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Prognostic Factors of Recovery and Discharge Outcome in Adults after Moderate Traumatic Brain Injury

Hossam Elnoamany[1] Yasser Bahgat El Sisi[1] Abdulla Mostafa Abdulla Abu Elsoud[1] Ayman Ahmed Omar[2] Hany Elkholy[1]

[1] Neurosurgery Department of Menoufia University, Shibin Elkom, Egypt
[2] General Surgery Department of Menoufia University, Shibin Elkom, Egypt

Address for correspondence Hany Elkholy, MD, Department of Neurosurgery, Faculty of Medicine, Menoufia University, Shibin Elkom 6131567, Egypt (e-mail: hany.elkhouli@med.menofia.edu.eg).

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Abstract

Background Traumatic brain injury (TBI) is a leading cause of mortality and morbidity particularly among young people. Identification of prognostic factors can be considerably helpful for clinical decision-making and prediction of outcome.

Objective The aim of this study was to identify prognostic factors supposed to be of value in predicting functional outcome in moderate TBI patients.

Materials and Methods This was a prospective case series study conducted from March 2023 to January 2024 involving 72 TBI patients with a Glasgow Coma Scale (GCS) score of 9 to 13. Demographic, clinical, laboratory, and management data were collected, analyzed, and correlated with patient outcomes. Based on the Extended Glasgow Outcome Scale (GOSE), patients were assigned to have either favorable outcome (GOSE score: 5–8) or poor outcome (GOSE score: 1–4).

Results The mean age was 38.76 ± 18.30 years. The mean GCS score on admission was 11.68 ± 1.27. Surgical intervention was indicated in 29 patients (40.3%). The average length of hospital stay was 9.01 ± 7.88 days. Sixty-five patients (90.3%) had a favorable outcome and 7 patients (9.7%) had a poor outcome. Prognostic factors with significant impact on outcome included the GCS score on admission ($p = 0.002$); pupillary responses ($p = 0.011$); blood pressure ($p = 0.005$); acute subdural hematoma (ASDH) as a primary lesion ($p = 0.049$); and time to admission, comorbidities, blood glucose, hemoglobin%, oxygen saturation, coagulation profile, endotracheal intubation, and tracheostomy ($p < 0.001$).

Conclusion In moderate TBI patients, delayed hospital arrival, low GCS score, unequal pupils, pretrauma comorbidities, hypotension, hypoxia, anemia, endotracheal intubation, tracheostomy, and ASDH were associated with unfavorable functional recovery and could be considered as poor prognostic factors.

Keywords
- functional recovery
- head trauma
- moderate traumatic brain injury
- outcome
- prognostic factors

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Introduction

Traumatic brain injury (TBI) is a major public health problem worldwide. The annual incidence of TBI approximately reaches up to 50 million cases around the world.[1] TBI is the leading cause of disability and cognitive impairment particularly affecting young people.[2] Head injury is responsible for one-third of all injury-related deaths. The overall mortality in moderate TBI is approximately 21% at 30 days and increases to 50% for severe TBI.[3,4]

The burden of the disease and the need for care are often greater at hospitals in emerging economies where access to advanced monitoring may be limited.[5] Prognosis of TBI patients is still unclear, and multiple studies have tried to identify predictors of outcome in these patients.[2]

Prognostic models combine characteristics related to patients, diseases, and treatments aiming to predict the possibility of an outcome of interest and thus can play an important role in clinical decision-making.[6] Few studies have specifically focused on characteristics and prognosis in patients with moderate TBI, which according to existing classification is defined by a Glasgow Coma Scale (GCS) score of 9 to 13 at presentation.[7,8] Hence, this study aimed to establish a prognostic model based on the admission criteria and identify the combination of factors that can best predict the discharge outcome among patients with moderate TBI.

Materials and Methods

This prospective observational case series study was conducted in our neurosurgery department after being approved by the ethical scientific committee of our institution (IRB: 3/2023.SURG.37). This study was performed on patients who were admitted with moderate TBI during the period from March 2023 to January 2024.

