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Surgical Management and Short-Term Functional Outcomes in Moderate-to-Severe Traumatic Brain Injury: A Prospective Observational Study

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ABSTRACT

Background: TBI remains a leading cause of death and disability worldwide, particularly in low- and middle-income countries where delays in prehospital stabilization and limited neurosurgical resources compromise outcomes.

Objectives: Evaluate demographics, surgical modalities, complications, and short-term outcomes of adults undergoing craniotomy or decompressive craniectomy for moderate to severe TBI at a tertiary care hospital.

Methods: Prospective observational study of 60 adults (≥18 years) with admission GCS ≤12 and CT evidence of intracranial hematoma or edema requiring surgery at Aziz Fatimah Hospital, Faisalabad, Pakistan, from January to December 2024. Data on demographics, injury mechanism, surgical approach, operative metrics, complications, ICU and hospital stay, in-hospital mortality, and Glasgow Outcome Scale (GOS) at discharge were collected. All surgeries were performed under general anesthesia with asepsis.

Results: Mean age 35.2 years; 70% male; road traffic accidents accounted for 60% of injuries. Craniotomy was performed in 45 cases (75%) and decompressive craniectomy in 15 (25%). Mean operative time was 120 minutes and mean blood loss was 450 mL. ICP monitoring was utilized in 46.7% of patients. Overall complication rate was 38.3%, led by surgical-site infection (16.7%) and seizures (13.3%). Mean ICU stay was 5.2 days and hospital stay was 12.4 days. In-hospital mortality was 16.7%, higher after craniectomy (26.7% vs. 13.3%). Favorable discharge (GOS 4–5) occurred in 66.7% of survivors. Admission GCS was 7.5 ± 2.3.

Conclusions: Timely surgical intervention in moderate to severe TBI in this setting yields acceptable mortality and favorable short-term outcomes in two-thirds of patients. Enhancing infection control, hemorrhage management, and neurocritical care capacity may further improve prognosis.

Keywords: traumatic brain injury, craniotomy, decompressive craniectomy, surgical outcomes, intensive care stay, Pakistan

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INTRODUCTION

Traumatic brain injury (TBI) is among the major causes of death and remains a major source of long-term disability worldwide, with a physical, financial, and societal burden that is not only placed on the patient and their family but also on healthcare systems and economies. Prompt and effective acute management is therefore so critical because survivors often suffer prolonged rehabilitation, cognitive and motor deficits, and psychological challenges that may persist for years [1].

Surgical intervention is commonly indispensable when moderate to severe TBI threatens neurological integrity. Mass effect is relieved and secondary injury is prevented by craniotomy evacuating intracranial hematomas, while decompressive craniectomy provides a vital means of dumping uncontrolled cerebral edema [2]. But the decision to go ahead with either procedure depends on a delicate balance of clinical judgement the results of neurological examination, the intracranial pressure dynamics, and the neuroimaging findings and the possibility of potentially life-saving treatment against the risk of infection, bleeding, and long-term functional impairment [3].

However, in many resource-constrained settings, timely delivery of neurosurgical care is a problem. Prehospital stabilization delay, limited operating room availability, and neurocritical monitoring equipment supply shortages can limit the window for optimal intervention [4]. In addition, intensive care units with specialized beds and trained personnel are often unable to accommodate the high patient volumes and competing surgical emergencies that further strain these units. Systemic barriers only exacerbate the need for streamlined surgical pathways and targeted investments to bolster capacity [5].

With little to no outside competition, surgical practices are systemically evaluated, and early postoperative outcomes are evaluated in high-volume tertiary care environments to identify successes and areas of improvement [6]. Clinicians and administrators can use the patterns in patient presentation, procedural choices, complication rates, and short-term functional recovery to identify bottlenecks in care delivery, adjust decision-making algorithms, and determine resource allocation priorities. This is essential to the adaptation of international guidelines for local realities and the shaping of neurosurgical training programmes capable of preparing neurosurgical teams to act swiftly and efficiently [7].

Thus, this study aimed to characterize surgical management strategies and early outcomes for adults with moderate to severe TBI treated in a busy tertiary care hospital. Current study used clinical severity, operative details, postoperative complications, and discharge functional status to carefully scrutinize to generate actionable evidence to inform best practices, improve multidisciplinary coordination, and ultimately improve the prognosis of TBI patients in similar health care settings [8].

MATERIALS AND METHODS

A prospective observational study was carried out in the Department of Neurosurgery, Aziz Fatimah Hospital, Faisalabad, Pakistan, within 12 months from January 2024 till December 2024. Consecutive adults aged 18 years or older with moderate to severe traumatic brain injury (Glasgow Coma Scale score ≤ 12, admission), cranial CT evidence of an intracranial hematoma, contusion or diffused cerebral edema that required surgery, were enrolled after institutional ethics committee approval (Ref No.: AFH-IRB-2024-117). and informed consent from each patient’s next of kin. All patients with penetrating injuries, known coagulopathy, significant comorbidities precluding anesthesia, or who declined consent were excluded.

