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# PROGNOSTIC INDICATORS FOR DETERMINING OUTCOME IN MODERATE TO SEVERE TRAUMATIC BRAIN INJURY

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## Abstract

**Background:** Traumatic brain injury (TBI) is emerging as a major health burden and socio- economic problem affecting all countries and societies of the world. With an estimated 10 million people affected annually by TBI, the burden of mortality and morbidity that this condition imposes on society, makes TBI a pressing public health and medical problem. Assessing prognosis after traumatic brain injury was both very important and difficult. **Materials and Methods:** The study was conducted in the Department of Neurosurgery, Vardhman Mahavir Medical College and Safdarjung hospital, New Delhi. Around 200 Traumatic brain injury patients admitted and who fit into the moderate to severe injury criteria were analyzed. The five prognostic parameters are Glasgow Coma Scale (GCS), Demographics, Pupillary Size and Reaction, Computed tomography Characteristics and Comorbid Conditions (Hypotension, Hypoxia). At the end of the study the prognostic indicators were categorize based upon their impact on outcome as most important, less important and least important. **Result:** In this study, the outcomes of 200 traumatic brain injury (TBI) patients were categorized into favorable and unfavorable outcomes. The data indicates that 49.00% of the patients experienced unfavorable outcomes, while 51.00% had favorable outcomes. These results align closely with findings from other major studies, such as the IMPACT and CRASH studies, which reported unfavorable outcomes in 48.00% and 47.00% of cases, respectively, and favorable outcomes in 52.00% and 53.00% of cases, respectively. **Conclusion:** These prognostic indicators gave a reasonable discrimination among patients for good and poor outcome 6 months after traumatic brain injury. Patients who presented with GCS 5 and below had very high mortality. Patients with unequal pupils who underwent early surgery had a significant improvement in outcome compared to those who did not undergo surgery. Based on these prognostic variables, probable outcome could be arrived at, thereby enabling us to take suitable decisions regarding the use of appropriate medical or surgical management techniques in order to achieve a better outcome in these group of patients.

## INTRODUCTION

Traumatic brain injury (TBI) is emerging as a major health burden and socio- economic problem affecting all countries and societies of the world. With an estimated 10 million people affected annually by TBI, the burden of mortality and morbidity that this condition imposes on society, makes TBI a pressing public health and medical problem.[1] Further, TBI is classified according to injury severity as mild, moderate, or severe. Table provides one widely-used set of criteria.[2]

Assessing prognosis after traumatic brain injury was both very important and difficult. There were a lot of different prognostic factors related to outcome that could help. The most powerful independent variables were: age, Glasgow Coma Scale motor score, pupil response, Marshall CT classification and traumatic subarachnoid hemorrhage.[3,4] Other important prognostic factors included: hypotension, hypoxia, glucose, coagulopathy, hemoglobin and category of CT characteristic, such as mid-line shift, mass lesion and basal cistern.[3-6] This study aims to identify prognostic factors in moderate to severe traumatic brain injury.

| CLASSIFICATION OF TBI | | |
|---|---|---|
| **Mild** | **Moderate** | **Severe** |
| Normal structural Imaging | Normal or abnormal structural Imaging | Normal or abnormal structural Imaging |
| LOC = 0-30 min | LOC > 30 min and < 24 h | LOC > 24 h |
| AOC = a moment up to 24 h | AOC > 24 h; severity based on other criteria | AOC > 24 h; severity based on other criteria |
| PTA = 0-1 d | PTA > 1 d and < 7 d | PTA > 7 d |
| GCS score = 13-15 | GCS score = 9-12 | GCS score = 3-8 |

## MATERIALS AND METHODS

The study was conducted in the Department of Neurosurgery, Vardhman Mahavir Medical College and Safdarjung hospital, New Delhi.

**Inclusion Criteria**

1. Traumatic brain injury patients of age more than 5 years.
2. Glasgow Coma Scale ≤ 13.
3. Traumatic brain injury patients within 7 days of injury.

Around 200 Traumatic brain injury patients, admitted and who fit into the moderate to severe injury criteria were analyzed after calculating sample size from Steyerberg EW et al study.[7] The five criteria were chosen and applied and the outcome was recorded from prospectively collected, individual patient data was used.

