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Original Research Article

WHETHER EARLY SURGERY CHANGES THE OUTCOME OF PATIENTS IN TRAUMATIC BRAIN INJURY WITH PREDOMINANT TEMPORAL CONTUSION/ HEMATOMA

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ABSTRACT

Background: Temporal lobe contusions/hematomas constitute a major subset of surgically relevant traumatic brain injury (TBI) due to their proximity to the brainstem and propensity for rapid deterioration. The optimal timing of surgical intervention in this subgroup remains controversial, with prior series reporting conflicting outcomes for early versus delayed evacuation. The aim is to determine whether early surgical intervention in patients with TBI and predominant temporal contusion/hematoma influences neurological outcome, as assessed by the Glasgow Outcome Scale (GOS), and to identify the optimal timing window for surgery.
Materials and Methods: This single-centre prospective study enrolled 120 consecutive patientswith predominant temporal contusion/hematoma over 3 years and 3 months, with 1-year mean follow-up. Patients were stratified by a novel CT grading system (based on size, location, ambient cistern status, and associated injuries) and grouped by surgical timing (≤6 hours, 6-12 hours, >12 hours). Outcomes were analyzed using ordinary least square regression against age, sex, CT grade, GCS, mode of injury, and timing of surgery.
Results: Of 120 patients (mean age 43.32 years; 81 males), 95 underwent surgery and 25 were managed conservatively. Overall mortality was 10.52% among operated patients. Regression analysis identified age, CT grade, and time interval to surgery as statistically significant independent predictors of GOS at discharge and at 3, 6, and 12 months ($p<0.01$), with earlier surgery (≤6 hours) associated with higher probability of favorable outcome (GOS 4-5), particularly in higher CT grades.
Conclusion: Earlier surgical intervention, combined with higher CT grade and younger age, favorably influences neurological outcome in TBI patients with predominant temporal contusion/hematoma.
Keywords: Brain Injuries, Traumatic; Craniotomy; Glasgow Outcome Scale; Hematoma; Time-to-Treatment; Tomography, X-Ray Computed

INTRODUCTION

Traumatic brain injury (TBI) remains one of the leading causes of death and disability worldwide, and is projected to surpass many other diseases as a major contributor to the global disease burden. Road traffic accidents account for 45-60% of TBI cases in India, with falls contributing a further 20-30%, a pattern that closely mirrors global data from the Global Burden of Disease Study.[1,2] Within the spectrum of TBI, focal cerebral contusions represent the most common primary traumatic parenchymal lesion, accounting for approximately 45% of primary intra-axial injuries, and they arise most frequently in the frontal and temporal lobes due to the brain's contact against the irregular bony surfaces of the anterior and middle cranial fossae.[2]

The temporal lobe occupies a particularly vulnerable position within the skull. When injury is mild, it may remain clinically silent, but when substantial, it produces significant mass effect, raised intracranial pressure, and progressive neurological deterioration. Temporal contusions constitute a major subgroup among all TBI patients requiring surgical intervention, and their distinctive clinical trajectory was formally characterized as the "temporal lobe contusion syndrome" by McLaurin and Helmer in 1965 and later elaborated upon by Kalyanraman in 1980.[3] This syndrome is clinically significant because of the temporal lobe's proximity to the brainstem and the tentorial incisura, making even moderate degrees of swelling capable of precipitating rapid uncal herniation, pupillary asymmetry, and life-threatening compression of midbrain structures.[3,4]

