volume was calculated in three dimensions. The width was measured as the transverse diameter, the length as the anteroposterior diameter, and the depth as the superoinferior diameter. Approximated volume was computed by multiplying the three dimensions using the Petersen and Espersen[9] equation: volume = ABC / 2.

Management

Resuscitation efforts were carried out for all patients, including assessment and stabilization of airway patency, breathing, and circulation. After confirming the diagnosis with CT brain, patients were shifted to the operating room where surgical evacuation of the EDH was done by the neurosurgical team on duty. Postoperatively, patients were kept under close neurological observation; routine follow-up CT brain was done during the first postoperative 24 hours and just before discharge, while it was done on urgent basis once indicated.

Outcome Measures

The two study groups were compared regarding postoperative clinical recovery and improvement, complications, survival, and length of hospital stay. The Extended Glasgow Outcome Scale (GOSE) score demonstrated in ►**Table 1** is a measure of the association between traumatic injuries and diverse aspects of daily functioning.[10] GOSE score was measured at discharge and 1 month later. Patients who had moderate disability or good recovery (GOSE score from 5 to 8) were included together in the favorable functional recovery group while patients who were severely disabled, vegetative, or died (GOSE score from 1 to 4) were included together in the unfavorable recovery group.

Table 1 The Extended Glasgow Outcome Scale (GOSE) score[10]

Category number	Name	Definition
8	Good recovery (upper)	No current problems related to the brain injury that affects daily life
7	Good recovery (lower)	Minor problems that affect daily life; resumes >50% of the preinjury level of social and leisure activities
6	Moderate disability (upper)	Reduced work capacity; resumes <50% of the preinjury level of social and leisure activities
5	Moderate disability (lower)	Unable to work or only in sheltered workshop
4	Sever disability (upper)	Can be left alone >8 hours during the day, but unable to travel and/or go shopping without assistance
3	Sever disability (lower)	Requires frequent help of someone to be around at home most of the time every day
2	Persistent vegetative state	Unresponsive and speechless
1	Death	

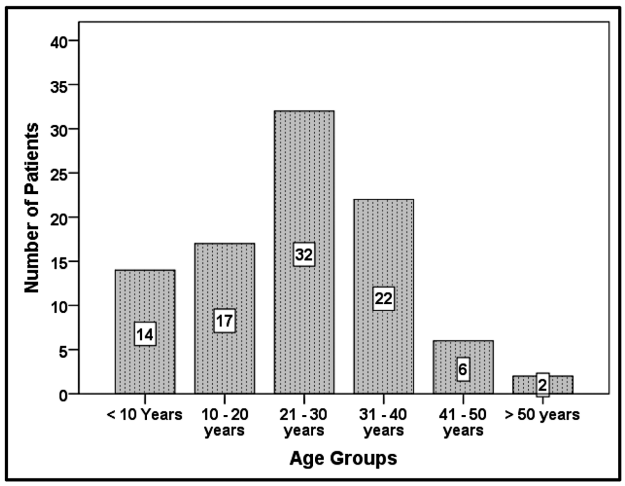

Fig. 1 Distribution of included patients among the different age groups. The highest percentage of patients (34.4%) were in the age group from 21 to 30 years, followed by 23.7% from 31 to 40 years and only 2.2% were > 50 years. No significant difference was found between the two groups in this regard.

Statistical Analysis

To tabulate and statistically analyze the results, SPSS V.22 (IBM Corporation, Armonk, New York, United States) and Microsoft Excel 2010 (Microsoft Corporation, Redmond, Washington, United States) were used. The descriptive statistics included mean (x) and standard deviation. The count data were expressed as the rate and analyzed using the chi-square test. Standard Student's t-test, for independent samples, was used for comparing the means between the two groups in various factors of the study. A p-value of ≤ 0.05 was considered statistically significant.

Results

A total of 112 TBI patients were diagnosed with acute large volume EDH that required urgent surgical evacuation; 19 patients were excluded (10 patients presented with GCS score 14 or 15, 1 patient presented with GCS 3 and bilateral dilated fixed pupils, 3 patients had concomitant intracranial hemorrhagic lesions, and 5 patients had associated significant systemic injury). So, 93 patients were actively included in our study. In regards to the time from injury to surgery, 50 patients (53.8%) were operated upon within the first 6 hours after trauma and 43 patients (46.2%) had operations later than 6 hours.

