Original Article

Role of computed tomography scores and findings to predict early death in patients with traumatic brain injury: A reappraisal in a major tertiary care hospital in Nepal

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Abstract

Background: Glasgow Coma Scale has been a long sought model to classify patients with head injury. However, the major limitation of the score is its assessment in the patients who are either sedated or under the influence of drugs or intubated for airway protection. The rational approach for prognostication of such patients is the utility of scoring system based on the morphological criteria based on radiological imaging. Among the current armamentarium, a scoring system based on computed tomography (CT) imaging holds the greatest promise in conquering our conquest for the same.

Methods: We included a total of 634 consecutive neurosurgical trauma patients in this series, who presented with mild-to-severe traumatic brain injury (TBI) from January 2013 to April 2014 at a tertiary care center in rural Nepal. All pertinent medical records (including all available imaging studies) were reviewed by the neurosurgical consultant and the radiologist on call. Patients' worst CT image scores and their outcome at 30 days were assessed and recorded. We then assessed their independent performance in predicting the mortality and also tried to seek the individual variables that had significant interplay for determining the same.

Results: Both imaging score (Marshall) and clinical score (Rotterdam) can be used to reliably predict mortality in patients with acute TBI with high prognostic accuracy. Other specific CT characteristics that can be used to predict early mortality are traumatic subarachnoid hemorrhage, midline shift, and status of the peri-mesencephalic cisterns.

Conclusion: We demonstrated in this cohort that though the Marshall score has the high predictive power to determine the mortality, better discrimination could be sought through the application of the Rotterdam score that encompasses various individual CT parameters. We thereby recommend the use of such comprehensive prognostic model so as to augment our predictive power for properly dichotomizing the prognosis of the patients with TBI. In the future, it will therefore be important

to develop prognostic models that are applicable for the majority of patients in the world they live in, and not just a privileged few who can use resources not necessarily representative of their societal environment.

Key Words: Computed tomography variables, Marshall score, prognosis, Rotterdam score, traumatic brain injury

INTRODUCTION

Traumatic brain injury (TBI) is a silent epidemic that has paramount short- and long-term consequences. To allow proper resource allocation (which is of preeminent importance in developing countries) there is a need for such system that correctly predicts the outcome. One of the most widely used clinical pearls for such prediction is the Glasgow Coma Scale (GCS).[36] However, its major shortcoming is the limitation of its use in the patients who are sedated, under the effect of drugs or are intubated.[4,6,10,20,23] This hindrance has been compensated with the use of the scoring system based on morphological criteria based on radiological imaging. Among them, magnetic resonance studies are basically limited for detecting white matter changes in the later phase.[11,37] Hence, among current armamentarium, scoring models based on computed tomography (CT) imaging remains the valid option for prognostication of the patients with TBI.

The introduction of the scoring model has revolutionized the treatment algorithm for the patients with head injuries with leaps and bounces.[34,35] Absence of intracranial pathologies certainly adds up the odds for better outcome.[8] Moreover, the role of individual characteristics within the model such as status of the cisterns,[9,10,15,17-19,29,32,38] midline shift (MLS),[1,10,15,19,27,28,30,32,39] subarachnoid hemorrhage (SAH),[1,10,12,14,16,18,19,22,25,26,31,32] and mass lesions[1,2,7,15,18,19,24] in the outcome of the patients have already been detailed and verified.

Previous studies have verified the role of CT scores in predicting the mortality of patients following TBI.[18,19] The added benefits of this scoring system are its simplicity of their usage, reproducibility, and minimal interobserver bias. This study therefore investigates the validity of Marshall and Rotterdam scores for predicting the early mortality in patients with acute TBI. It also examines the role of early surgical intervention and its effect on overall mortality in this cohort.

In our context, the trauma-related injury is the third leading cause of overall deaths.[3] It also predominantly affects male patients in the age group of 20–50-year-old individuals.[5] This comprises the economically most productive age group in any developing nation. In one study, 64.6% of patients with severe head injury managed conservatively died whereas only 44.8% of those who underwent surgical intervention succumbed.[33] TBI remains a major health issue in developing nations such as Nepal. A simple and valid scoring system to predict outcomes after head injury will have a profound impact on resource allocation for immediate care and rehabilitation needs and reconsidering financial aspects governing it.