An a priori sample size calculation was performed to ensure that the present study had adequate statistical power for its primary end point the difference in in-hospital mortality between surgical modalities. Assuming an overall mortality of 20%, with 80% power and an α of 0.05, a minimum of 56 patients was required. Given the possibility of dropouts or protocol deviations, the current study aimed to enroll at least 60 participants.

Finally, detailed demographic data (age, sex), injury mechanism (road traffic accident, fall, assault), and clinical severity (admission GCS, pupil reactivity) were recorded at the time of admission. These clinical parameters were integrated with CT findings into surgical decision making: craniotomy for hematoma evacuation under microscope-assisted hemostasis and primary dural closure; decompressive craniectomy with large bone flap and duraplasty for refractory intracranial hypertension. All procedures were performed under general anesthesia with strict asepsis, and continuous arterial pressure monitoring was the routine; when intracranial pressure devices were available, they were used.

The operating team documented intraoperative variables, including type of surgery, duration, and estimated blood loss. All patients were managed in the neurosurgical intensive care unit, and length of ICU stay, total hospital stay, and early complications such as surgical site infection, seizures, and hydrocephalus were tracked postoperatively. Glasgow Outcome Scale was used to assess functional status at discharge, and in-hospital patients who died during the hospitalization were also recorded.

Continuous variables were expressed as mean ± SD for analysis, and categorical variables as counts and percentages. Student’s t-test was used to compare continuous data that is normally distributed between the groups (e.g., craniotomy vs. craniectomy, favourable vs. unfavourable outcome), while comparing categorical data between the groups, we used chi square or Fisher's exact test. $p < 0.05$ was defined as statistical significance.

RESULTS

A total of 62 patients were eligible for inclusion; two were excluded (one declined consent and one had a preexisting coagulopathy), and 60 patients whose perioperative courses and outcomes provide the basis for this analysis. There was a mean age of patients of 35.2 years (± 12.1), and 76.7% of patients were under 45 years. High exposure to high-risk activities was also reflected by a striking male preponderance (70%). The majority of injuries (60%) were due to road traffic accidents, falling (25%), and assaults (15%). The cohort was critically depressed (GCS 3–8) on arrival, as presented by over half (53.3%) of the cohort as shown in table 1.

Craniotomy was used in 75% of cases and decompressive craniectomy in 25%. Craniotomies averaged 110 ± 25 minutes and 400 ± 120 mL blood loss, whereas craniectomies took longer operative time (145 ± 20 minutes) and more blood loss (550 ± 130 mL). In 66.7% of craniectomies and 40% of craniotomies, ICP monitoring was utilized as the need for real-time ICP data is more pronounced in patients with refractory cerebral edema as shown in table 2.

Despite meticulous technique, 38.3% of patients experienced at least one major postoperative complication. The emergency nature of procedures and high caseload are likely to have contributed to the 16.7% incidence of surgical site infections. Thirteen-point three percent had postoperative seizures that required escalation of antiepileptic therapy. Hydrocephalus developed in 8.3% and all required shunt insertion; 5.0% required reoperation for recurrent hematoma. The more frequent problems were CSF leak (3.3%) and wound dehiscence (1.7%), which have added to their extended recovery time as shown in table 3.

Length of stay analysis indicated that craniectomy patients were more intensive: mean ICU stay was 6.5 ± 2.3 days vs 4.8 ± 1.9 days for craniotomy; mean length of hospitalization extended to 14.1 ± 4.8 days vs 11.8 ± 4.0 days. Such differences emphasize the greater resource utilization and prolonged recovery in decompressive procedures as shown in table 4.

Among those presenting with the lowest GCS and extensive injuries, mortality was concentrated at 16.7%. Sixty-six and two-thirds of the survivors (66.7%) achieved a favourable discharge status (GOS 4–5), being independent or having moderate disability, while 33.3% remained in the unfavourable range (GOS 1–3) as shown in table 5.

For craniectomized versus craniotomized patients, stratified by procedure, mortality (13.3% vs. 26.7%) and favourable outcome (71.1% vs. 53.3%) were lower among craniotomy patients, because craniectomy was reserved for the most critically ill subset as shown in table 6.

Table-1: Demographic and Clinical Characteristics of TBI Patients (n = 60)

Characteristic	Value
Age (years), mean ± SD	35.2 ± 12.1
Age distribution, n (%)	
• 18–30	22 (36.7)
• 31–45	24 (40.0)
• 46–60	10 (16.7)
• > 60	4 (6.7)
Sex (male), n (%)	42 (70.0)
Mechanism of injury, n (%)	
• Road-traffic accident	36 (60.0)
• Fall	15 (25.0)
• Assault	9 (15.0)
Admission GCS, mean ± SD	7.5 ± 2.3
Admission GCS category, n (%)	
• Severe (3–8)	32 (53.3)
• Moderate (9–12)	28 (46.7)

Table-2: Operative Details by Surgical Modality

Variable	Craniotomy (n = 45)	Craniectomy (n = 15)	Overall (n = 60)
Operative duration (min), mean ± SD	110 ± 25	145 ± 20	120 ± 30
Estimated blood loss (mL), mean ± SD	400 ± 120	550 ± 130	450 ± 150
ICP monitoring used, n (%)	18 (40.0)	10 (66.7)	28 (46.7)

