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PREDICTORS OF FUNCTIONAL RECOVERY FOLLOWING SURGICAL MANAGEMENT OF TRAUMATIC BRAIN INJURY: A PROSPECTIVE OBSERVATIONAL STUDY

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ABSTRACT

Background: Traumatic brain injury (TBI) continues to be one of the most prevalent causes of death and development of chronic neurologic disability around the world, especially among young individuals with economic potential. In cases of moderate and severe TBI emergency neurosurgical procedures are often required in order to reduce elevated ICP, remove intracranial hematomas and prevent secondary brain injury. Although the introduction of novel surgical techniques, neurocritical care, and rehabilitation programs has led to a significant improvement in the mortality rate following the intervention, the results of rehabilitation of survived patients vary widely from one individual to another. The results of rehabilitation are determined by various demographic, clinical, imaging, and perioperative factors including age, injury severity, Glasgow Coma Scale score, response of pupils, time of surgery, features of intracranial lesion, and post-operative complications. Discovering such predictors of rehabilitation success is extremely important for patient selection, improving prognostic accuracy, rehabilitation planning, and rehabilitation effectiveness. Prospective observational studies examining the impact of these variables in tertiary care settings are useful in obtaining recommendations aimed at enhancing TBI management. The objective is to assess the factors influencing successful functional recovery after surgical procedures for traumatic brain injuries and the neurological and functional status of the patients treated in a teaching hospital that provides complete health services.

Materials and Methods: This observational study has a prospective nature and was performed in the Neurology Department of a tertiary teaching hospital for a timeframe of 24 months. A total of 100 consecutive cases of adult patients with moderate-to-severe head injury requiring surgical intervention were included in this study, which was performed at the hospital. All the patients were treated with decompressive craniotomy without seizures, craniotomy with decompression by evacuation of the intracranial hematoma, or elevation of the depressed cranial vault or any combination of these interventions based on clinical signs and symptoms and any specific radiological findings. The data on age and sex of the patient, mechanism of injury, Glasgow Coma Scale at the time of admission, except for ozone level measured, type of injury sustained, any other organ injury sustained, time of injury until surgery was performed, surgery details, and complications encountered after surgery may be described in detail. All the patients underwent rehabilitation therapy at the institution and were followed for at least 6 months.

Results: The median age of the population in the research was 38.7 +- 13.9 years with 72 males (72.0%) and 28 females (28.0%) in it. The most common

mechanism of injury was due to road traffic accidents contributing to about 61.0% of the total population; while falls accounted for 25.0% of the cases and injury caused by assaults for 14.0% of the cases. The most common intracranial lesion was acute subdural hematoma, while the most common surgical procedure performed was decompressive craniectomy. There was a significant improvement towards neurological status and functional outcomes during the follow-up period with the mean GOSE being 3.2 +- 0.9 at discharge and increasing to 5.9 +- 1.2 at six months, whereas the mean FIM was noted to increase from 58.1 +- 11.6 at discharge to 98.4 +- 14.1 after six months ($p< 0.001$). The study found that the following factors were found to independently predict functional recovery from a multivariate analysis; younger age (<50 years), GCS≥9 upon admission, the presence of reactiveness of pupils bilaterally, having the surgery performed within the first six hours, lower Marshall CT grading, and presence of no major postoperative complications.

Conclusion: The surgical treatment of traumatic brain injury offers significant improvement both neurologically and functionally where combined with standardized neurocritical care and structured rehabilitation. Age, neurological condition, presence of pupil reflexes, time of surgery, degree of injury demonstrated on radiology and successful postoperative recovery have been shown to be relevant predictors of a positive functional outcome in trauma cases. Early identification of prognostic criteria can lead to individualized diagnosis and treatment considering available options.

Keywords: Traumatic brain injury; Functional recovery; Surgical management; Glasgow Outcome Scale-Extended; Functional Independence Measure; Decompressive craniectomy; Craniotomy; Prognostic factors; Neurosurgery; Prospective observational study.