The five prognostic parameters: Glasgow Coma Scale (GCS), Demographics, Pupillary Size and Reaction, Computed tomography Characteristics and Comorbid Conditions (Hypotension, Hypoxia).

At the end of the study the prognostic indicators were categorize based upon their impact on outcome as most important, less important and least important.

The 6-month outcome probability score was defined using the Glasgow Outcome Scale score. The criteria were then grade according to their outcome, by the Glasgow Outcome Scale at 6 months.

In order to simplify analysis, this was further considered into

1. Favorable (good or moderate recovery)
2. Unfavorable (severe disability, vegetative, dead) The study was then compared to the outcome obtained in the IMPACT study.

## RESULTS

Based on the data collected, the following statistics was arrived at the age distribution of patients with moderate to severe traumatic brain injury (TBI) shows a diverse range, with the highest frequencies observed in the 41 to 50 years age group (23.5%) and 21 to 30 years age group (22.5%). This distribution suggests that middle-aged adults are most commonly affected by TBI in this cohort.

The gender distribution of patients with moderate to severe TBI indicates a significant male predominance, with males comprising 78.5% of the sample and females 21.5%. This suggests that males are more frequently affected by TBI in this cohort. [Table 2]

The primary mode of injury among patients with moderate to severe TBI is road traffic accidents, comprising 84.5% of cases. Self falls account for 11.5%, while assaults represent 4%. This emphasizes road traffic accidents as the major cause of TBI in this cohort. [Table 3]

The Glasgow Coma Scale (GCS) distribution shows that the majority of patients (76.5%) have a GCS score between 7 and 12, indicating moderate to severe TBI. A smaller percentage of patients have more severe scores: GCS 3 (13%), GCS 4 (3.5%), GCS 5 (4%), and GCS 6 (3%), reflecting varying levels of consciousness impairment within the cohort. [Table 4]

Pupil reactivity among patients with moderate to severe TBI shows that 44% have pupils reacting to light normally, while 31.5% exhibit sluggish reaction. Unequal pupils reacting to light and sluggishly reacting account for 8% and 5.5% respectively. Notably, 11% of patients have pupils not reacting to light, indicating a severe level of brain injury in these cases. [Table 5]

Among patients with moderate to severe TBI, 13.5% have hypotension and 3.5% have hypoxia as co-morbidities, indicating these are common additional health issues in this cohort. [Table 6]

CT findings in patients with moderate to severe TBI show subdural hematoma as the most common injury (27.5%), followed by subarachnoid hemorrhage and epidural hematoma (both 19%). Hemorrhagic contusions occur in 15% of cases, while diffuse axonal injury and multiple lesions account for 8% and 10.5% respectively. [Table 7]

Outcomes for patients with moderate to severe TBI indicate that 34% achieve good recovery, while 17% experience moderate disability. Severe disability is seen in 5% of cases, 1.5% remain in a vegetative state, and 42.5% succumb to their injuries, highlighting a high mortality rate in this cohort. [Table 8]

Outcomes for patients with moderate to severe TBI are nearly evenly split, with 51% experiencing favorable outcomes and 49% experiencing unfavorable outcomes. [Table 9]

There is a significant association between age and TBI outcomes ($P < .0001$). Younger patients (<=20 years) have better recovery rates (58.33%), while older age groups, particularly 41-50 years and 61-70 years, show higher mortality rates (55.32% and 60%, respectively). This suggests younger patients generally experience more favorable outcomes compared to older patients.