The pathophysiology underlying the delayed deterioration seen in temporal contusions is now understood to unfold across at least three temporally distinct phases of edema formation. In the earliest phase, breakdown of cell membrane lipids and proteins generates idiogenic osmoles, raising local tissue osmolality from a normal baseline of approximately 310 mOsm to 370-390 mOsm within the contused tissue, thereby drawing free water into the area of injury. A second phase, dominant at 24-48 hours post-trauma, is mediated by thrombin activation following triggering of the coagulation cascade, which disrupts the blood-brain barrier in concert with inflammatory mediators. A third phase follows red cell lysis within the intracerebral clot, during which hemoglobin breakdown products generate reactive oxygen species and activate cytokine and complement pathways. This staged, evolving edema explains why contusions that appear radiologically unremarkable on initial imaging may progress dramatically over the subsequent 24-72 hours, with delayed hemorrhage developing in up to 46% of patients with an initially non-hemorrhagic low-density lesion.[5,6,7]

Despite this well-characterized pathophysiological rationale for early decompression, the question of optimal surgical timing in temporal contusion/hematoma has remained persistently controversial. Early surgical dogma held that patients with contusions requiring operation within 24 hours of injury, if unconscious, rarely survived. Yet Tandon et al. reported that 10 of 22 patients (45.4%) operated within 24 hours nonetheless survived, directly challenging this assumption.[8,9] McLaurin et al., by contrast, observed that patients requiring early surgery tended to have poorer recovery, with only 7 of 12 patients achieving good outcomes, most requiring surgery within two days of injury.[10] Schönauer et al. reported an even starker contrast: operative mortality was 65.2% in patients operated within 24 hours, compared with just 12.5% in those operated beyond 72 hours post-trauma.[11] More recent series have added further conflicting data; Wilberger et al. and Hatashita et al. both reported higher mortality with very early (within 4 hours) surgical intervention compared with delayed intervention, whereas Rubiano et al. and Sharma et al. demonstrated statistically significant benefit from early surgery (within 12-24 hours) in terms of favorable GOS outcomes.[12,13] Mathai et al. have argued that surgery should ideally be "ultra-early" (within 6 hours), reasoning that the onset of life-threatening brain swelling in contusions begins as early as 2-3 hours post-injury.[14]

This persistent lack of consensus is compounded by the absence of a standardized, reproducible radiological grading system capable of stratifying temporal contusions by severity and guiding timing decisions objectively, as most prior series have relied on heterogeneous inclusion criteria, variable GCS thresholds, and non-uniform definitions of "early" versus "late" surgery. No prior study has combined a quantitative CT-based severity grading system with a structured, multi-timepoint GOS-based outcome analysis specifically restricted to temporal lobe contusion/hematoma as the predominant lesion.[12,15]

Given the persistent controversy surrounding the timing of surgical intervention in temporal contusions and the absence of Class I evidence addressing this question, there is a clear need for a systematically graded, prospectively followed patient cohort to clarify this relationship. The aim of the present study was therefore to determine whether early surgical intervention alters the neurological outcome, assessed using the Glasgow Outcome Scale, in patients with traumatic brain injury and predominant temporal contusion/hematoma, and thereby to indicate the optimal timing window for surgery in this specific patient population.

MATERIALS AND METHODS

Study Design and Setting: This was a single-centre, prospective, observational study conducted at the National Neurosciences Centre, Peerless Hospital, Kolkata, a tertiary referral neurosurgical centre with comprehensive critical care and imaging support over a period of 3 years and 3 months, with a mean patient follow-up of 1 year.

Study Population: One hundred and twenty consecutive patients presenting with head injury and predominant temporal lobe contusion/hematoma were enrolled. Inclusion criteria were: age greater than 15 years, Glasgow Coma Scale (GCS) score of 5 or above, and admission within 12 hours of injury. Patients were excluded if they had a GCS of 3 or 4, presented beyond 12 hours post-injury, had extradural or subdural hematomas or other contusions/depressed fractures taking clinical precedence over the temporal lesion, had systemic hypotension (systolic BP <90 mmHg) from associated hemorrhagic injuries, or had a concomitant spinal injury.