Eligibility Criteria

We included adult patients aged $\geq$18 years who suffered TBI and presented within 24 hours from trauma with GCS scores between 9 and 13. We excluded patients with incomplete data, patients in whom assessment of the neurological prognosis was not possible (because of a previous disease or loss to follow-up), patients who arrived later than 24 hours after trauma, and patients who died secondary to extracranial trauma.

Management

In the emergency room (ER), all patients underwent primary survey to ensure patent airway, intact breathing ability, and adequate blood circulation. All patients were put under close clinical observation and monitoring of vital signs with intensive care unit (ICU) admission when needed, for example, GCS score $\leq$12 or systemic injury necessitating ICU care. Regular laboratory and radiological investigations were performed. Medical treatments included fluids, antibiotics, analgesics, measures to decrease intracranial pressure (ICP) such as mannitol and diuretics, and antiepileptic drugs in certain cases. In patients indicated for surgical management, standard surgical procedures were performed under general anesthesia according to the identified radiological pathology, and then patients were transferred to the postoperative ICU when needed.

Data Collection

Data were collected from participants who fulfill our eligibility criteria in ER, during admission, at discharge, and 1 month after discharge. Data included the following: age; sex; mode of trauma (road traffic accident [RTA], fall from height [FFH], and direct trauma); clinical presentations (loss of consciousness [LOC], headache, vomiting, amnesia, and seizures)[3]; general examination to detect other traumatic injuries and comorbidities[4]; full neurological assessment (GCS score, pupillary responses, and neurological deficits)[5]; routine laboratory investigations (complete blood picture, coagulation profile, liver and kidney function tests, and random blood sugar)[6]; computed tomography (CT) of the brain and skull bones[7]; duration of hospital stay and encountered complications during admission[8]; and outcome where the Extended Glasgow Outcome Scale (GOSE) score[9] was used to measure the surgical outcome at discharge and 1 month later. Patients with GOSE scores from 5 to 8 were assigned to have a good outcome, while those with GOSE scores from 1 to 4 were reported to have a poor outcome.

Clinical and radiological follow-up was done on regular bases every 2 weeks following discharge.

Statistical Analysis

Collected data were tabulated and analyzed by SPSS (statistical package for the social science software) version 26 on IBM compatible computer. Pearson's chi-squared test (χ^2) was used to study the association between two qualitative variables. Fisher's exact test (FE) was used to study the association between two qualitative variables if any of the expected cell frequencies was less than five. Student's *t*-test (*t*) was used to study the association between two quantitative normally distributed variables. Mann–Whitney *U* test (*U*) was used to study the association between two quantitative non-normally distributed variables. A *p*-value of less than 0.05 was considered statistically significant.

Results

During our study period from March 2023 to January 2024, a total of 98 patients were diagnosed to have moderate TBI (GCS score of 9–13). Based on our eligibility criteria, 26 patients were excluded: 16 patients younger than 18 years, 4 patients with incomplete data or incomplete follow-up, 3 patients who presented later than 24 hours after trauma, and 3 patients who died secondary to extracranial trauma. Thus, 72 patients with moderate TBI were actively included in this study. The mean time from trauma to ER presentation was 7.05 ± 5.23 hours. The mean age was

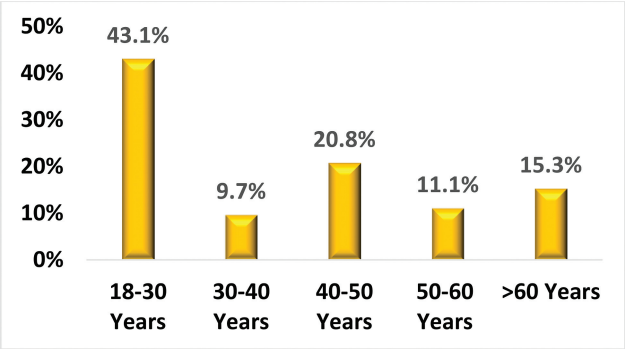

Fig. 1 Distribution of studied patients according to different age groups. A large number of patients (43.1%) were younger than 30 years. Patients older than 60 years represented 15.3% of the total cohort.