In the entire sample, the mean GCS score on presentation was (9.87 ± 2.401). The majority of patients (76.3%) had GCS score of 9 to 13 and 23.7% had GCS score of 4 to 8. Although the number of patients with low GCS was higher in group B 13 cases versus 9 cases in group A, this difference was statistically nonsignificant ($p = 0.166$).

The mean patients' age was 24.70 ± 12.107 years with a range from 2 to 59 years. ►**Fig. 1** illustrates the distribution of included patients among different age groups. The majority of patients (67.7%) were males. The most common mechanism of injury was RTA (55.9%) followed by FFH (31.2%) and assault (12.9%). In regards to preoperative examination, 16 patients (17.2%) had anisocoria and 21 patients (22.6%) presented with contralateral hemiparesis. Eight patients (8.6%) had preoperative coagulopathy. ►**Table 2** compares the general and clinical data between patients of the two study groups.

CT scan on presentation showed left-sided EDH in 52 patients (55.9%). In decreasing order of frequency, EDH location was parietal in 26.9%, frontal in 24.7%, temporoparietal in 21.5%, temporal in 17.2%, occipital in 7.5%, and posterior fossa in 2.2%. The mean EDH volume was $56.77 \pm 10.200\,cm^3$, 66 patients (71.0%) had EDH volume from 40 to $60\,cm^3$ and 27 patients (29.0%) had EDH volume $>60\,cm^3$. The mean MLS was 6.35 ± 1.558 mm. Thirty-six patients (38.7%) had concomitant skull fractures. ►**Table 3** compares the radiographic data between patients in the two study groups.

Noticeably, there was no significant difference between the two study groups regarding any of the preoperative

Table 2 Preoperative general and clinical data of patients in the two study groups

Parameters	Group A ($n = 50$)	Group B ($n = 43$)	p-Value
GCS (mean ± SD)	10.24 ± 2.317	9.44 ± 2.452	0.110
GCS range			0.166
9–13	41	30	
4–8	9	13	
Age in years (mean ± SD)	25.04 ± 13.429	24.30 ± 10.507	0.771
Gender (M/F)	34/16	29/14	0.954
Unequal pupils	7	9	0.377
Hemiparesis	11	10	0.885
Coagulopathy (high INR)	5	3	0.604
Time to surgery (mean ± SD)	4.210 ± 1.270	10.962 ± 3.440	< 0.001[a]

Abbreviations: F, female; GCS: Glasgow Coma Scale; INR, international normalized ratio; M, male; SD, standard deviation.
Note: Group A: patients operated upon ≤6 hours after trauma; group B: patients operated upon >6 hours. Time to surgery: the time interval from head injury to the beginning of surgery in hours.
[a]Statistically significant.

Table 3 Preoperative radiographic data of patients in the two study groups

Parameters	Group A ($n = 50$)	Group B ($n = 43$)	*p*-Value
EDH side (R/L)	23/27	18/25	0.689
EDH location			0.607
Parietal	12	13	
Frontal	15	8	
Temproparietal	8	12	
Temporal	10	6	
Occipital	5	4	
EDH volume, cm^3	57.04 ± 9.134	56.47 ± 11.419	0.788
MLS, mm	6.48 ± 1.632	6.21 ± 1.473	0.406
Associated skull fractures	17	19	0.315

Abbreviations: EDH, extradural hematoma; L, left; MLS, midline shift; R, right.
Note: Group (A): patients operated upon ≤ 6 hours after trauma; Group (B): patients operated upon > 6 hours.

clinical or radiological factors except for the mean time from injury to surgery ($p < 0.001$).

►**Table 4** displays the postoperative results in the entire sample and compares the results between the two study groups. Postoperative complications were encountered in 7 cases (7.5%). Five cases required resurgery, three cases were reoperated for recurrent EDH, one for large postoperative residual EDH, and one underwent decompressive craniectomy for massive postoperative cerebral infarction.

As illustrated in ►**Fig. 2**, the GOSE score was significantly higher in patients operated ≤ 6 hours both at discharge and 1 month after surgery ($p = 0.016$ and 0.043, respectively).

As demonstrated in ►**Table 5**, time from injury to surgery was the only independent predictor with significant impact on postoperative functional recovery.