CT Grading System: A novel CT-based grading system was devised specifically for temporal contusions, incorporating four weighted criteria:

lesion size (score 1-3, based on proportion of temporal lobe involved), anatomical location (score 1-3, polar/lateral to medial), status of the ambient cistern (score 1-3, open to fully effaced), and presence of associated injuries (score 1-3, none to contralateral temporal contusion/ICH/IVH). Composite scores stratified patients into Grade I (score 4), Grade II (score 5-8), or Grade III (score 9-12).

Treatment Protocol: Surgical decision-making was guided by clinico-radiological correlation: Grade III lesions, Grade II lesions converting to Grade III or showing radiological worsening despite conservative trial, and Grade I lesions progressing with cisternal effacement were selected for surgery. Patients were stratified into three groups by time-to-surgery from admission or neurological worsening: ≤6 hours, 6-12 hours, and >12 hours. The surgical technique consisted of a trauma flap with fronto-temporo-parietal craniotomy, durotomy, and contusion evacuation tailored to lesion location and intraoperative brain swelling; bone flap replacement was deferred in cases with large contusions (>1/2 temporal lobe), complete cisternal effacement, or poor preoperative motor scores, with flaps preserved in an abdominal subcutaneous pocket or cold storage.

Outcome Assessment: The primary outcome measure was the Glasgow Outcome Scale (GOS), assessed at discharge and at 3, 6, 12, and 18 months. GOS scores of 4-5 were classified as favorable, and scores ≤3 as unfavorable.

Statistical Analysis: Data were tabulated by age, sex, CT grade, GCS, mode of injury, and time-to-surgery against GOS outcomes at each follow-up interval. Conditional probability matrices were constructed to estimate the probability of specific GOS outcomes given CT grade and surgical timing. Multivariable ordinary least squares (OLS) regression was performed with GOS at each timepoint as the dependent variable, and age, gender, CT grade, hours-to-surgery, mode of injury, and associated injuries as independent variables, with ANOVA used to assess overall model significance.

RESULTS

The study enrolled 120 patients (81 males, 39 females; mean age 43.32 ± 17.16 years, range 22-79 years). Road traffic accidents (RTA) accounted for 89 of 120 injuries (72.2%), while non-RTA causes, predominantly domestic falls accounted for the remaining 31 cases (27.8%), with RTA victims being significantly younger (mean 33.13 years) than non-RTA victims (mean 65.04 years).

Table 1: Age Distribution and Mechanism of Injury

Age Group (years)	Total Cases	RTA	Non-RTA
20-30	35	34	1
30-40	23	23	0
40-50	21	19	2
50-60	16	11	5
60-70	13	2	11
70-80	12	0	12
Total	120	89	31

Road traffic accidents overwhelmingly affected the economically productive age group of 20-50 years (97.8% of RTA cases fell within 20-60 years), whereas non-RTA injuries, chiefly domestic falls, clustered in patients above 60 years (74.2% of non-RTA cases), reflecting age-related differences in exposure and mobility.

Table 2: CT Grade Distribution and Contusion Progression

CT Grade	Patients on Admission	Progression	Final Patients
I	25	15 progressed to Grade II	10
II	55	12 progressed to Grade III	58
III	40	—	52
Total	120	27	120

Of the 120 patients, 27 (22.5%) demonstrated radiological progression to a higher CT grade during observation, most commonly due to an increase in contusion size or progressive effacement of the ambient cistern, confirming the dynamic and evolving nature of temporal contusions on serial imaging.

Table 3: Surgical Timing by CT Grade

Time to Surgery	Grade II (n)	Grade III (n)	Total
≤6 hours	10	25	35
6-12 hours	15	23	38
>12 hours	18	4	22
Total	43	52	95

Of 120 patients, 95 (79.2%) ultimately required surgical evacuation while 25 were managed conservatively; among operated patients, 73 (76.8%) underwent surgery within 12 hours of injury or neurological worsening, and higher-grade (Grade III) contusions were preferentially operated earlier, reflecting a clinico-radiologically driven urgency to intervene in more severe lesions.