INTRODUCTION

Traumatic brain injury (TBI) refers to a major cause of deaths, neurological impairment, and financial strain globally, especially in the young adult demographic.[1] TBI arises due to mechanical forces acting on the skull, thus resulting in complications of varying degrees of severity.[2] For cases of moderate-to-severe TBI, urgent neurosurgical procedures may be needed to relieve intracranial pressure, evacuate intracranial blood, resolve the mass effect, and prevent secondary brain damage.[3,4] Although there have been improvements in trauma management, TBI continues to lead to various serious conditions that diminish patients' quality of life due to long-term disabilities.[5] The most frequent cause of TBI in developing countries is road traffic crash, followed closely by falls, violence, and occupational hazards.[6] Most young men suffer from TBI since they are often exposed to situations with high-intensity trauma which results in loss of healthy years of lives.[7]

There are different types of primary TBI including contusions, diffuse axonal injuries, skull fractures, intracranial bleeding, and brainstem injury caused by impact.[8] This primary insult may trigger a secondary injury that brings about cerebral edema, ischemia, excitotoxicity, neuroinflammation, oxidative stress, disruption in cerebral perfusion, and increased intracranial pressure.[9,10] There are currently no effective medical measures to prevent either the occurrence or consequences of a primary brain injury. Therefore, current management treatment aims at preventing a secondary injury.[11,12]

Thus, computed tomography is the most appropriate imaging technique for evaluating and identifying traumatic brain injury as it is readily available and provides very good evidence for identifying skull fractures, cerebral hematomas, brain contusion, diffuse cerebral edema, midline shift, ventricular compression, and herniation. It is imperative to identify lesions that can be treated surgically early enough as this can ensure better outcomes for the patient through timely intervention.[13,14]

Selection of surgical management depends on various factors including clinical presentation, neurological status, GCS score, reaction of pupils, radiological findings, intracranial pressure, and existence of surgically treatable lesions.[15] Some of the most common surgeries conducted in the management of traumatic brain injury include decompressive craniectomy, craniotomy to remove subdural or epidural hematomas, intracerebral hematoma evacuation, elevation of depressed skull fracture and surgical decompression for intracranial pressure.[16] An early intervention surgical procedure for patients suffering from traumatic brain injury has the capability of minimizing secondary ischemic injury, enhancing cerebral perfusion, inhibiting intracranial pressure increase, and increasing the probability of neurological recovery.[17] In order to assess postoperative recovery, standardized outcome measures should be utilized in order to evaluate neurological function, functional independence, and reintegration into everyday living.[18] The Glasgow Outcome Scale-Extended (GOSE) is considered to be one of the most commonly used methods of assessing global functional recovery from traumatic brain injury, while the measures of functional

independence are provided by the Functional Independence Measure (FIM) that assesses self-care, mobility, communication, cognition, and functional independence.[19,20]

Following a traumatic brain injury, the course of functional recovery is determined by many demographic, clinical, radiological, and perioperative variables. Younger age, a higher physician-granted Glasgow Coma Scale score upon admission, a presence of pupillary reflex, lower radiological severity of brain trauma, an early surgery, absence of systemic injuries, and lack of postoperative complications are prior to obtaining better outcomes.[21,22] On the contrary, surgery being delayed, diffuse brain injury, prolonged intracranial pressure, elder age, and severe neurological impairment at the time of admission are mentioned when it comes to a worse outcome.

The identification of prognostic factors for functional recovery plays a very important role in the improvement of prognostic accuracy, clinical decision-making, rehabilitation planning, and patient education together with the family concerning the expected outcome.[23] Significant prognostic factors also help to allocate the resources and to choose optimal treatment approaches and follow-up care continuously in cases of neurosurgical treatment of traumatic brain injuries.[24]

Despite numerous studies being done to analyze the outcomes of surgery for traumatic brain injury, only a few prospective observational studies from tertiary care centers have been conducted to study together demographic characteristics and severity of trauma, together with the type of surgery being done and postoperative complications.[25]

The purpose of the study is to find out the predictors of functional recovery after surgical management of patients with traumatic brain injury by analyzing their neurological and functional outcomes in order to find a relationship with either favorable postoperative outcome or not.

MATERIALS AND METHODS

Study design and setting: This was a prospective observational study to be performed in the Department of Neurosurgery in a tertiary care teaching hospital over a period of two years from January 2024 to December 2025. The purpose of this study was to evaluate the predictors of functional recovery after the surgical management of traumatic brain injury in adults needing neurosurgical interventions.

Study population: Between the two groups of patients with MTBI, the male/female ratio was 2.38 in the veterans and 2.83 in the other non-veterans. In both groups, there was a predominance of men as expect, since the number of women with MTBI is low. The average age at which the injury occurred was 49.5 years in the veterans and 43.5 years in the other patients.