Pupil reactivity significantly correlates with mortality in moderate to severe TBI ($P < .0001$). Patients with non-reactive pupils show the highest mortality rate (81.82%), while those with reactive pupils have a lower mortality rate (15.91%). This suggests pupil reactivity may serve as a prognostic indicator for TBI outcomes, with non-reactivity associated with poorer prognosis. [Table 10]

In TBI patients, hypotension is associated with an 81.48% mortality rate, while hypoxia shows a 71.43% mortality rate. These high rates suggest both conditions significantly worsen prognosis. [Table 11]

Mortality rates vary by CT findings in TBI patients, with intraventricular hemorrhage (100%) and effaced cistern (61.54%) being the highest. Subdural hematoma, subarachnoid hemorrhage, and diffuse axonal injury show similar mortality rates around 42-44%. Epidural hematoma has a lower mortality rate (34.21%). [Table 12]

In this study, the outcomes of 200 traumatic brain injury (TBI) patients were assessed, categorizing them into favorable and unfavorable outcomes. The data indicates that 49.00% of the patients experienced unfavorable outcomes, while 51.00% had favorable outcomes. These results align closely with findings from other major studies, such as the IMPACT and CRASH studies, which reported unfavorable outcomes in 48.00% and 47.00% of cases, respectively, and favorable outcomes in 52.00% and 53.00% of cases, respectively. [Table 13]

**Table 1: Age distribution.**

| Age | Frequency | Percentage |
|---|---|---|
| <=20 years | 12 | 6.00% |
| 21 to 30 years | 45 | 22.50% |
| 31 to 40 years | 32 | 16.00% |
| 41 to 50 years | 47 | 23.50% |
| 51 to 60 years | 35 | 17.50% |
| 61 to 70 years | 20 | 10.00% |
| 71 to 80 years | 6 | 3.00% |
| >80 years | 3 | 1.50% |
| Mean ± SD | 43.83 ± 16 | |
| Median (25th-75$^{th}$ percentile) | 45(29-55) | |
| Range | 14-85 | |

**Table 2: Gender distribution.**

| Gender | Frequency | Percentage |
|---|---|---|
| Female | 43 | 21.50% |
| Male | 157 | 78.50% |
| Total | 200 | 100.00% |

**Table 3: Mode of injury distribution**

| Mode of injury | Frequency | Percentage |
|---|---|---|
| Assault | 8 | 4.00% |
| Road traffic accident | 169 | 84.50% |
| Self-fall | 23 | 11.50% |
| Total | 200 | 100.00% |

**Table 4: GCS distribution.**

| GCS | Frequency | Percentage |
|---|---|---|
| GCS 3 | 26 | 13.00% |
| GCS 4 | 7 | 3.50% |
| GCS 5 | 8 | 4.00% |
| GCS 6 | 6 | 3.00% |
| GCS 7-12 | 153 | 76.50% |

**Table 5: Pupil distribution.**

| Pupil | Frequency | Percentage |
|---|---|---|
| Reacting to light | 88 | 44.00% |
| Sluggishly reacting to light | 63 | 31.50% |
| Unequal pupils reacting to light | 16 | 8.00% |
| Unequal pupils sluggishly reacting to light | 11 | 5.50% |
| Not reacting to light | 22 | 11.00% |
| Total | 200 | 100.00% |

**Table 6: Co-morbidities distribution.**

| Co-morbidities | Frequency | Percentage |
|---|---|---|
| Hypotension | 27 | 13.50% |
| Hypoxia | 7 | 3.50% |

**Table 7: CT findings distribution.**

| CT findings | Frequency | Percentage |
|---|---|---|
| Sub arachnoid hemorrhage | 38 | 19.00% |
| Epi dural hematoma | 38 | 19.00% |

| | | |
|---|---|---|
| Sub dural hematoma | 55 | 27.50% |
| Effaced cistern | 13 | 6.50% |
| Hemorrhagic contusion | 30 | 15.00% |
| Multiple lesions | 21 | 10.50% |
| Diffuse axonal injury | 16 | 8.00% |
| Intracerebral hemorrhage | 1 | 0.50% |
| Intra ventricular hemorrhage | 1 | 0.50% |

**Table 8: Outcome distribution.**

| Outcome | Frequency | Percentage |
|---|---|---|
| Good recovery | 68 | 34.00% |
| Moderate disability | 34 | 17.00% |
| Severe disability | 10 | 5.00% |
| Vegetative state | 3 | 1.50% |
| Died | 85 | 42.50% |
| Total | 200 | 100.00% |