Table 4: Postoperative Course and Mortality

Parameter	Value
Overall mortality (of 95 operated)	10 (10.52%)
Cause: Rebleed	2
Cause: Coagulopathy	3
Cause: Multi-organ failure	5
Postoperative ventilation required	65 (68.42%)
Chest infection	44.2%
Meningitis (all recovered)	9 (9.4%)
Bone flap not replaced	60
Cranioplasty performed	49

Overall surgical mortality was 10.52%, predominantly attributable to coagulopathy and multi-organ failure rather than direct surgical complications, and no cases of syndrome of the trephined, post-operative hydrocephalus, or extracerebral collections were observed despite a majority of patients undergoing decompressive (non-bone-flap-replaced) surgery.

Table 5: Probability of Favorable Outcome (GOS 4-5) by CT Grade, Timing, and Follow-Up

CT Grade	Timing	Discharge	3 mo	6 mo	12 mo	18 mo
II	≤6 hrs	40%	40%	80%	100%	12% (n small)
II	6-12 hrs	40%	43%	78%	93%	22%
II	>12 hrs	22%	25%	56%	63%	0%
III	≤6 hrs	12%	19%	28%	58%	97%
III	6-12 hrs	22%	25%	55%	85%	83%
III	>12 hrs	0%	0%	25%	33%	33%

Across both CT Grade II and Grade III contusions, patients operated within 6 hours or between 6-12 hours consistently demonstrated higher probabilities of favorable outcome (GOS 4-5) at every follow-up interval compared with those operated beyond 12 hours, with the gap in favorable outcome most pronounced at the 12-month assessment (e.g., Grade III: 58-85% for early/intermediate surgery vs. 33% for delayed surgery). Notably, the >12-hour delayed surgery group in Grade III contusions showed a markedly blunted and statistically unreliable trend of improvement over time compared with the steep, consistent recovery curves seen in earlier surgical groups.

Table 6: Multivariable Regression: Predictors of GOS at Discharge, 3, 6, and 12 Months

Variable	GOS-Discharge (p)	GOS-3mo (p)	GOS-6mo (p)	GOS-12mo (p)
Age	0.006 (Sig.)	0.002 (Sig.)	0.004 (Sig.)	0.009 (Sig.)
Hours to Surgery	0.0004 (Sig.)	<0.001 (Sig.)	<0.001 (Sig.)	0.002 (Sig.)
CT Grade	0.0008 (Sig.)	<0.001 (Sig.)	<0.001 (Sig.)	<0.001 (Sig.)
Gender	0.064 (NS)	0.715 (NS)	<0.001 (Sig.)	<0.001 (Sig.)
Mode of Injury	0.434 (NS)	0.275 (NS)	0.055 (NS)	0.167 (NS)
Associated Injury	0.311 (NS)	0.123 (NS)	0.177 (NS)	0.916 (NS)

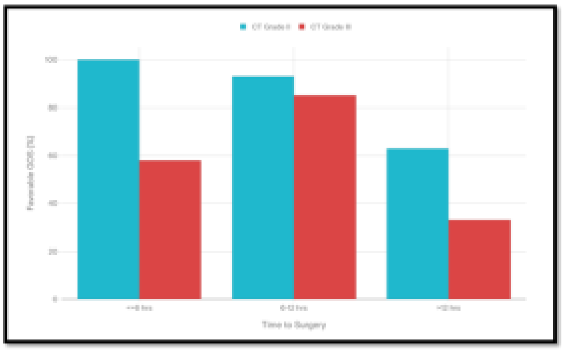

Figure 1: Favorable Outcomes at 12 months by Surgery timing

Ordinary least squares regression, adjusted for confounders (adjusted $R^2 = 0.70$ for the discharge model), confirmed that increasing time-to-surgery, higher CT grade, and older age were all independently and significantly associated with poorer GOS outcomes at every assessed timepoint, whereas mode of injury and associated injuries did not reach statistical significance in any model. This regression analysis provides the strongest quantitative evidence supporting the study's central hypothesis: shorter time-to-surgery independently predicts better neurological recovery, even after controlling for age, CT severity grade, and injury mechanism.