38.76 ± 18.30 years; distribution of patients according to different age groups is illustrated in ►**Fig. 1**. Our study included 53 males (73.6%) and 19 females (26.4%). The mean GCS score on admission was 11.68 ± 1.27. Pupillary responses were bilaterally reactive in 64 cases (88.9%), unequal in 6 patients (8.3%), and bilaterally nonreactive in 2 patients (2.8%). Sixteen patients (22.2%) had one or more episodes of hypotension and 10 patients (13.8%) had at least a single episode of hypoxia. ►**Table 1** demonstrates the demographic and clinical data of the included cases on admission.

Extradural hematoma (EDH) was the predominant pathology (27.8%) found in brain CT at the time of ER presentation, while diffuse axonal injury (DAI) and intraventricular hemorrhage (IVH) were the least frequent CT findings among studied patients, accounting for 1.4% of all findings.

Among admitted cases, 10 patients (13.8%) required intubation, and tracheostomy was done for 10 cases (13.8%). Forty-three patients (59.7%) were subjected to conservative treatment and 29 patients (40.3%) underwent cranial surgery. The initial and follow-up CT scans for one of our included cases are illustrated in ►**Fig. 2**.

The average length of hospital stay was 9.01 ± 7.88 days (range: 2–37 days); 67 patients (93.1%) had a hospital stay for less than 2 weeks, while 5 patients (6.9%) were admitted for a longer period. Complications encountered during admission are enumerated in ►**Table 2**. A statistically significant improvement ($p < 0.001$) in the GCS score was observed among studied patients at discharge and after 1 month (►**Fig. 3**).

Favorable outcome (GOSE score from 5 to 8) was observed in 65 patients (90.3%), while outcome was unfavorable (GOSE score from 1 to 4) in 7 patients (9.7%). It is worth mentioning that the mean GOSE score statistically improved from 7.24 ± 1.95 at discharge to 7.31 ± 1.94 after 1 month ($p = 0.024$).

As demonstrated in ►**Table 3**, there was no statistically significant relation between patients' age, sex, or mode of trauma and the outcome ($p > 0.05$). Among studied patients having pretrauma comorbidities, longer time from trauma to

Table 1 Demographic, clinical, and laboratory data among included patients on admission

Parameter	No.	%
Pretraumatic comorbidities		
DM	7	9.7
HTN	8	11.1
Cardiac	3	4.2
Renal	3	4.2
Hepatic	3	4.2
Coagulopathy	2	2.8
Mode of trauma		
Assault	17	23.7
FFH	23	31.9
RTA	32	44.4
General vital signs		
Hypotension	16	22.2
O_2 saturation	Mean ± SD (94.60 ± 4.84)	Range (75–99)
Laboratory data		
Blood glucose	Mean ± SD (118.28 ± 39.55)	Range (40–250)
Hemoglobin%	Mean ± SD (12.56 ± 1.84)	Range (7.5–16.8)
PT	Mean ± SD (80.83 ± 13.14)	Range (45–100)

Abbreviations: DM, diabetes mellitus; FFH, fall from height; HTN, hypertension; PT, Prothrombin time; RTA, road traffic accident; SD, standard deviation.
Note: Some patients had more than one comorbidity.