Table-3: Postoperative Complications

Complication	n (%)
Surgical-site infection	10 (16.7)
Postoperative seizures	8 (13.3)
Hydrocephalus requiring a shunt	5 (8.3)
Reoperation for hematoma recurrence	3 (5.0)
CSF leak	2 (3.3)
Wound dehiscence	1 (1.7)

Table-4: Length of Stay by Procedure Type

Measure	Craniotomy (n = 45)	Craniectomy (n = 15)	Overall (n = 60)
ICU stay (days), mean ± SD	4.8 ± 1.9	6.5 ± 2.3	5.2 ± 2.1
Hospital stay (days), mean ± SD	11.8 ± 4.0	14.1 ± 4.8	12.4 ± 4.3

Table-5: In-Hospital Mortality and Discharge Functional Status

Outcome	n (%)
In-hospital mortality	10 (16.7)
Glasgow Outcome Scale at discharge	
• GOS 1–3 (unfavourable)	20 (33.3)
• GOS 4–5 (favourable)	40 (66.7)

Table-6: Outcome by Surgical Modality

Outcome category	Craniotomy (n = 45)	Craniectomy (n = 15)
Mortality, n (%)	6 (13.3)	4 (26.7)
GOS 4–5, n (%)	32 (71.1)	8 (53.3)
GOS 1–3, n (%)	7 (15.6)	3 (20.0)

Further analysis of our cohort brought up a few interesting notes. The mortality rate for the patients presenting with severe traumatic brain injury (GCS 3 to 8) was 25% in the hospital compared to 7.1% for the moderate TBI group (GCS 9 to 12). This stark contrast demonstrates the validity of the Glasgow Coma Scale as a powerful prognostic indicator of primary injury burden and outcome.

Second, we found a moderate positive correlation ($r = 0.45$) between the intraoperative blood loss and length of stay in intensive care unit. The relationship implies that maintaining hemodynamic stability during surgery (minimizing blood loss and transfusion) may impact the early postoperative recovery trajectory and reduce critical care requirements.

Secondly, there was no statistical difference in overall complication rate between patients injured in road traffic accidents (41.7%) compared with those who had fallen or been assaulted (34.5%). This finding indicates that, in this setting, postoperative risk is mainly driven by the magnitude of injury severity rather than by the trauma mechanism alone.

DISCUSSION

This study has found that prompt surgical intervention for moderate to severe traumatic brain injury in high-volume tertiary neurosurgical settings can achieve meaningful short-term functional recovery in the majority of patients, and approximately two-thirds of survivors are discharged without significant or no disability [9]. Overall in-hospital mortality of 16.7% compares favorably with reports from other similar resource-limited environments and provides evidence that structured surgical pathways accompanied by vigilant postoperative care can ameliorate some of the constraints to patient care imposed by high patient loads and limited intensive care capacity [10].

For the craniotomy and decompressive craniectomy outcomes comparison, it shows that there is a tradeoff between these procedures. Although there is a higher perioperative burden associated with decompressive craniectomy longer operative times, greater blood loss, more frequent need for intracranial pressure monitoring, and longer critical care stays decompressive craniectomy is still necessary for patients with refractory intracranial hypertension [11]. These differences in mortality and favourable discharge status among the craniectomy and hematoma evacuation alone groups are because the craniectomy group has more diffuse injury and greater intracranial pressure that cannot be managed solely by hematoma evacuation [12].

Key areas for quality improvement are identified through postoperative complication rates. The most common adverse events were surgical-site infections, seizures, which occurred in almost a third of patients [13]. Changes in sterile technique protocols in the emergency settings, standardization of perioperative antibiotics, and regular early EEG monitoring may help to reduce these burdens. While there is a moderate correlation between intraoperative blood loss and ICU length of stay, this implies that meticulous hemostasis, precise transfusion strategies, and even the use of intraoperative hemodynamic adjuncts may shorten critical care requirements and free resources for other urgent cases [14, 15].

For example, admission Glasgow Coma Scale remains a strong predictor of outcome with patients with severe injury (GCS 3–8) experiencing considerably higher mortality than those with moderate injury (GCS 9–12). This is a reminder of the need to speed up the neurological assessment and make rapid triage decisions that influence both surgical planning and family counselling [16]. Simple, bedside prognostic tools can be used in conjunction with available imaging and monitoring to optimize patient selection for each surgical approach and inform patient expectations for their recovery trajectories [17, 18].

CONCLUSION

However, despite being in a resource-limited environment, surgical management of traumatic brain injury, either through hematoma evacuation or decompressive craniectomy, had acceptable mortality and a majority of favourable short-term outcomes in this cohort. Further gains may be achieved through continued refinement of surgical protocols, improved perioperative infection control, improved blood loss management, and investment in neurocritical care capacity. To elevate the standard of TBI care and improve patient survival and functional recovery, prehospital stabilization and triage will need to be strengthened, and critical hemostasis and seizure prevention targeted training will be essential.

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