MATERIALS AND METHODS

This study included 634 consecutive neurosurgical trauma patients with mild-to-severe TBI admitted in the Department of Neurosurgery, College of Medical Sciences, Bharatpur, Nepal, from January 2013 to August 2014. Data were collected prospectively, and each patient underwent a full clinical examination and imaging on admission. Both imaging score (Marshall) [Table 1 and Figure 1] and clinical score (Rotterdam) [Table 2] were obtained for each individual. The respective score was calculated by the neurosurgical consultant and the radiologist on duty separately and then be tallied. Whenever there was a difference in the score between the two assessments, the highest score was taken for the purpose of this study. A retrospective analysis was then performed. This observational cohort study examined whether clinical, and/or imaging scores were related to early death (30 days mortality); it further compared their accuracy in predicting early death, and beyond this it sought to identify the individual characteristics that had high predictability for early death. Results were formatted, calculated, and P values were assessed using the SPSS 20 software. (IBM SPSS statistics 20 software, Armonk New York, USA)

Factors such as hypotension, hypoxia, seizure, time lapse to arrival to hospital, and prehospital management do have an impact on the outcome of the patients. But in
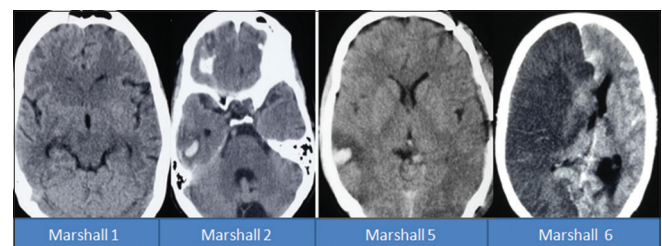

Figure 1: Computed tomography images with different Marshall computed tomography scores

the context of a rural medical infrastructure, the proper prehospital management via a rapid response ambulance and paramedical team are still lacking. All the patients brought to the emergency with head injury were initially triaged according to the revised trauma score. After achieving hemodynamic stability, CT scanning and other relevant investigations were carried out to fully assess or rule out coexisting polytrauma as a confounding factor for mortality of the patient.

This study was approved by the ethics board of the institution. We avoided a purely retrospective study to avoid a *post hoc* effect on to the scoring system. Written consent was obtained from all patients or their relatives.

RESULTS

The mean age of the patient with a head injury was 29.1 years, and the age group in our cohort with the highest number of patients enrolled was at ages between 30 and 50 years [Figure 2]. The ratio of adult and pediatric patients was 2.7:1. The male and female ratio was 2.62:1 in our cohort study. The mortality in males was 10% compared to 8% in the females ($P = 0.437$). Around 40% of the total cases were referred from places that were at least 120 km far from our center. The GCS of the patients listed as per different age groups are shown in Table 3.

When the age group was adjusted for patients with moderate and severe head injury only, the number of patients was also highest in the age group of 30–50 years (47%), followed by the age group of 10–30 years (32%), the age group of 50–70 years (13%), the age group of above 70 (5%), and finally the age group below 10 years (3%). The mortality was highest in the age group of 30–50 years (46.66%) followed by age group of 10–30 years (31.66%), 50–70 years (13.33%), above 70 years (5%), and finally below 10 years (3.33%) [Figure 3].
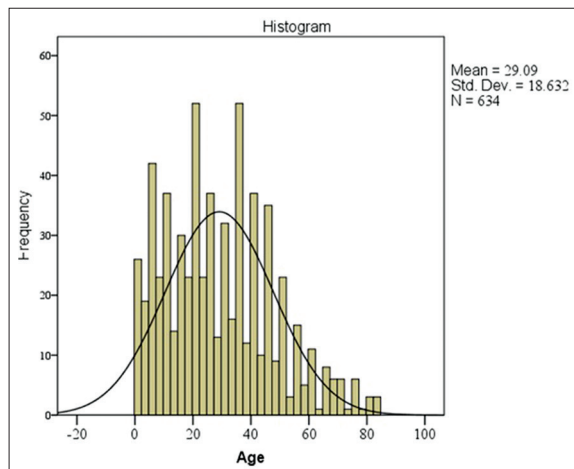
This table signifies the importance of the Marshall CT score in predicting mortality in patients with TBI. The mortality in patients with Marshall score 1 and 2 in our cohort was 0%, for score 3 it was 40%, for score 4 it was 0%, for score 5 it was 18.79%, and for score 6 was 95.66% [Figure 4]. This reflects improved outcomes secondary to the evacuation of lesions with mass effect (Marshall score 5) in patients with severe TBI, resulting in reduced mortality when compared to patients with