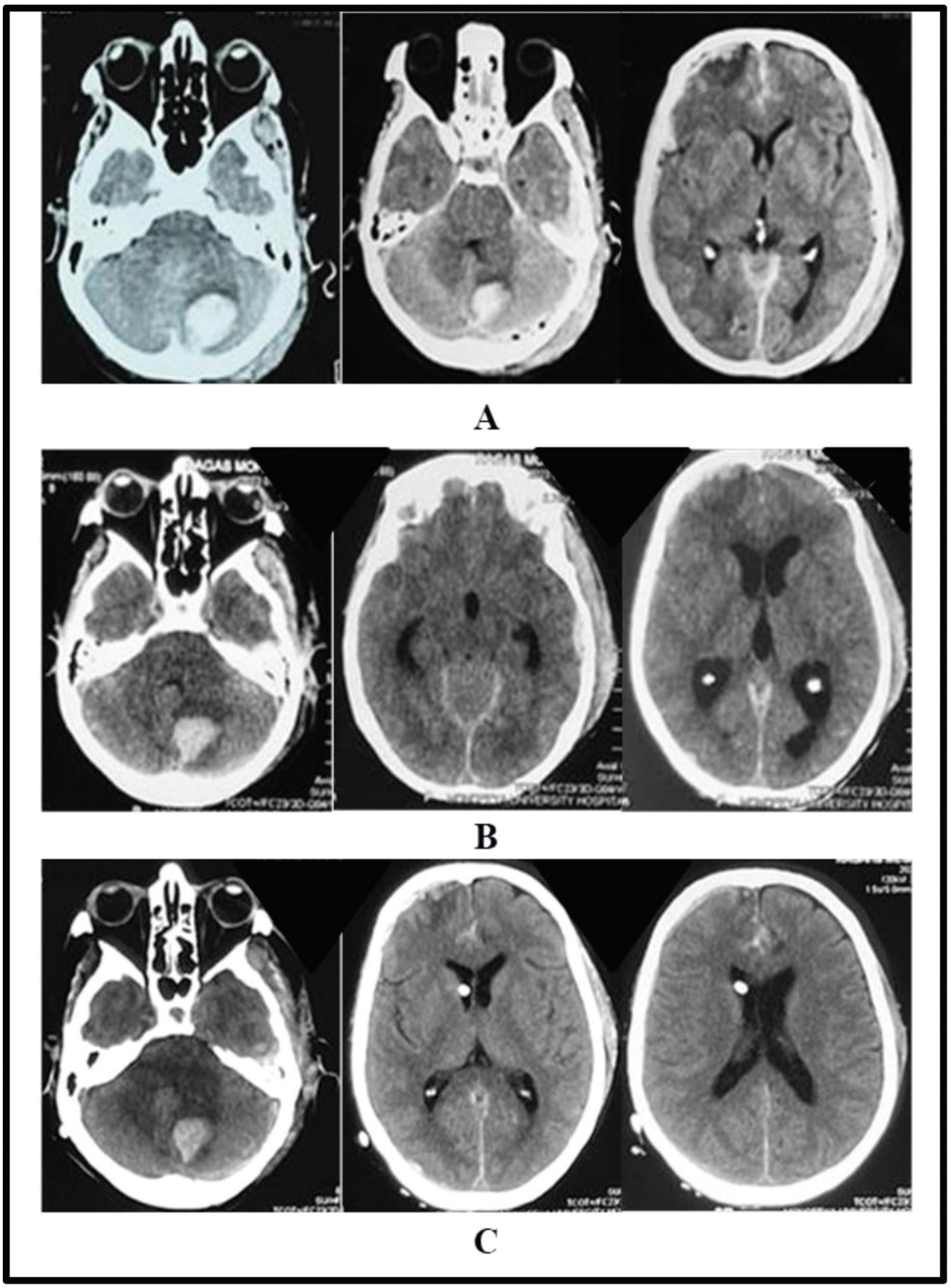

Fig. 2 Male patient aged 65 years involved in road traffic accident (RTA) and presented to our emergency room (ER) 9 hours after trauma with a Glasgow Coma Scale (GCS) score of 11/15. **(A)** Initial brain computed tomography (CT) showed left cerebellar hemorrhagic contusion, left temporal rim of extradural hematoma, and subarachnoid hemorrhage. The patient was kept under close observation in the intensive care unit (ICU) and was planned for conservative treatment. The patient developed sudden disturbed consciousness (GCS score of 8/15) on day 5. **(B)** Urgent brain CT was done immediately after deterioration, which revealed hydrocephalic changes. A ventriculoperitoneal shunt was inserted and the patient was returned to the ICU intubated. **(C)** Follow-up brain CT after ventriculoperitoneal shunt insertion. This patient died after 15 days from admission.

admission, low GCS score at admission, unequal pupils, acute subdural hematoma (as a primary lesion), hypotension, hypoxia, low blood glucose, anemia, coagulopathy, tracheal intubation, tracheostomy, and development of complications were significant predictors associated with unfavorable outcome (►**Table 4**).