**Table 9: Unfavorable/ favorable outcome distribution.**

| Unfavorable/ favorable outcome | Frequency | Percentage |
|---|---|---|
| Unfavorable | 98 | 49.00% |
| Favorable | 102 | 51.00% |
| Total | 200 | 100.00% |

**Table 10: Distribution of pupil in mortality.**

| Pupil | Total | Mortality(n=85) |
|---|---|---|
| Reacting to light | 88 | 14 (15.91%) |
| Sluggishly reacting to light | 63 | 43 (68.25%) |
| Unequal pupils reacting to light | 16 | 2 (12.50%) |
| Unequal pupils sluggishly reacting to light | 11 | 8 (72.73%) |
| Not reacting to Light | 22 | 18 (81.82%) |
| Total | 200 | 85 (42.50%) |

**Table 11: Distribution of co-morbidities in mortality.**

| Co-morbidities | Total | Mortality(n=85) |
|---|---|---|
| Hypotension | 27 | 22 (81.48%) |
| Hypoxia | 7 | 5 (71.43%) |

**Table 12: -Distribution of CT findings in mortality.**

| CT findings | Total | Mortality(n=85) |
|---|---|---|
| Sub arachnoid hemorrhage | 38 | 16 (42.11%) |
| Epi dural hematoma | 38 | 13 (34.21%) |
| Sub dural hematoma | 55 | 24 (43.64%) |
| Effaced cistern | 13 | 8 (61.54%) |
| Hemorrhagic contusion | 30 | 13 (43.33%) |
| Multiple lesions | 21 | 11 (52.38%) |
| Diffuse axonal injury | 16 | 7 (43.75%) |
| Intracerebral hemorrhage | 1 | 0 (0%) |
| Intra ventricular hemorrhage | 1 | 1 (100%) |

**Table 13. Comparison with IMPACT and CRASH study**

| Unfavorable/ favorable outcome | Frequency | Percentage | Impact study | Crash study |
|---|---|---|---|---|
| Unfavorable | 98 | 49.00% | 48.00% | 47.00% |
| Favorable | 102 | 51.00% | 52.00% | 53.00% |
| Total | 200 | 100.00% | 100.00% | 100.00% |

## DISCUSSION

Prognostic models enable us to predict fairly accurately at the time of admission, as to what the outcome for a given injury might be. Scores like the GCS help us to predict outcome only 24 hours following injury.

Clinically, they help doctors as well as patients in decision making about the modality of treatment. They are also help in research studies to compare outcomes in various patients' groups and in randomized controlled trials.

When considering prognostic predictors, characters that can be reliably and easily determined within the initial few hours are chosen.

Subsequently five important predictors were chosen which had an important bearing on patient outcome

**They were:**

1. Glasgow Coma Scale
2. Demographics
3. Pupillary Size And Reaction
4. CT Characteristics
5. Comorbid Conditions (Hypotension, Hypoxia


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**Glasgow Coma Scale Score**

In 1974 TEASDALE and JENNETT developed the GCS scoring system. It was an objective measure of the level of consciousness and is used widely as a clinical measure of the severity of injury in patients with traumatic brain injuries.

Another factor was regarding best location for application of painful stimuli for assessing motor response, i.e nail bed pressure, supraorbital pressure, sternal pressure etc.[8] The distribution of Glasgow Coma Scale (GCS) scores among 200 patients with traumatic brain injury (TBI) reveals significant insights into the severity of their conditions. Most patients (76.50%) fall within the GCS 7-12 range, indicating moderate TBI where patients exhibit some level of eye, verbal, and motor responses. Conversely, the more severe cases, represented by GCS scores of 3 to 6, account for 23.50% of the patients. Specifically, 13.00% of patients have a GCS score of 3, indicating deep coma or brain death, which correlates with a poor prognosis and high mortality. The remaining 10.50% with GCS scores of 4 to 6 also face severe brain injuries, requiring immediate and intensive medical care to improve their chances of survival and recovery.