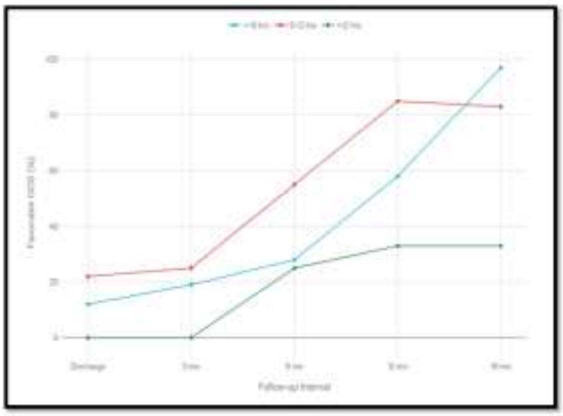

Figure 2: Grade III Favorable Outcome Trend across follow-up

DISCUSSION

Traumatic brain injury (TBI) remains a leading cause of morbidity and mortality worldwide, disproportionately affecting low- and middle-income countries where road traffic accidents predominate as the causative mechanism. Temporal lobe contusions pose a unique challenge because of their propensity for delayed progression and proximity to critical brainstem structures. Despite extensive neurosurgical experience, controversy persists regarding optimal timing of surgical intervention.[3,14] This uncertainty, coupled with the lack of CT-grade-stratified outcome data, prompted this study to evaluate the clinico-radiological profile of temporal contusions and correlate CT grade and time-to-surgery with Glasgow Outcome Scale (GOS) outcomes.

The present study found that road traffic accidents (RTAs) accounted for 72.2% of injuries, with a mean surgical mortality of 10.52% among the 79.2% of patients who underwent operative intervention. Patients operated within 12 hours of injury demonstrated superior GOS outcomes at every follow-up interval compared with those operated beyond 12 hours, and multivariable regression confirmed age, hours-to-surgery, and CT grade as independent predictors of GOS at discharge, 3, 6, and 12 months. These findings correspond closely with the South Indian retrospective study by Gopalan et al., who similarly reported RTA as the dominant mechanism (71%) in patients undergoing decompressive craniectomy, although their overall mortality of 39% was considerably higher than the present cohort; a discrepancy attributable to their inclusion of more severe GCS categories and higher rates of bilaterally dilated pupils, both established negative prognostic markers.[16] The lower mortality observed in the present study likely reflects the benefit of a structured CT-grade-based triage protocol that facilitated more judicious patient selection rather than blanket decompressive craniectomy.

The central hypothesis of the present study, that earlier surgical intervention yields better functional recovery is strongly corroborated by the prospective cohort study of Sikandar, which demonstrated significantly lower mortality (10% vs. 22%) and a higher proportion of good recovery (GOS 4-5: 56% vs. 38%) in patients operated within 3 hours compared with those operated between 3 and 8 hours post-injury.[17] This concordance strengthens the internal validity of the present study's finding that the ≤6-hour and 6-12-hour surgical windows were associated with superior outcomes relative to intervention beyond 12 hours, particularly in Grade III contusions where the difference in 12-month favorable outcome was most pronounced. Similarly, the Eastern Indian cohort by Kumar et al. identified older age, lower GCS, abnormal pupillary reflex, intraventricular hemorrhage, and sulcal effacement as independent predictors of six-month mortality, findings that mirror the present study's regression model in which age and CT grade (a composite marker incorporating cisternal effacement) emerged as consistently significant predictors across all follow-up timepoints.[18] Notably, Kumar et al. also found that burr-hole surgery yielded the best functional recovery (93.3%) while craniectomy carried the highest mortality (45.0%), suggesting that the extent of surgical intervention itself, independent of timing, substantially influences prognosis which is an important nuance that complements the present study's timing-focused analysis.