Discussion

EDH is considered a serious neurosurgical emergency following TBI. Despite the advances in prehospital and inhospital management for trauma patients, there are still relatively high rates of morbidity and mortality in patients with large volume traumatic EDH.[11,12]

In our case series, 50 patients (53.8%) underwent surgical evacuation for their EDH in ≤ 6 hours following trauma with a mean time to surgery of 4.210 ± 1.270 hours and 43 patients (46.2%) had operations later than 6 hours with a mean time to surgery of 10.962 ± 3.440 hours. Worth mentioning, that delayed arrival of TBI patients to our emergency department after trauma was behind the delay in surgery.

In point of fact, previous studies showed considerable variance in the time from trauma to EDH surgery; this variance can be explained by the differences in the time of EDH diagnosis and/or the time of patients' reception. Khaled et al[5] found that the time interval between trauma and surgery was within 13 to 24 hours in 54% of their cases. In

Table 4 Postoperative results of patients in the two study groups

Parameters	Entire sample ($n = 93$)	Group A ($n = 50$)	Group B ($n = 43$)	*p*-Value
Complications				
Residual hematoma	1 (1.1%)	0	1	0.278
Recurrent hematoma	3 (3.2%)	2	1	0.649
Cerebral Infarction	2 (2.2%)	0	2	0.123
Wound infection	1 (1.1%)	1	0	0.351
Resurgery	5 (5.4%)	2	3	0.526
Mortality	8 (8.6%)	1	7	0.014[a]
Hospital stay (mean ± SD)	5.75 ± 2.565	5.08 ± 2.174	6.53 ± 2.780	0.006[a]
GOSE score at discharge	5.40 ± 1.764	5.82 ± 1.289	4.91 ± 2.102	0.016[a]
Recovery at discharge				0.010[a]
Favorable	70 (75.3%)	43 (86.0%)	27 (62.8%)	
Unfavorable	23 (24.7%)	7 (14.0%)	16 (37.2%)	
GOSE score after 1 month	6.34 ± 1.119	6.55 ± 0.980	6.06 ± 1.241	0.043[a]
Recovery after 1 month				0.023[a]
Favorable	76 (89.4%)	47 (95.9%)	29 (80.6%)	
Unfavorable	9 (10.6%)	2 (4.1%)	7 (19.4%)	

Abbreviations: GOSE, Extended Glasgow Outcome scale; SD, standard deviation.
Note: Group A: patients operated upon ≤ 6 hours after trauma; group B: patients operated upon > 6 hours. Hospital stay: the length of stay "in days" in our department till discharge. Recovery after 1 month: was calculated after exclusion of the 8 cases who expired during the hospital stay.
[a]Statistically significant.

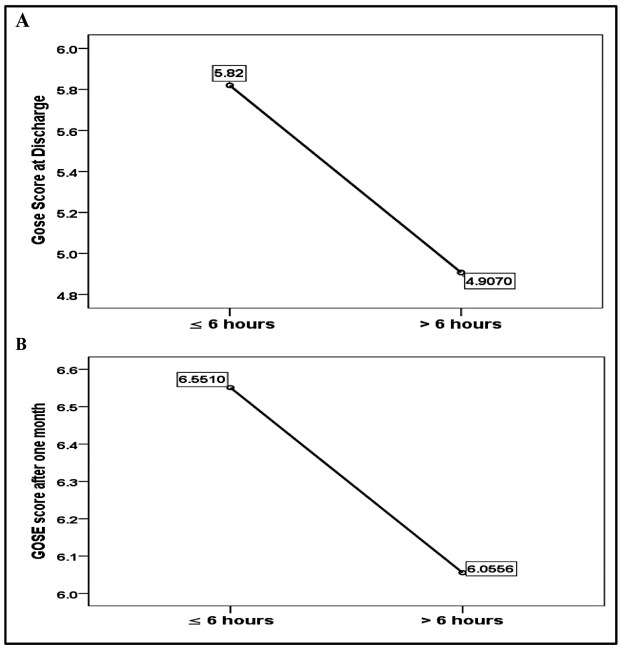

Fig. 2 The correlation between time from injury to surgery and the Extended Glasgow Outcome Scale (GOSE) score at discharge (**A**) and after 1 month (**B**). Short time from injury to surgery was a significant predictor for higher GOSE score ($p = 0.016$ and 0.043 at discharge and after 1 month, respectively).

