IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)
e-ISSN: 2279-0853, p-ISSN: 2279-0861.Volume 15, Issue 2 Ver. VIII (Feb. 2016), PP 108-113
www.iosrjournals.org

Evaluation of CT Imaging Features in Predicting Clinical Outcome in Moderate to Severe Traumatic Brain Injury

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Abstract:
Background*: Traumatic brain injury (TBI) is a major cause of morbidity, mortality and loss of productivity in resource-limited settings. The objectives of this study were to assess the imaging characteristics of primary brain injury on CT scan post trauma and to evaluate these imaging features as predictors of clinical outcome in patients with TBI.*
Settings And Design*: Prospective, cross sectional hospital-based study*
Materials And Methods*: This study is based on analysis of 85 patients admitted following head injury with GCS ≤ 12 over a period of two years. Patients with polytrauma were excluded from the study. CT scan of the patients was studied for the presence of intracranial hemorrhage, contusion and various other abnormalities. Clinical outcome of the patients were evaluated at 6 months according to the Glasgow outcome score (GOS)*
Results*: The mean age at presentation was 39.3±14.2 years. Majority of patients (57.6%) were in the 20-40 years age group. RTA was the most common mode of injury (78.5%), followed by fall (12.2%) and assault (9.3%). The major CT imaging findings observed were (in order of frequency) subarachnoid hemorrhage (77/85), contusion (71/85), subdural hemorrhage (60/85) and midline shift (30/85). Intraventricular hemorrhage, effacement of basal cisterns, midline shift, diffuse axonal injury and herniation were significant predictors of unfavorable outcome.*
Conclusion*: Along with clinical findings, CT variables can serve as prognostic indicators in patients with moderate to severe TBI and are useful to ensure rational utilization of limited resources and during counseling of relatives of patients.*
Keywords: *Computed tomography, intracranial hemorrhage, Midline shift, Traumatic brain injury.*

I. Introduction

Traumatic brain injury (TBI) is a form of acquired brain injury resulting from an external mechanical force leading to temporary or permanent impairment of cognitive, physical and psychological functions with associated diminished or altered state of consciousness. TBI is a major public health problem worldwide and is predicted to surpass many diseases as a major cause of death and disability by the year 2020. [1] The majority (60%) cases are due to road traffic accidents (RTA), followed by falls (20-25%) and violence (10%). [2]

RTA in India has increased dramatically in recent years due to widespread motor vehicle access and inadequate safety protocols. India has the dubious distinction of leading the world in terms of highest mortality rates from RTA as a result of head injury. Outcome prediction after severe head injury is of great clinical importance especially in countries like India, for better targeting of the limited intensive care resources and assist health care professionals in providing support and education to family members during the acute stage of injury. [3]

Although several clinical variables such as the age, Glasgow coma scale (GCS), pupillary reactivity and brainstem reflexes are commonly used both individually as well as in combination to predict outcome, no model has been found to be ideal. An accurate estimation of the GCS score and changes in the GCS score in the initial hours after trauma is difficult to obtain and also low score of GCS do not necessarily predict bad outcome. [4]

The goal of imaging in the management of head trauma is to identify treatable injuries to prevent secondary damage. Computed Tomography (CT) provides objective assessment of the structural damage to brain following TBI. Despite various advances in radiology, CT remains the investigation of choice in cases of suspected TBI because of availability, affordability and shorter scan time along with bone fracture delineation.

The objectives of this study were to assess the imaging characteristics of primary brain injury on CT scan post trauma and to evaluate these imaging features as predictors of clinical outcome in patients with traumatic brain injury.

II. Materials And Methods

This study is based on prospective analysis of patients admitted following head injury to a tertiary care hospital in South India between July 2012 and August 2014 with GCS of 12 or less and positive intracranial findings on CT imaging. Patients with polytrauma were excluded from the study.

Patients with GCS of 9-12 were considered to have moderate head injury and those with GCS less than 8 were classified as having severe head injury. The CT scans of the patients were studied for the presence of intracranial bleed, contusion, effacement of basal cisterns, midline shift, diffuse axonal injury and herniation. Patients with significant operable lesions were operated upon immediately and others were managed conservatively with ventilator support, anti edema measures and anticonvulsants.