Regional comparison with the Thai retrospective study by Khawprapa and Khawprapa offers a particularly instructive parallel, as their cohort undergoing surgery within 4 hours of diagnosis demonstrated significantly better GOSE scores at 3 months compared with those operated beyond 4 hours, despite no significant difference in mortality between groups.[19] The improved functional outcome without a corresponding mortality benefit from early surgery echoes the present study's observation that the survival advantage of early intervention was more modest than the magnitude of improvement seen in favorable GOS scores, suggesting that timing predominantly influences neurological recovery trajectory rather than acting as the sole determinant of survival. However, not all literature supports this directionality: the Pan-Asian Trauma Outcomes Study registry found that patients receiving the earliest neurosurgical intervention paradoxically had the highest mortality (36.1%) compared with delayed intervention (18.3%), a finding attributed to compromised quality of care and inadequate physiological stabilization prior to rushed early surgery in resource-limited settings.[20] This counterintuitive result underscores that the benefit of early surgery demonstrated in the present study is contingent upon adequate perioperative optimization and cannot be extrapolated indiscriminately to all institutional contexts, particularly those with limited critical care infrastructure.

Further corroboration comes from the Karri et al. institutional study on decompressive craniectomy, which identified diabetes and ischemic heart disease as significant comorbid predictors of poor functional outcome, and found that early aggressive intervention (within 48 hours) improved prognosis and quality of life at one year, aligning broadly with the present study's timing-outcome relationship despite differences in the underlying pathology studied (malignant stroke versus TBI).[21] Additionally, the large Vellore cohort reinforced age, GCS motor score, and specific CT features, including basal cistern status and midline shift as independently associated with inpatient mortality, lending external validity to the present study's CT-grade-driven prognostic framework.[22]

The present study carries several notable strengths and limitations that merit consideration. Its principal advantage lies in the systematic CT-grade stratification combined with serial radiological follow-up, which allowed characterization of contusion progression (22.5% of patients) and provided a more nuanced timing-outcome analysis than studies relying solely on binary early-versus-late classification. The extended follow-up to 18 months additionally permitted observation of the trajectory of neurological recovery beyond the immediate perioperative period, a feature often absent from comparable Indian studies limited to discharge or 6-month outcomes. However, the study is limited by its single-centre design, which may restrict generalizability to institutions with differing infrastructure and surgical expertise, and by the relatively modest sample size within certain CT-grade and timing subgroups (particularly the >12-hour Grade III category), which reduced the statistical power of some sub-analyses. The observational, non-randomized design also introduces potential selection bias, as more severely injured patients may have been preferentially triaged toward earlier surgery, potentially confounding the timing-outcome relationship. Clinically, these findings reinforce the imperative for expedited neuroimaging, early neurosurgical consultation, and streamlined triage pathways for patients with temporal lobe contusions, particularly those with higher CT grades, to optimize the window for favorable neurological recovery. The demonstrated age- and CT-grade-dependent variation in prognosis further supports individualized, risk-stratified counseling for patients and families rather than a uniform surgical timing protocol, while also highlighting the need for larger multicentric Indian studies to validate these CT-grade-specific timing thresholds across diverse healthcare settings.

CONCLUSION

This study demonstrates that earlier surgical intervention (within 12 hours, optimally within 6 hours) in temporal lobe contusions is associated with significantly better Glasgow Outcome Scale scores across all follow-up intervals, particularly in higher CT-grade lesions. Age, hours-to-surgery, and CT grade independently predicted outcomes, while overall surgical mortality remained low at 10.52%. These findings support CT-grade-based triage protocols and timely neurosurgical intervention to optimize functional recovery, underscoring the clinical value of structured, radiologically-guided decision-making in temporal contusion management.

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