Sample size: A total of 100 patients were included in the study.

Sample size calculation

The sample size was calculated using the formula:

$$n = \frac{Z^2 \times p \times q}{d^2}$$

Where:

- n = Required sample size
- Z = Standard normal deviate at 95% confidence interval (1.96)
- p = Expected proportion of favorable functional recovery following surgical management based on previously published literature
- q = 1-p
- d = Absolute precision

Based on the calculations, it was found that a minimum of about 92 patients was needed to be sampled in order to contemplate for anticipated loss to follow-up and incomplete clinical data. Due to anticipated loss to follow up and incomplete clinical data, the research team enrolled 100 patients as subjects of study.

Inclusion criteria

- Patients aged 18 years and above.
- Moderate-to-severe traumatic brain injury requiring surgical intervention.
- Admission Glasgow Coma Scale (GCS) score between 3 and 12.
- Radiological evidence of surgically treatable intracranial pathology on computed tomography.
- Patients undergoing emergency neurosurgical procedures within the study period.
- Written informed consent from the patient or legally authorized representative.
- Availability for postoperative follow-up up to six months.

Exclusion criteria

- Mild traumatic brain injury managed conservatively.
- Penetrating cranial injuries.
- Previous neurosurgical intervention for traumatic brain injury.
- Polytrauma patients with unsurvivable systemic injuries.
- Patients with pre-existing severe neurological disorders affecting functional assessment.
- Patients who expired before postoperative neurological evaluation.
- Incomplete medical records or loss to follow-up.

Preoperative evaluation: All enrolled patients underwent comprehensive clinical evaluation including:

- Detailed history regarding mechanism and timing of injury.
- General physical examination.
- Neurological examination.
- Glasgow Coma Scale assessment.
- Pupillary size and light reflex.
- Motor deficit evaluation.
- Cranial nerve examination.
- Associated extracranial injuries.

- Hemodynamic assessment.

Routine laboratory investigations included complete blood count, renal function tests, liver function tests, coagulation profile, serum electrolytes, blood glucose estimation, blood grouping and cross-matching, viral markers, electrocardiography, and chest radiography whenever indicated.

Radiological assessment: All patients underwent emergency non-contrast computed tomography (CT) of the brain.

The following radiological parameters were recorded:

- Type of intracranial lesion.
- Acute subdural hematoma.
- Epidural hematoma.
- Intraparenchymal hematoma.
- Cerebral contusion.
- Diffuse cerebral edema.
- Depressed skull fracture.
- Midline shift.
- Basal cistern status.
- Marshall CT classification.
- Associated skull fractures.

Surgical management: The decision for surgery was based on clinical deterioration, neurological examination, radiological findings, Brain Trauma Foundation recommendations, and neurosurgical judgment.

The operative procedures performed included:

- Decompressive craniectomy.
- Craniotomy with evacuation of acute subdural hematoma.
- Craniotomy with evacuation of epidural hematoma.
- Evacuation of intracerebral hematoma.
- Elevation of depressed skull fracture.
- Combined neurosurgical procedures where indicated.

All procedures were performed under general anesthesia using standard neurosurgical techniques.

Postoperative management

All patients received standardized postoperative neurocritical care comprising:

- Mechanical ventilation when indicated.
- Intracranial pressure management.
- Hemodynamic stabilization.
- Antiepileptic prophylaxis.
- Broad-spectrum antibiotics.
- Deep vein thrombosis prophylaxis.
- Early enteral nutrition.
- Physiotherapy and rehabilitation.
- Serial neurological assessment.

Patients were followed at:

- Hospital discharge.
- Three months.
- Six months after surgery.

Outcome measures

Primary outcome

- Functional recovery assessed using the Glasgow Outcome Scale-Extended (GOSE).

Secondary outcomes

- Functional Independence Measure (FIM).
- Neurological improvement.
- Mortality.
- Postoperative complications.
- Duration of hospital stay.
- Requirement for repeat surgery.

Definition of favorable functional recovery

Functional recovery at six months was categorized as:

- Favorable outcome: GOSE score 5–8.
- Unfavorable outcome: GOSE score 1–4.