Howlader et al[13] study, 66.31% of patients underwent surgery within 6 to 24 hours after trauma. In Niaz et al[14] study, 70.0% of patients had EDH evacuation in less than 6 hours after injury. Gerlach et al[15] reported that the mean time to surgery was 19.9 hours; however, 53.8% of patients underwent surgical EDH evacuation within 6 hours. In the study of Ozkan et al,[16] only 23.5% of cases with EDH got operation in less than 6 hours after trauma.

Time to Surgery and Postoperative Hospital Course

In our series, long time from injury to EDH evacuation showed a negative feedback on postoperative hospital course, where surgery done later than 6 hours after trauma was associated with a high risk for postoperative cerebral infarction, higher rate of mortality, and longer duration of hospital stay.

We encountered two cases (4.7%) that developed postoperative cerebral infarction and both of them had delayed surgery > 6 hours. This can be attributed to the longer brain tissue compression by the large hematoma volume that can result in increased intracranial pressure and disturbed cerebral autoregulation leading to impairment of cerebral blood flow and cerebral perfusion. Also, this may be related to a secondary brain insult such as uncontrolled blood pressure or hypoxia that may develop following TBI.

Also, delayed EDH evacuation was significantly associated with higher postoperative mortality ($p = 0.014$). Among the 43 patients who had delayed surgery >6 hours after trauma, 7 patients (16.2%) expired. In agreement with our result, Ozkan et al[16] in their retrospective analysis reported that mortality rate was 23.5% in patients operated later than 6 hours of injury. Also, in the series of Das et al[12] 55 patients (3%) expired, all of whom had time between injury and surgery of more than 12 hours. On contrary to our results, Lafta et al[17] reported that the time interval between injury and patient reception had no effect on mortality. This difference from our results can be attributed to: in their series, 46% of patients had the time interval between injury and reception of <3 hours and 38% of received patients presented with high GCS.

In our study, time to surgery proved to have a significant impact on the length of postoperative hospital stay. Patients who had surgery ≤6 hours showed a significant short length

Table 5 Predictors for postoperative functional recovery

Parameters	Favorable recovery ($n = 70$)	Unfavorable recovery ($n = 23$)	*p*-Value
GCS (mean ± SD)	10.13 ± 2.245	9.09 ± 2.729	0.071
GCS range			0.378
9–13	55	16	
4–8	15	7	
Age (mean ± SD)	25.46 ± 12.554	22.39 ± 10.547	0.295
Sex (M/F)	48/22	15/8	0.765
Pupillary responses			0.193
Normal pupils	60	17	
Unequal pupils	10	6	
Time to surgery			0.010[a]
≤6 h	43	7	
>6 h	27	16	
EDH volume (mean ± SD)	56.06 ± 9.616	58.96 ± 11.772	0.239
MLS (mean ± SD)	6.47 ± 1.558	6.00 ± 1.537	0.210

Abbreviations: EDH, extradural hematoma; F, female; GCS: Glasgow Coma Scale; M, male; MLS, midline shift; SD, standard deviation.
Note: Time to surgery: the time from onset of trauma to the beginning of surgery.
[a]Statistically significant.

of hospital stay ($p = 0.006$). No previous studies addressed the association between time to EDH surgery and length of hospital stay.

Time to Surgery and Postoperative Functional Recovery

At discharge, 70 patients (75.3%) showed favorable functional recovery while 23 patients (24.7%) showed unfavorable recovery, including 8 patients who expired. One month after surgery, the percentage of favorable recovery was increased to 89.4%. In literature there is agreement that despite being a serious neurosurgical emergency, EDH mostly carries a good prognostic outcome after surgery.[2,11,14,18,19] ►**Fig. 3** illustrates the pre- and postoperative CT scans of a patient who was operated upon for large volume EDH within 6 hours after trauma and despite of having a low GCS on presentation, this patient had postoperative favorable recovery.

Although there was no significant differences between the two studied groups regarding the preoperative clinical or radiological parameters, we observed significantly favorable postoperative functional recovery both at discharge ($p = 0.010$) and after 1 month of follow-up ($p = 0.023$) in patients operated $\leq$ 6 hours following trauma. This finding signifies the golden value of the short time from injury to surgery in achieving favorable postoperative outcome.