Discussion

Our study was conducted on 72 TBI patients presented to ER within 24 hours after trauma with a GCS score of 9 to 13. The mean age of the included cases was 38.76 ± 18.30 years and the vast majority of patients (43.1%) were aged 18 to

Table 2 Complications among studied patients during admission

Parameter	Frequency	%
None	52	72.2
Seizures	6	8.3
Wound infection	4	5.6
Chest infection	3	4.2
Multiple surgeries	2	2.8
Pulmonary embolism	2	2.8
Expansion of primary lesion	1	1.4
Hydrocephalus	1	1.4
Subdural empyema	1	1.4

Note: The largest percentage of studied patients (72.2%) had no complications during admission. The most common complication among studied patients was seizures (8.3%), followed by wound infection (5.6%).

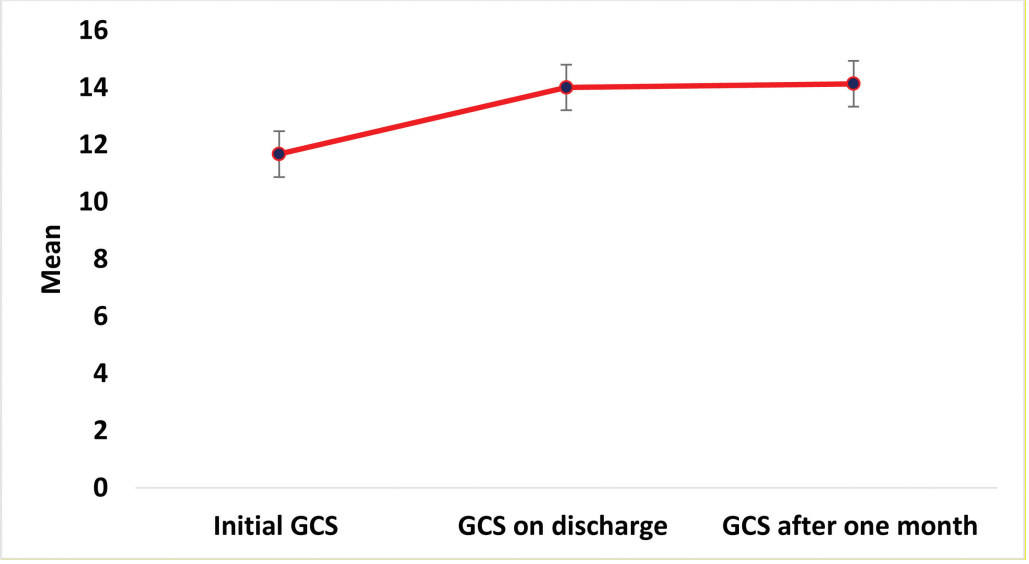

Fig. 3 Improvement of Glasgow Coma Scale (GCS) score among studied cases. A statistically significant improvement was observed in the GCS score at discharge and after 1 month ($p < 0.001$). The mean GCS score was 14.01 ± 2.85 on discharge and 14.14 ± 2.83 after 1 month.

Table 3 Outcome in relation to demographic and general data among studied patients

Variable	Favorable outcome ($n = 65$)		Unfavorable outcome ($n = 7$)		Test of significance	*p*-value
	No.	%	No.	%		
Sex						
Male Female	47 18	72.3 27.7	6 1	85.7 14.3	FE = 0.59	0.667
Age (mean ± SD)	37.58 ± 17.68		49.71 ± 21.77		$U = 1.53$	0.126
Comorbidities	11	16.9	7	100	FE = 23.26	<0.001[a]
Mode of trauma						
Assault FFH RTA	17 21 27	26.2 32.3 41.5	0 2 5	0 28.6 71.4	$\chi^2 = 3.13$	0.234
Time (mean ± SD)	6.12 ± 4.17		15.72 ± 6.42		$U = 3.51$	<0.001[a]

Abbreviations: FFH, fall from height; RTA, road traffic accident; SD, standard deviation; Time, time interval (in hours) from trauma to hospital arrival.
[a]Statistically significant.