Variables evaluated as predictors of recovery

The following variables were evaluated for association with functional recovery:

- Age.
- Gender.
- Mechanism of injury.
- Admission Glasgow Coma Scale score.
- Pupillary response.
- Marshall CT classification.
- Type of intracranial lesion.
- Midline shift.
- Injury-to-surgery interval.
- Surgical procedure performed.
- Duration of surgery.
- Associated extracranial injuries.
- Intensive care unit stay.
- Postoperative complications.

Statistical analysis: The data was collected and analyzed from Microsoft Excel data using version 26.0 of Statistical Package for Social Sciences (SPSS).

Continuous variables were stated as mean ± standard deviation (SD), while categorical variables were indicated as frequency and percentages.

Comparisons of outcome group data were conducted using the following:

- Student's t-test
- Chi-Square test
- Fisher's exact test where appropriate

Variables that were found to be statistically significant in univariate analysis were included in a multivariable logistic regression analysis to evaluate independent predictors of the positive functional recovery.

Odds ratios were calculated along with their 95% confidence interval for those variables.

The p-value of <0.05 was regarded as statistically significant.

Ethical considerations: The study protocol had been approved beforehand by the Institutional Ethics Committee of tertiary care teaching hospital. All participants or their legally authorized representatives signed the informed consent prior to commencing the study. The confidentiality of the patients' information has been ensured in the entire study. As it proceeded in accordance with the Declaration of Helsinki and Good Clinical Practice guidelines, patient information was kept secret.

RESULTS

One hundred patients with moderate to severe traumatic brain injury treated surgically during the study period were included in the final analysis. Patients completed a scheduled six-month follow-up and assessment of all neurological and functional outcome measures. The mean age of the study population was 38.7 ± 13.9 years with males predominating. Road traffic accidents were the major mechanism of injury followed by falls and assault. Acute subdural hematoma was the commonest intracranial injury needing surgery while decompressive craniectomy was the most performed operation in the cohort. There was significant improvement in outcome measures in terms of both neurological and functional outcomes. There was progressive improvement over time seen in both GOSE and FIM score. Very satisfactory functional recovery (GOSE 5-8) was recorded in the majority of patients at six months. A younger age, higher admission GCS score, bilateral pupils reacting to light, lower Marshall CT grading, early surgery and no postoperative complications resulted in better functional outcomes. Overall, successful surgical management in combination with standardized neurocritical care and structured rehabilitation resulted in satisfactory neurological improvement and better functional independence in patients.

The baseline demographic profile and injury characteristics of patients undergoing surgical management are presented below.

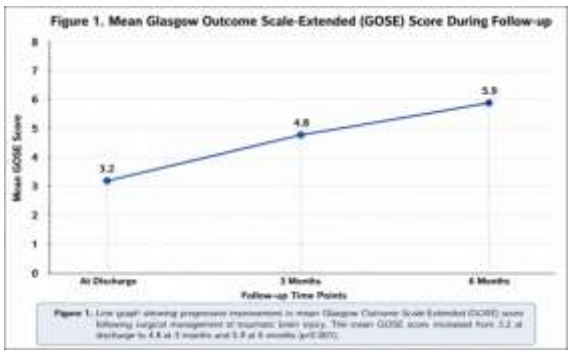
Table 1: Baseline demographic and injury characteristics of the study population

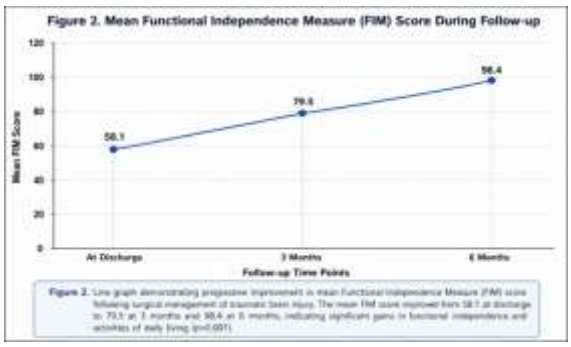
Variable	Number (n=100)	Percentage (%)
Age group (Years)		
18–30	28	28.0
31–40	26	26.0
41–50	22	22.0
51–60	16	16.0
>60	8	8.0
Mean age (Years)	38.7 ± 13.9	—
Gender		
Male	72	72.0
Female	28	28.0
Mechanism of injury		
Road traffic accident	61	61.0
Fall	25	25.0
Assault	14	14.0
Admission GCS		
Severe (3–8)	56	56.0
Moderate (9–12)	44	44.0

The preoperative CT findings and neurosurgical procedures performed are summarized below.