There is a wide consensus among previous studies about the importance of early surgery for EDH patients. In Niaz et al[14] study, almost 70% of patients were operated within 6 hours of injury and all of them ended up with good outcome, while in the 30% with delayed surgery >6 hours, 63.7 and 36.3% had poor and good outcome, respectively ($p < 0.001$). Niryana et al[20] reported that preoperative duration $\geq$12 hours was a pure risk factor for unfavorable outcome. Korinth et al[21] mentioned that delayed EDH treatment would result in a poor outcome. Lafta et al[17] reported that better functional recovery ($p = 0.001$) was found among patients with a shorter time interval between injury and patient reception ($\leq$3 hours). Also, in the series of Das et al,[12] all patients (100%) who were operated within 12 hours of injury achieved good outcome, while 94% in whom surgery was done between 12 and 24 hours achieved good outcome and only 64% of those who were operated beyond 24 hours ended up with good outcome.

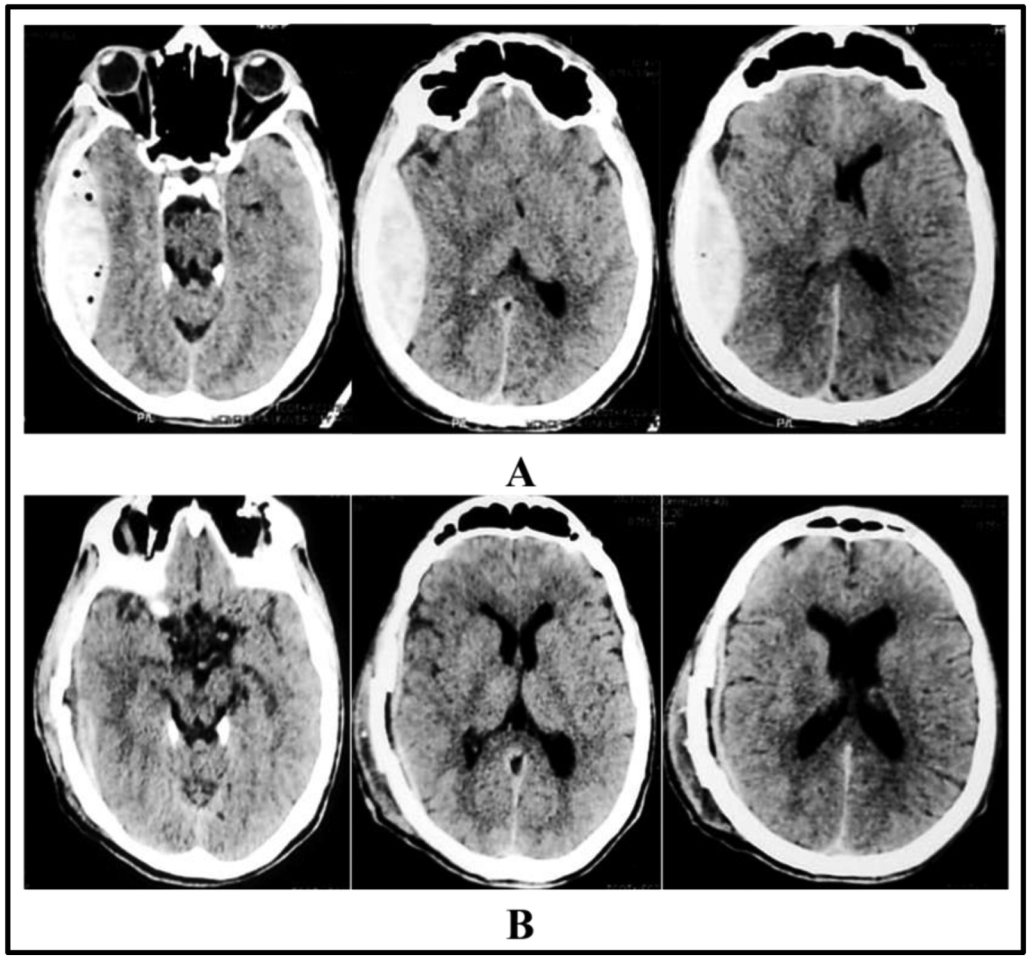

Fig. 3 (**A**, **B**) Adult patient presented 2 hours after road traffic accident with Glasgow Coma Scale (GCS) 8/15. (**A**) Initial computed tomography (CT) brain showing right temporoparietal large volume extradural hematoma (EDH) with midline shift. Patient underwent early surgical evacuation of EDH "within the first 6 hours after trauma." (**B**) Postoperative CT brain showing complete hematoma evacuation with improvement of midline shift. Postoperatively, GCS was improved to 14/15 and the patient had favorable clinical recovery at discharge.