Clinical outcome of the patients were evaluated at 6 months according to the Glasgow outcome score (GOS): Grade 1- good recovery, Grade 2- moderate disability, Grade 3- severe disability, Grade 4- persistent vegetative state and Grade 5- death. The study was conducted according to local ethics committee requirements.

III. Statistical Analysis

Data are presented as mean and standard deviation or as frequency and percent. The software used for statistical analysis was SPSS version 19. GOS of 1 and 2 were categorized as having a favorable outcome and GOS of 3-5 were considered as unfavorable outcome for statistical analysis. Association between categorical variables was detected using the Pearson's coefficient and Chi-square analysis was used where indicated. Multiple logistic regression analysis was performed to determine the predictors of clinical outcome. Statistical significance was set at $p < 0.05$.

IV. Results

A total of 85 patients with head injury were included in this analysis. The mean age at presentation was 39.3±14.2 years (range-16 to 70 years). Majority of patients (57.6%) were in the 20-40 years age group. (TABLE 1)

71 patients (83.5%) were males and 14 (16.5%) were females. RTA was the most common mode of injury (78.5%), followed by fall (12.2%) and assault (9.3%). Mode of injury did not have any significant relation with unfavorable outcome. The mean GCS at presentation was 8±2 (range-1 to 12). 39 patients (45.9%) were noted to have moderate head injury and 46 (54.1%) had severe head injury. TABLE 2 shows the major CT findings observed among patients with TBI.

The influence of CT findings on the final outcome of patients is shown in TABLE 3. Presence of intraventricular hemorrhage, effaced basal cisterns, diffuse axonal injury, midline shift and cerebral herniation were significantly associated with an unfavorable outcome ($P<0.05$) Out of the 85 patients studied, 63 (74.1%) had a favorable outcome while the outcome was found to be unfavorable in 22 (25.9%) patients.

V. Discussion

Traumatic brain injury (TBI) is a common and potentially devastating problem. Although it affects all ages, majority of road traffic accidents which lead to TBI occur in young adults of productive age group, as observed in our study. TBI is thus associated with significant socioeconomic losses in India as well as other developing countries, placing a considerable burden on the health care system in these countries.

Assessment of prognosis of TBI is one of the neglected areas in research, barring a few attempts to create a scoring system. [5, 6] Although several combinations of predictors of outcome have been applied to assess the prognosis of these patients no model has satisfied all the requirements of an ideal model. Most of the models are from population in high income countries and only a few are developed using populations from low and middle income countries, where most of trauma occurs. Therefore the generalizability of the models to these settings is limited. [7]

This prospective cohort study included 85 patients with moderate to severe head injury (GCS ≤12). Various CT parameters (observed on first CT scan post trauma) were studied for their effect on clinical outcome of patients. The major CT imaging findings observed were (in order of frequency) subarachnoid hemorrhage (77/85), contusion (71/85), subdural hemorrhage (60/85) and midline shift (30/85). Compared to previous studies done elsewhere we observed a greater prevalence of intracranial hemorrhage in our series of patients with TBI (Fig: 1-3). The rates of intracranial hemorrhage following TBI have been reported to vary between 46-56%. [8, 9]

This can be attributed to the fact that, ours being a tertiary referral centre most patients included in our study had been referred for critical care after emergency management elsewhere and had presented later than 4 hours following injury. Slow bleeds are more likely to be detected at a later scan and may be missed on early imaging. The possibility of bias cannot be excluded as patients referred for more serious injury may be more likely to present with a bleed. Also none of our patients had associated severe chest, abdominal or orthopedic trauma. The presence of a major extra-cranial injury has been said to be associated with a reduction in the risk of having an intracranial hemorrhage and time from injury to presentation is an important predictor for intracranial hemorrhage. [10]Despite legislation and public awareness campaigns there is no effective enforcement of helmet wear among two wheeler riders in this part of the country is also a factor that needs to be taken into account.

Several studies have reported the presence of subarachnoid hemorrhage in TBI as a powerful factor associated with poor outcome. [11, 12]But in our study we could not find an association between subarachnoid hemorrhage and unfavorable outcome.