Table 2: Radiological findings and operative procedures

Variable	Number (n=100)	Percentage (%)
Intracranial lesion		
Acute subdural hematoma	38	38.0
Epidural hematoma	24	24.0
Cerebral contusion with mass effect	18	18.0
Intraparenchymal hematoma	12	12.0
Depressed skull fracture	8	8.0
Marshall CT classification		
Grade II	22	22.0
Grade III	34	34.0
Grade IV	28	28.0
Grade V–VI	16	16.0
Surgical procedure		
Decompressive craniectomy	42	42.0
Craniotomy with hematoma evacuation	46	46.0
Elevation of depressed skull fracture	8	8.0
Combined procedures	4	4.0





The perioperative characteristics of the study population are presented below.

Table 3: Perioperative characteristics of patients undergoing surgical management

Variable	Number (n=100)	Percentage (%)
Time from injury to surgery		
≤6 hours	58	58.0
>6 hours	42	42.0
Pupillary response at admission		
Bilaterally reactive	68	68.0
Unilateral sluggish/non-reactive	22	22.0
Bilaterally non-reactive	10	10.0
Mean operative duration (minutes)	142.6 ± 28.4	—
Mean intraoperative blood loss (mL)	318.4 ± 96.2	—
Mean ICU stay (days)	5.8 ± 2.3	—
Mean hospital stay (days)	12.7 ± 4.5	—

Table 4: Neurological and functional outcomes during follow-up

Outcome Measure	At Discharge	3 Months	6 Months	p-value
GOSE Score	3.2 ± 0.9	4.8 ± 1.1	5.9 ± 1.2	<0.001
Functional Independence Measure (FIM)	58.1 ± 11.6	79.5 ± 12.9	98.4 ± 14.1	<0.001

Neurological and functional recovery following surgical management was assessed using the Glasgow Outcome Scale-Extended (GOSE) and Functional Independence Measure (FIM).
Both GOSE and FIM scores demonstrated statistically significant improvement throughout the six-month follow-up period, indicating progressive neurological recovery and restoration of functional independence following surgical intervention.

Table 5: Postoperative complications

Complication	Number (n=100)	Percentage (%)
Surgical site infection	6	6.0
Postoperative seizures	8	8.0
Cerebrospinal fluid leak	3	3.0
Hydrocephalus requiring VP shunt	4	4.0
Rebleeding requiring re-exploration	3	3.0
Ventilator-associated pneumonia	9	9.0
Neurological deterioration	5	5.0
Reoperation	4	4.0
In-hospital mortality	7	7.0

The postoperative complications observed during the study period are summarized below.

Table 6: Factors associated with favorable functional recovery at six months (Univariate analysis)

Variable	Favorable Recovery (n=72)	Unfavorable Recovery (n=28)	p-value
Age <50 years	56	12	0.004
Male gender	54	18	0.382
Admission GCS ≥9	38	6	<0.001
Bilaterally reactive pupils	58	10	<0.001
Surgery within 6 hours	49	9	0.002
Marshall CT Grade II–III	46	10	0.006
No major extracranial injuries	60	16	0.018
No postoperative complications	64	13	<0.001

The association between baseline demographic, clinical, and radiological variables and favorable functional recovery (GOSE 5–8) is presented below.

Table 7: Multivariate logistic regression analysis of independent predictors of favorable functional recovery

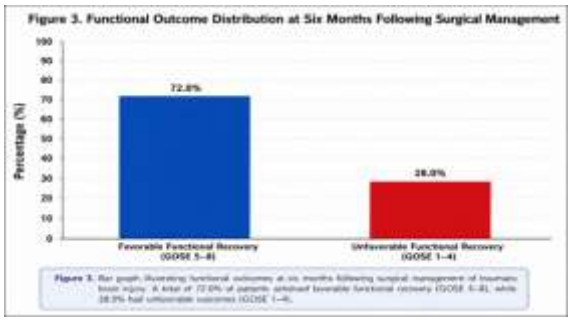
Predictor	Adjusted Odds Ratio (95% CI)	p-value
Age <50 years	2.84 (1.24–6.52)	0.013
Admission GCS ≥9	4.63 (1.91–11.22)	<0.001
Bilaterally reactive pupils	3.76 (1.53–9.27)	0.004
Surgery within 6 hours	3.18 (1.34–7.56)	0.009
Marshall CT Grade II–III	2.57 (1.08–6.09)	0.032
Absence of postoperative complications	3.42 (1.37–8.54)	0.008

Multivariate logistic regression was performed to identify independent predictors of favorable functional recovery at six months.