The age distribution across different Glasgow Coma Scale (GCS) scores in a cohort of 200 traumatic brain injury (TBI) patients reveal significant correlations between age and injury severity. Younger patients, specifically those aged 20 years or below, all had GCS scores between 7 and 12, indicating moderate brain injury and no severe cases (GCS 3 to 6). This suggests that younger individuals might have a better prognosis following TBI. In contrast, older age groups show a higher prevalence of severe injuries. For instance, 20% of patients aged 51 to 60 had a GCS of 3, and this percentage increases with age, reaching 66.67% for those over 80, reflecting a tendency for more severe outcomes as age increases. The mean age for patients with GCS 3 was 50 years, while those with higher GCS scores (7- 12) had a mean age of 42.39 years, further emphasizing that older patients are more likely to sustain more severe brain injuries. These findings, statistically significant with a p-value of <0.0001 using Fisher's exact test, suggest that age is a crucial factor in TBI severity and outcomes.

**Demographics**

The distribution of GCS scores in relation to age highlights significant insights into the impact of traumatic brain injury (TBI) across different age groups. The data indicates a pronounced trend where younger individuals, particularly those aged 20 years or below, exhibit better GCS scores, predominantly in the range of 7 to 12. Specifically, all patients within this age group had GCS scores in this range, signifying moderate brain injury and no instances of severe injury (GCS 3 to 6). This suggests that younger patients have a higher resilience to severe brain injury, possibly due to better neuroplasticity and overall health.[9]

Conversely, older age groups show a higher prevalence of severe injuries. For instance, in the 51 to 60 age group, 20% had a GCS of 3, indicating a severe brain injury. This percentage increases significantly in older cohorts, with 66.67% of those aged over 80 presenting with a GCS of 3. The mean age for patients with the lowest GCS scores (3) is 50 years, while those with higher GCS scores (7-12) have a mean age of 42.39 years. These findings, statistically significant with a p-value of <0.0001, underscore the vulnerability of older adults to more severe TBIs. Factors contributing to this could include diminished neuroplasticity, presence of comorbidities, and a general decline in physiological resilience with age.

Further analysis of outcomes relative to age reveals notable patterns. Younger patients (<=20 years) predominantly achieve favorable outcomes, with 58.33% classified as having good recovery and no instances of moderate disability. However, a shift is observed in the older age groups, where severe disability, vegetative states, and mortality rates increase. Among the oldest cohort (>80 years), a significant 66.67% succumb to their injuries, indicating the high mortality risk in this age group.

The gender distribution shows a marked disparity, with males comprising 78.50% of the cases, a reflection of the higher incidence of TBI among males, possibly due to greater exposure to high-risk activities and environments. Females account for 21.50% of the cases. The mode of injury predominantly involves road traffic accidents (84.50%), underscoring the critical need for road safety measures and interventions. Self-fall injuries (11.50%) and assaults (4.00%) also contribute to the incidence of TBIs, though to a lesser extent.[10]

**Pupillary Diameter and Reaction**

The light reflex pathway is mediated by the third cranial nerve which is located near to the brainstem areas which controls consciousness, and near the medial temporal lobe.

The timing of surgical evacuation of significant hematomas and underlying pathology also influence the outcomes of bilateral nonreactive pupils.[11]

**In our dataset, we observed diverse pupillary responses:**

- Reacting to light: 44% of patients
- Sluggishly reacting to light: 31.5% of patients
- Unequal pupils reacting to light: 8% of patients
- Unequal pupils sluggishly reacting to light: 5.5% of patients
- Not reacting to light: 11% of patients

Hence pupil reactivity to light can serve as an important prognostic indicator of outcome.

Additionally, the association between pupillary reaction and mortality is notable:

- Among patients with reacting pupils, the mortality rate was 15.91%.
- Patients with sluggishly reacting pupils had a mortality rate of 68.25%.


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- For those with unequal pupils reacting to light, the mortality rate was 12.50%.
- Unequal pupils sluggishly reacting to light had a mortality rate of 72.73%.
- Patients with non-reacting pupils had the highest mortality rate at 81.82%.

These findings underscore the prognostic significance of pupillary assessment in TBI patients. Non-reactive pupils were associated with the highest mortality rate, indicating more severe brain injury and poorer prognosis

**CT scan features**

Many patients are brought to the hospital paralyzed, intubated and on ventilator support. Accurate estimation of the GCS score in the initial few hours after trauma are therefore often difficult.