Table 1: Marshall CT Classification

Category	Definition
Diffuse injury 1 (no visible pathology)	No visible intracranial pathology on CT scan
Diffuse injury 2	Cisterns are present with midline shift of 0-5 mm and/or lesions densities present; no high or mixed density lesion >25 cm³ may include bone fragments and foreign bodies
Diffuse injury 3 (swelling)	Cisterns compressed or absent with midline shift of 0-5mm; no high or mixed density lesion >25 mm
Diffuse injury 4 (shift)	Midline shift >5 mm; no high or mixed density lesion >25 cm³
Evacuated mass lesion	Any lesion surgically evacuated
Non evacuated mass lesion	High or mixed density lesion >25 cm³; not surgically evacuated

CT: Computed tomography

Table 2: Rotterdam score system

Predictor value	Score
Basal cisterns	
Normal	0
Compressed	1
Absent	2
Midline shift	
No or <5 mm	0
Shift >5 mm	1
Epidural mass lesion	
Present	0
Absent	1
Intra-ventricular blood or tSAH	
Absent	0
Present	1
Sum score	+1

tSAH: Traumatic subarachnoid hemorrhage

Figure 2: Age distribution of the patients

Table 3: GCS and age category of the patients

GCS	Age category (years)					Total
	Below 10	10-30	30-50	50-70	70 above	
Mild	110	180	138	43	12	483
Moderate	8	29	36	15	2	90
Severe	5	22	27	4	3	61
Total	123	231	201	62	17	634

GCS: Glasgow Coma Scale

compressed cisterns, MLS and nonevacuated hematomas of >25 ml blood. There were very few patients in Group 4 because most patients with significant MLS were taken for operative evacuation (after an initial Marshall score of 5). This corresponds to the observed overall mortality, which was found to be 18.79% in these cases. The mortality was highest for Marshall score 6 (95.66%).

The mortality in patients with Rotterdam score 1 and 2 in our cohort was 0%, for score 3 it was 6%, for score 4 it was 35%, for score 5 it was 53.65%, and for score 6 it was 58.33% [Figure 5]. This observation reflects that a higher Rotterdam score in patients with TBI correlated with a worse outcome.

When the Marshall score is adjusted for the patients with moderate and severe head injury, then the mortality in patients with score 1 and 2 was 0%, for score 3 was 90%, for score 4 was 31.97%, for score 5 was 31.97%, and for score 6 was 100% [Table 4]. This again shows that the respective Marshall score has positive predictive value in predicting mortality in patients with traumatic head injury.

The Rotterdam score adjusted for patients with moderate and severe head injury shows that the mortality for the patients with scores of 1 and 2 was 0%, for score 3 was 20%, for score 4 was 55.85%, for score 5 was 76%, and for score 6 was 77% [Figure 6]. Correlation between Marshall and Rotterdam scores in the cohort study is outlined in the Table 5.

The area under the curve (AUC) was significant for both the scoring system with 0.912 for Marshall and 0.929 for Rotterdam scores, respectively. When the study included other variables, then the AUC was 0.929 for cisternal anatomy, 0.897 for GCS score, 0.733 for MLS, and 0.643 for age category, respectively, in predicting the mortality [Figure 7]. This model had the significance value of 90.5% (omnibus scale) in predicting early mortality in patients with TBI.

DISCUSSION

Our cohort study clearly corroborates the validity of Marshall and Rotterdam scores in its ability to predict early mortality in patients with acute TBI. It demonstrates the role of early surgical intervention in reducing the overall mortality. We are furthermore able to show that distinct individual parameters such as GCS, age, status of the cisterns, presence of MLS, and traumatic SAH had a significant impact on the outcome of these patients.

However, a number of limitations regarding the use of CT score models must be recognized.[18,19] The results of the previous data that was pooled from the study among patients with moderate and severe head injuries cannot be correctly extrapolated to the patients with minor head
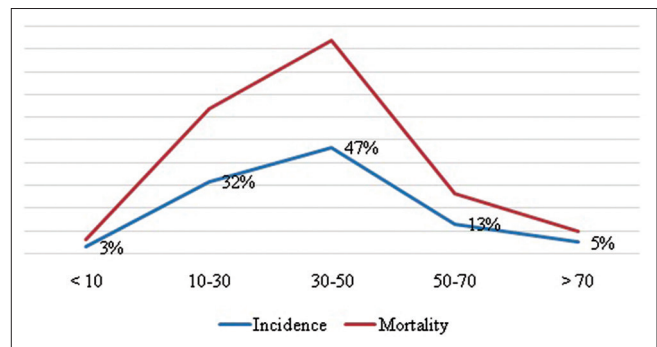