Table 8: Overall clinical outcomes at six months

Clinical Outcome	Number (n=100)	Percentage (%)
Favorable functional recovery (GOSE 5–8)	72	72.0
Unfavorable functional recovery (GOSE 1–4)	28	28.0
Independent ambulation	74	74.0
Functional independence (FIM ≥90)	69	69.0
Return to activities of daily living	67	67.0
Return to previous occupation/education*	54	54.0
Persistent neurological deficit	21	21.0
Reoperation during follow-up	4	4.0
Six-month mortality	9	9.0

The overall neurological and functional outcomes following surgical management are summarized below.



[Table 1] The total number of patients was 100, with an average age of 38.7 years and a predominance of male subjects. The majority of patients had experienced injuries due to road traffic accidents, while over 50% suffered from severe TBI with a GCS of 3–8. [Table 2] The most frequently occurring lesion was acute subdural hematoma followed by epidural hematoma. The most common CT grading according to Marshall classification was Grade III, while the most frequent treatment was craniotomy with hematoma evacuation and decompressive craniectomy. [Table 3] Most patients underwent surgery within six hours of admission and had been admitted with bilaterally reactive pupils. [Table 4] Recovery from TBI was satisfactory during follow-up with a significant improvement in the GOSE score from discharge to six months ($p<0.001$). [Table 5] Complications after surgery occurred infrequently. The most common complications included ventilator-associated pneumonia and seizures with both reoperation and mortality rates remaining low. [Table 6] Good functional recovery after TBI was positively correlated with younger age and higher initial GCS score as well as the presence of preserved pupillary reflexes and having undergone surgery early (within six hours). [Table 7] According to the multivariate logistic regression analysis, independent predictors of favorable functional recovery were age less than 50 years, GCS ≥9 at admission, presence of bilaterally reactive pupils, and surgery occurring within six hours from injury. [Table 8] In total 72.0% of patients were able to achieve favorable functional recovery at six months after admission.

DISCUSSION

Traumatic brain injury (TBI) constitutes an important public health issue and is one of the most prevalent causes of mortality, long-standing neurological impairment, and economic losses worldwide.[1] Surgery has a crucial role in the treatment of moderate to severe TBI as it alleviates intracranial pressure, removes space-occupying masses, reinstates tissue perfusion, and reduces secondary brain injuries.[2] The current observational study aimed to assess predictors of functional outcome after surgical treatment of TBI in 100 patients receiving care at a tertiary hospital.[3] Improvement in neurological and functional status was significant throughout the follow-up of 6 months, with nearly 75% of the cohort showing good functional outcomes.[4] The following factors were predictive of successful recovery at the end of follow-up time: younger age, higher admission Glasgow Coma Scale score, intact pupillary light reflex, timely surgical intervention, lower Marshall CT score, and absence of postoperative complications.[5,6]

The average age of patients was 38.7 years, while the majority belonged to the younger and economically active population.[7] Male sex constituted almost 75% of the cohort. This demographic structure shows the greater danger for younger males in terms of trauma obtained from high-velocity accidents/occupational accidents and road accidents.[8] The results of this study demonstrate the growing burden of high-speed

traffic accidents and give credence to the need for preventative measures, such as safety education, enforcement of helmet and seatbelt laws, speed control, and reduction of driving under the influence of alcohol.[9,10] Because traumatic brain injuries mostly affect younger people, it is important to have effective preventative measures to minimize both deaths and long-term disability.[11]

Over half of the patients suffered from severe traumatic brain injury according to Glasgow Coma Scale score on admission. Acute subdural hematoma was the most common intracranial injury requiring surgical treatment. Most surgical procedures performed were for decompressing craniectomy and craniotomy with hematoma evacuation.[12] This correlates with neurosurgical emergencies seen at tertiary trauma centers where acute intracranial bleeding and increased intracranial pressure require immediate surgical decompression.[13]