A EUROPEAN BRAIN INJURY CONSORTIUM survey indicated that full GCS score could be testable in only 56% of patients at the time of admission. Hence prognostic features that depend on technical investigations like CT scans are therefore required. CT scan is ordered routinely in all patients with moderate and severe TBI as it provides vital information which have direct implications regarding operative intervention or for intracranial pressure (ICP) monitoring, and also important information regarding prognosis.[12,13]

In summary, the CT findings provide a crucial diagnostic tool in assessing the severity of TBIs and guiding treatment decisions. The data shows that subdural hematoma, effaced cisterns, and multiple lesions are associated with the highest mortality rates, reflecting the severe nature of these injuries. Early and aggressive management of elevated ICP, surgical intervention for hematomas, and comprehensive care for diffuse axonal injuries are essential strategies to improve outcomes for TBI patients. The findings also underscore the importance of preventive measures to reduce the incidence of severe TBIs, particularly those resulting from road traffic accidents, which are the predominant cause of these injuries.

**Comorbid Conditions**

Secondary brain injury is defined as insults to the brain following trauma arising from extracranial sources and intracranial hypertension. They are commonly seen due to hypotension, hypoxia, ischemia, low hemoglobin, infective causes etc.

The presence of co-morbidities such as hypotension and hypoxia in traumatic brain injury (TBI) patients significantly influences outcomes, particularly mortality rates. In our study, 13.50% of the patients presented with hypotension, and an alarming 81.48% of these patients succumbed to their injuries. The data clearly indicates that managing blood pressure aggressively through fluid resuscitation and vasopressors is vital to improve survival rates in TBI patients.[14]

Similarly, hypoxia was observed in 3.50% of the patients, with a mortality rate of 71.43%. Hypoxia leads to insufficient oxygenation of brain tissue, causing cellular energy failure and promoting mechanisms such as anaerobic glycolysis, acidosis, and excitotoxicity, which further damage brain cells. The combination of hypoxia and hypotension creates a synergistic effect that severely compromises the brain's ability to maintain adequate perfusion and oxygenation, resulting in higher mortality. These findings underscore the necessity for prompt recognition and management of hypotension and hypoxia in TBI patients.

In this study, the outcomes of 200 traumatic brain injury (TBI) patients were assessed, categorizing them into favorable and unfavorable outcomes. The data indicates that 49.00% of the patients experienced unfavorable outcomes, while 51.00% had favorable outcomes. These results align closely with findings from other major studies, such as the IMPACT and CRASH studies, which reported unfavorable outcomes in 48.00% and 47.00% of cases, respectively, and favorable outcomes in 52.00% and 53.00% of cases, respectively.

The slight differences in the outcome percentages between this study and the IMPACT and CRASH studies can be attributed to variations in study populations, the severity of injuries, and differences in healthcare protocols and resources. However, the overall consistency in the data highlights the reliability of these findings and underscores the global burden of TBI and the critical need for effective management strategies.

Comparing this study's outcomes with the IMPACT and CRASH studies underscores the importance of using standardized metrics and methodologies in TBI research to ensure comparability and to benchmark progress in patient care. These studies collectively contribute to a better understanding of TBI outcomes and the factors that influence recovery, thereby guiding future research and healthcare practices aimed at improving survival rates and quality of life for TBI patients.

## CONCLUSION

These prognostic indicators gave a reasonable discrimination among patients for good and poor outcome 6 months after traumatic brain injury.

Patients who presented with GCS 5 and below had very high mortality. Patients with dilated pupils and hypotension along with hypoxia also had a very high mortality rate.

Patients with unequal pupils who underwent early surgery had a significant improvement in outcome compared to those who did not undergo surgery. Patients above the age of 70 had more unfavorable outcome. Patients with multiple lesions along with mass effect and midline shift at the time of admission also had a poor prognosis. Based on these prognostic variables, probable outcome could be arrived at, thereby enabling us to take suitable decisions regarding the use of appropriate medical or surgical management techniques in order to achieve a better outcome in these group of patients.

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