The presence of intraventricular hemorrhage, effaced basal cisterns, diffuse axonal injury, midline shift and cerebral herniation (Fig: 4-7) on baseline CT were significantly associated with adverse outcome in our study. Fearnside et al have also reported that midline shift was an important predictor of mortality along with intra-ventricular blood and cerebral edema. [13]

Presence of midline shift more than 10 mm (Fig: 2) was associated with unfavorable outcome in 80% of patients in our study. Our observations are in contrast to those of Wardlaw et al who have noted that the presence of SAH and the “overall appearance of the scan” (severe focal or diffuse injury as opposed to normal/mild/moderate injury) were very useful in predicting outcome, while midline shift on CT scan did not have much significance. [14]

Although diffuse axonal injury (DAI) is difficult to diagnose by CT, its presence was significantly associated with an unfavorable outcome. Out of the 6 patients with diffuse axonal injury, 3 patients had an unfavorable outcome (50%). All 3 patients who had an unfavorable outcome were found to have grade 3 DAI with involvement of dorsolateral midbrain in addition to the subcortical white matter and corpus callosum.

VI. Conclusion

The study is limited by its small sample size. The consideration of presence or absence of intracranial hemorrhage as a prognostic factor is a potential limitation of the study since the outcome may vary depending on the severity and location of bleed. The fact that except for GCS at presentation, the influence of other clinical variables like oculocephalic reflex, pupillary reaction, hypoxia or hypotension could not be studied is another limitation of this study since both clinical and CT findings are important in the prediction of outcome following traumatic brain injury.

To conclude, predicting outcome in patients with severe traumatic brain injury is challenging and controversial. Features on CT such as intraventricular hemorrhage, effacement of basal cisterns, midline shift, diffuse axonal injury and herniation are associated with unfavorable outcome. By noting these easily identifiable features on CT it would be possible to identify more severely injured patients with worse prognosis and target their management accordingly.

VII. Figures And Tables

Fig 1: Axial NECT showing classical biconvex extradural hemorrhage. Note heterogeneity within the hematoma, the “swirl“sign suggesting active bleeding.

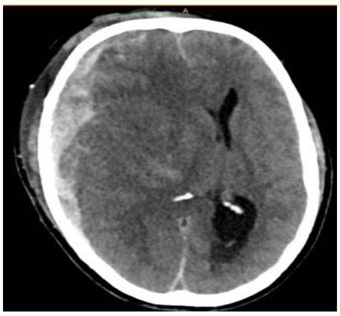

Fig 2: Axial NECT showing large subdural hemorrhage along right hemisphere with midline shift to left and subfalcine herniation with compressed right and dilated left lateral ventricle.

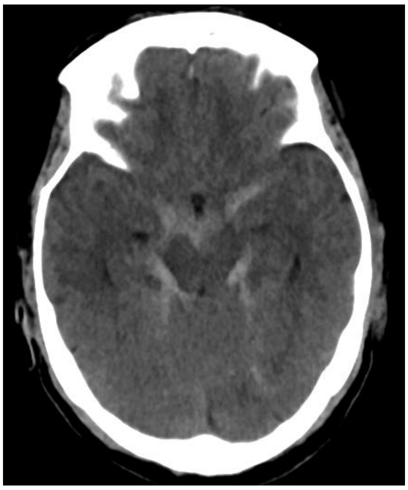

Fig 3: Axial NECT showing traumatic subarachnoid hemorrhage within the basal cisterns and sylvian fissure.

Fig 4: Axial NECT showing intraventricular hemorrhage in right lateral ventricle.

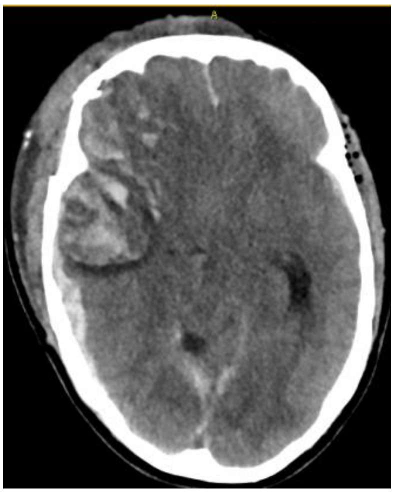

Fig 5: Axial NECT showing a large hemorrhagic contusion involving the right frontal brain with subdural and subarachnoid hemorrhage and midline shift to left.