A major observation of the present study was the improvement in neuro-functional outcomes with surgical intervention. Mean Glasgow Outcome Scale Extended (GOSE) scores showed gradual increase during the follow-up period while Functional Independence Measure (FIM) scores also showed significant improvements during this period indicating a steady return of neurological function, mobility, self-care, ability to communicate, cognition, and functional independence after the surgical treatment and the implementation of neurocritical care and rehabilitation process.[14,15]

After six months, a good percentage (72%) of patients had favorable functional recovery. Most patients regained their ability to walk independently, have functional independence, and perform activities of daily living.[16] More than half of those who were employed or studying before the accident returned to their employment or educational activities.[17] The results show that surgical intervention not only helps to prolong life, but is also very important in terms of long-term rehabilitation. The admission score on the Glasgow Coma Scale (GCS) has proven to be one of the best predictors of a good outcome from surgery.[18] With moderate traumatic brain injuries (GCS score 9–12), patients have considerably better function than patients with severe brain injury. High GCS scores indicate less primary brain injury, meaning a greater chance of resuming normal brain functions. Therefore, the neurological status of the patient should always be monitored and taken as one of the most reliable indicators of prognosis.[19,20]

Preserved pupillary reflexes are also seen as a sign of good outcome. The presence of reactive pupils indicates intact brainstem function and low intracranial pressure on admission. If the pupils are fixed on either side, it shows brain edema, brain stem herniation, and other damaging conditions for which the prognosis is bad. Hence the examination of pupils' response plays a very important role in the assessment of neurological deficits.[21]

Early surgical intervention was found to be very beneficial for recovery after surgery.All these facts reinforce the findings of the current research regarding the importance of early surgical intervention in patients suffering from traumatic brain injuries to facilitate recovery and minimize long-lasting brain damages.[22]

The severity of radiological findings based on the Marshall CT classification is known to provide important prognostic information. While patients with lower Marshall grades showed much better recovery from surgery in comparison to those with severe radiological damage, patients with massive brain edema and midline shift experience higher primary brain damage and worse recovery of neurological function, even though surgery was performed successfully. Thus, preoperative CT findings are to be viewed as valuable data for surgical planning.[23,24]

As for postoperative complications, only a small percent of patients had such adverse events as pneumonia developed as a result of mechanical ventilation, seizures, or infections on surgical sites. However, reoperation and mortality rates appeared lower compared to other studies. Patients having no postoperative complications received better outcome from surgery, which highlights the importance of effective surgical procedures, neurocritical care, early rehabilitation programs, infection control, and seizures prevention.[25]

The findings of the current research can facilitate the improvement of clinical practice in terms of provision of early identification of patients with positive prognostic factors and practitioners can make individualized treatment plans for patients. Meanwhile, identification of patients at a higher risk of neurological damage helps physicians to provide more intensive monitoring.

Despite the light cast on the situation, some drawbacks of the research should be discussed. It was a single-center study with 100 patients participating, which means that the results cannot be applied on a wider group of people in different clinical settings. Follow-up was carried out only for six months and thus researchers cannot take full cognizance of the cognitive rehabilitation process of patients. Also, advanced neuropsychological testing was not applied and no particular biomarkers of TBI were analyzed. Therefore, future multicenter prospective research is necessary in order to improve the outcomes of this study.

In conclusion, surgical treatment of TBI allows obtaining considerable improvements in neurological functioning of patients. Patients of younger age, higher Glasgow Coma Scale score, preserved pupil reaction to light, and early surgery are more prone to get positive results from their treatment.

CONCLUSION

The application of surgical intervention for trauma-related cranial injuries gives rise to a remarkable enhancement in terms of both neurological condition

and function of patients suffering from medium to severe head injuries as long as the procedure is done in good time followed up by comprehensive neurocritical care programs and structured rehabilitation regime. In this research, it was found that there was an amazing improvement in the extended Glasgow outcome scale and the functional independence assessment conducted within the following six months after surgery where the vast majority of patients showed high-rate recovery in terms of functionality. Age of a patient as well as the onsets of coma scale score measured upon their arrival to the hospital, maintaining of pupillary reflexes by a patient, the number of Marshall CT grading, assessment of a patient's health condition by doctors as well as possible postoperative complications, were determined as crucial independent markers of their recovery after surgery. This monitoring will assist in the effective selection of patients based on the prognostic factors and various treatment plans that will help to receive realistic prognoses with regard to the health of patients after surgery as well as for further rehabilitation initiatives.

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