Table 4 Outcome in relation to clinical, laboratory, and management data among studied patients

Variable	Favorable outcome ($n=65$)		Unfavorable outcome ($n=7$)		Test of significance	*p*-value
	No.	%	No.	%		
GCS (mean ± SD)	11.75 ± 1.23		11.00 ± 1.53		$t=0.92$	0.002[a]
Pupils						
Dilated fixed RRR Unequal	1 61 3	1.5 93.7 4.6	1 3 3	14.3 42.9 42.9	$\chi^2=16.64$	0.011[a]
BP (hypotension)	11	16.9	5	71.4	FE = 10.86	0.005[a]
O_2 sat. (mean ± SD)	95.31 ± 3.91		88.00 ± 7.59		$t=4.22$	< 0.001[a]
Blood glucose (mean ± SD)	122.48 ± 35.75		79.29 ± 53.96		$U=3.13$	0.002[a]
Hb% (mean ± SD)	12.99 ± 1.34		8.57 ± 0.68		$t=14.51$	< 0.001[a]
PT (mean ± SD)	83.98 ± 9.21		51.57 ± 5.56		$t=13.55$	< 0.001[a]
Tracheal intubation	3	4.6	7	100	FE = 48.07	< 0.001[a]
Tracheostomy	3	4.6	7	100	FE = 48.07	< 0.001[a]
Cranial surgery	26	40	3	42.9	FE = 0.02	1.000
Complications	13	20	7	100	FE = 20.16	< 0.001[a]

Abbreviations: BP, blood pressure; GCS, Glasgow Coma Scale; Hb%, hemoglobin%; O_2 sat.: oxygen saturation; PT, prothrombin time; RRR, round, regular, and reactive; SD, standard deviation.
*Statistically significant.

30 years. Consistent with our results, El-Matbouly et al[10] reported that TBI was incidentally higher among middle-aged people. The current study showed no statistically significant relation between patients' age and outcome. Contrary to our result, the study of Spears et al[11] found that the proportions of mortality and unfavorable outcome were increased with increased age.

Males are more commonly affected by head trauma than females, and in our series, males constituted 73.6% of the cases. Male predominance can be probably explained by the higher involvement of men in physical and outdoor activities, more exposure to traffic accidents, violence, and assault. RTA was the most common cause of head trauma and accounted for 44.4% of the total. Either the patients' sex or the mode of trauma was a significant predictor for outcome, and this is in agreement with most of the previous studies.[12–14]

The mean time from trauma to ER presentation and initiation of management was 7.05 ± 5.23 hours. Shorter time periods were significantly associated with favorable outcome ($p<0.001$). Our finding is in line with that reported by Vaca et al[15] who found that the average time to neurosurgical evaluation of moderate TBI was 7 hours.

In our study, the mean GCS score on admission was 11.68 ± 1.27. We noticed a statistically significant improvement in the mean GCS among studied patients both at discharge and after 1 month ($p<0.001$). Lu et al[16] and Niryana et al[17] concluded similar results; they stated that GCS score was considered one of the most influential attributes in functional outcome in TBI patients. Lower initial GCS score is usually associated with longer recovery periods, thereby increasing hospital length of stay. In our series, GCS score on admission was a significant predictor for functional recovery; this result is in agreement with some of previous studies correlating initial GCS scores to outcome in TBI patients.[18,19]

In our study, 18 patients (25%) had one or more comorbidities. There was a statistically significant difference between patients with favorable outcomes and those with unfavorable outcomes regarding pretrauma comorbidities ($p<0.001$). In agreement with our finding, Xiong et al[20] also found a significant association between favorable outcome and the presence of pretrauma comorbidities.

Hoffmann et al[21] stated that normal pupillary responses were associated with good outcome. Our results demonstrated a similar finding where normal pupillary response was a significant predictor for favorable outcome and 60% of patients with abnormal pupillary reflex showed poor functional recovery on discharge. We also found that patients who suffered episodes of hypotension (systolic blood pressure < 90) or hypoxia (O_2 saturation < 90%) had an unfavorable outcome; this comes in line with Manley et al.[22]

In our study, anemia (hemoglobin% < 10 g/dL), hypoglycemia (random blood sugar < 60 mg/dL), and coagulopathy (including history of bleeding, clotting disorders, or current treatment with anticoagulants) all were associated with poor functional recovery and unfavorable outcome. Our result is consistent with that reported by Imen et al[23] who found that laboratory variables including blood glucose, prothrombin time, and hemoglobin% had a strong association with outcome.