In contrast to our results, the study of Ayogu et al[2] failed to demonstrate an association between outcome and the time interval from trauma until surgery. Patients operated upon within the first 6 hours of presentation did not show a significantly better outcome when compared with patients who had surgery later than 6 hours ($p = 0.083$). Also, Nnadi et al[18] reported that time to surgery did not have significant effect on the outcome ($p = 0.760$). The difference between our results and these studies can be explained by the high percentage of patients with mild TBI and high GCS score (13–15) who were included in these studies; 51 and 38% in Ayogu et al[2] and Nnadi et al[18] study, respectively.

In regards to the factors that can influence the postoperative functional recovery, the prognostic impact of patients' age, preoperative anisocoria, admission GCS, and hematoma volume have been studied most frequently in previous studies.[12,14,17,20,22,23] In our series, none of these factors was a significant predictor for favorable functional recovery.

Concerning patients' age, the majority of patients (58.1%) were young adults (age 21–40 years) and only 2.2% were > 50 years; this was behind the reduced impact of patients' age on the postoperative outcome. Preoperative anisocoria was reported in a small number of our patients (16 cases) and 7 cases of them were operated $\leq$6 hours after trauma. No doubt that the GCS on admission has an important role in the prognosis of EDH patients. In the current study, patients with GCS score 14 or 15 were excluded because mostly they will achieve favorable outcome and also the number of patients with low admission GCS (4–8) was relatively small 22/93. These reasons reduced the impact of GCS on postoperative outcome. Concerning the EDH volume, our study was conducted only on large volume EDH ($\geq 40\,cm^3$) and there were no significant variations between included cases in regards to their EDH volume.

Study Limitations

The present study had some limitations that come from its retrospective nature. Also, our study population was selected from only one single center and to a lesser extent the sample size was quite small with short period of postoperative follow-up after discharge. Some exclusion criteria were also applied to GCS score. Nevertheless, this study can be beneficial in realizing the prognostic value of time from injury to surgery in TBI patients with large volume EDH and can provide worthy contributions in future-related studies.

Conclusion

Timely surgical intervention for large volume traumatic EDH is the gold standard. In moderate or low GCS head injury patients operated for large volume EDH, the time from injury to surgery proved to have a highly significant impact on postoperative functional recovery. Early surgery "within 6 hours from trauma" not only can save patients' life but also is significantly associated with postoperative favorable clinical recovery, low morbidity, and short hospital stay. Surely, hard efforts should be spent to shorten the time interval between injury and receiving TBI patients.

Study Design

A retrospective study conducted on 93 traumatic brain injury patients presented with Glasgow Coma Scale from 4 to 13 and were operated upon in our department for large volume ($\geq 40\,cm^3$) extradural hematomas from July 2020 to December 2022. Surgery was done either within the first 6 hours following trauma (group A) or later than 6 hours (group B). Our objective was to evaluate the impact of time from injury to surgery on postoperative clinical recovery, complications, survival, and hospital stay in head injury patients operated for large volume extradural hematomas.

Note

This study was performed in the Department of Neurosurgery, Faculty of Medicine, Menoufia University Hospital, Shibin Elkom, Egypt.

Authors' Contributions

All authors made a significant contribution to the work reported, whether that was in the conception; study design; execution; and acquisition, analysis, and interpretation of data. All authors took part in drafting, revising, and final approval of the article. This article has been read and approved by all authors and all agreed to be accountable for all aspects of the work.

Data Sharing Statement

All data and materials included in this work are available.

Ethics Approval

This study was approved by the clinical research committee of the Faculty of Medicine, Menoufia University (IRB approval number: 4-2023.NEUS. 4-1) and it followed the tenets of the Declaration of Helsinki.

Funding

None.

Conflict of Interest

None declared.

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