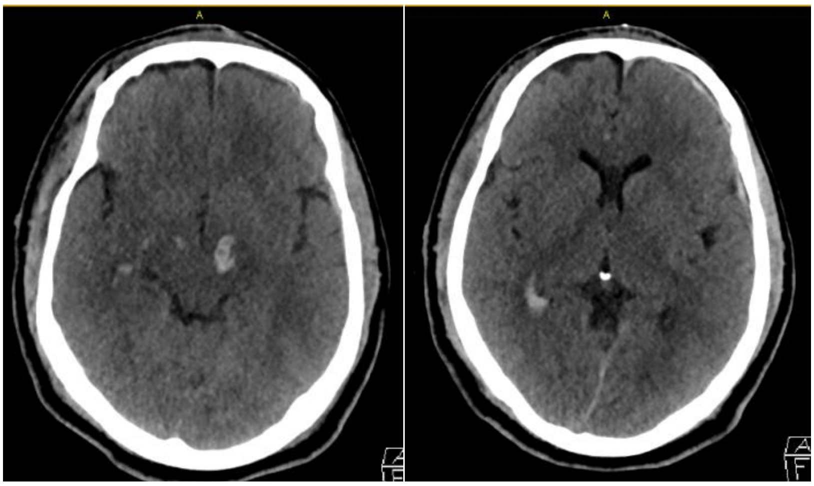

Fig 6(A-B): Axial NECT showing hemorrhagic foci in midbrain and cerebral peduncle with punctuate hemorrhages in subcortical and deep cerebral white matter suggesting diffuse axonal injury and thin left frontal subdural hematoma.

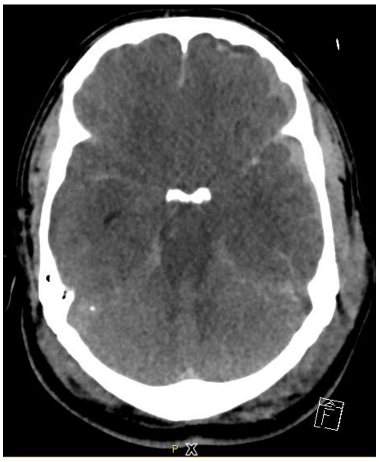

Fig 7: Axial NECT showing diffuse edema of brain and descending herniation with effacement of basal cisterns. Diffuse subarachnoid hemorrhage and left fronto-temporal subdural hemorrhage are also seen.

Table 1 showing the age distribution of patients

Age (in years)	Number of patients (%)
<20	4 (4.7%)
20-40	49 (57.6%)
40-60	20 (23.5%)
>60	12 (14.2%)

Table 2 showing major CT findings observed in patients with TBI

CT findings	Number of patients (%)
Extradural hemorrhage (EDH)	27 (31.8%)
Subdural hemorrhage (SDH)	60 (70.6%)
Subarachnoid hemorrhage (SAH)	77 (90.6%)
Contusion	71 (83.5%)
Intraventricular hemorrhage (IVH)	12 (14.1%)
Effacement of basal cisterns	16 (18.8%)
Midline shift	30 (35.3%)
Diffuse axonal injury	6 (7.1%)
Herniation	5 (5.9%)

Table 3: Prognostic factors on CT in traumatic brain injury

Prognostic factor	Subgroup	Number of patients	% of unfavorable outcome	Significance
EDH	Present Absent	27 58	11.1 41.4	NS
SDH	Present Absent	60 25	33.7 28	NS

SAH	Present Absent	77 8	33.8 12.5	NS
Contusion	Present Absent	71 14	31 35.7	NS
IVH*	Present Absent	12 73	75 24.7	P=0.017
Basal cisterns*	Effaced Uneffaced	16 69	50 27.5	P=0.042
Midline shift*	Present <10mm >10mm Absent	25 5 55	32 80 27.3	P=0.036
Diffuse axonal injury*	Present Absent	6 79	50 30.4	P=0.04
Herniation*	Present Absent	5 80	80 28.8	P=0.008

* Statistically significant, NS not significant

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