ASDH was the only primary CT lesion with a significant impact on outcome. ASDH was more prevalent in those with unfavorable outcome ($p = 0.049$). Our result is similar to that reported in Gupta et al's[24] study in which patients diagnosed with ASDH had a poor outcome.

In TBI patients, tracheal intubation and tracheostomy can carry multiple risks including increased ICP and potential airway complications. We found that endotracheal intubation and tracheostomy carried a significant risk of unfavorable functional recovery. This result was not in line with some previous studies such as Gravesteijn et al[25] who found that in-hospital intubation was associated with better functional outcome in patients with GCS scores of $\leq$10.

Among included cases, 43 patients (59.7%) were treated conservatively, while the remaining 29 patients (40.3%) underwent cranial surgery at some point after hospital admission. No statistically significant difference between patients with favorable outcome and those with unfavorable outcome regarding surgical intervention was noticed in our study. In contrast to our finding, Niryana et al[17] reported that cranial surgery in TBI patients had a significant impact on patients' outcome.

Among our cases, the mean length of hospital stay was 9.01 ± 7.88 days. During the period of admission, complications were encountered in 20 cases (27.7%), with seizures being the most common complication (8.3%). Among postoperative complications, wound infection was reported in four cases (5.6% of total) but with no mortality attributed to wound infection. This comes in agreement with Dashti et al's[26] study that concluded that although wound infection was a common complication following craniotomy, it had no significant relation to morbidity. Posttraumatic hydrocephalus was reported in one patient (1.4%), a finding that is close to the findings of Yoon et al[27] who reported a 2.5% incidence of posttraumatic hydrocephalus. It is worth noting that development of complications during the period of admission had a significant impact on outcome ($p < 0.001$); all the seven cases with unfavorable outcome developed complications. This finding is similar to that reported in Baum et al's[28] study.

At time of discharge, the mean GOSE score was 7.24 ± 1.95. The majority of included cases (80.6%) had excellent recovery with little to no effort on their function (GOSE score of 8), 2 patients (2.8%) were discharged in a vegetative condition, and 4 patients (5.6%) expired. One month after discharge, the mean GOSE score was significantly improved to 7.31 ± 1.94; 86.1% of the patients had a GOSE score of 8, while four patients with GOSE score of 7 on discharge improved to 8 after 1 month. Consistent with our result, Baum et al[28] reported favorable outcome following TBI. McCrea et al[29] also assessed the outcome in major areas of life function at 1, 3, 6, and 12 months after moderate TBI. They found that at 1 month after injury, 41% with moderate TBI had favorable outcomes and by 12 months, 75% achieved favorable outcomes.

On the other hand, patients' outcome in our study seems different from some previous studies. Bullock et al[30] and Bahloul et al[31] in their series reported death rates varying from 20 to 40%. The deviation of our study population toward a better outcome could be attributed to our inclusion criteria regarding the inclusion of patients older than 18 years, patients with moderate degree of TBI, and arrival within the first 24 hours after trauma.

Limitations

The current study has some limitations that come from and the short period of postoperative follow-up after discharge. Nevertheless, this study can be beneficial in the management of moderate TBI patients through realization of the prognostic factors with significant impact on functional recovery and discharge outcome.

Conclusion

Moderate TBI can be a significant cause of morbidity and mortality and thus necessitates considerable awareness for timely diagnosis and management. In our community, males are more commonly affected than females and RTAs are the most common cause of adult TBI. In moderate TBI patients, some factors such as delayed hospital arrival, low GCS score, unequal pupils, pretrauma comorbidities, hypotension, hypoxia, anemia, endotracheal intubation, tracheostomy, and ASDH can be associated with unfavorable functional recovery and could be considered as poor prognostic factors.

Note

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

Authors' Contributions

All the 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 the authors took part in drafting, revising, and final approval of the article. This article has been read and approved by all the authors and all the authors agreed to be accountable for all aspects of the work.

Ethical Approval

This study was approved by the clinical research committee of the Faculty of Medicine, Menoufia University (IRB approval number: 3/2023.SURG.37) and it followed the tenets of the Declaration of Helsinki.

Funding

None.

Conflict of Interest

None declared.

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