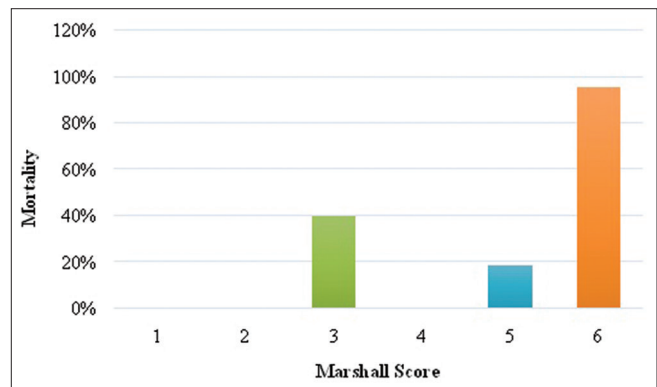Figure 3: Age group and mortality among patient in moderate and severe head injury

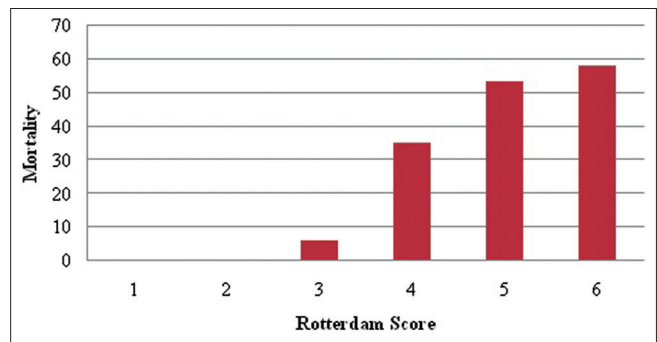Figure 4: Relationship between Marshall score and mortality

Figure 5: Relationship between Rotterdam score and mortality

Table 4: Marshall score in moderate and severe head injury

Marshall	Mortality		Mortality	Inference
	No	Yes		
1	7	0	0	$P<0.001$
2	40	0	0	
3	1	9	90	
4	49	23	31.97	
5	0	21	100	
Total	97	53		

injuries. Second, it is more justifiable for the inclusion of the score from the worst CT[30] of the patients rather than the analysis of the first scan undertaken in many previous
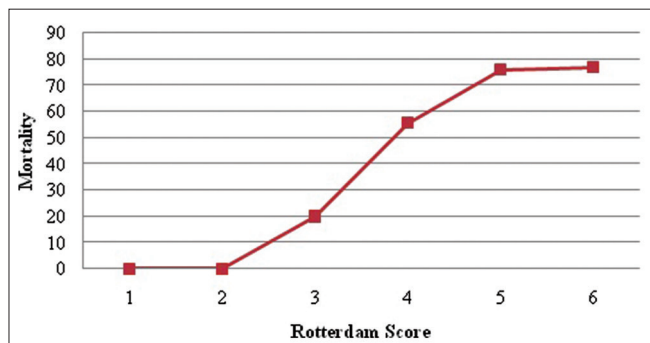
Figure 6: Relationships between Rotterdam score and mortality in moderate and severe head injury patients

Table 5: Correlation between Rotterdam and Marshall CT score

Marshall	Rotterdam						Total
	1	2	3	4	5	6	
1	0	184	1	0	0	0	185
2	46	114	86	5	0	0	251
3	0	0	9	14	2	0	25
4	0	0	0	0	1	0	1
5	3	30	39	40	30	7	149
6	0	0	3	7	8	5	23
Total	49	328	138	66	41	12	634

CT: Computed tomography

studies for correct assessment of the outcome. Third, in contrast to the analysis of the outcome at 6 months, for our cohort study, we chose early mortality as the relevant measure rather than relying on the glasgow outcome score (GOS) at any later point in time, which dichotomizes the patient cohort into groups with unfavorable versus favorable clinical course. Early death thus constitutes an objective endpoint, and we were not missing any outcome data over the period investigated. Another point of debate would be the time frame taken for considering the outcome of the study. Some authors have advocated the inclusion of mortality at 1 week so as to avoid the biased skewness of the deaths due to medical complications as a result of a long stay in the intensive care unit.[21]

Another drawback of the CT scoring model is the issue of interobserver or interrater bias. Studies have shown that there is a significant difference in scoring of the CT image among trained radiologist as well.[11,13] Such differences in film read out may translate into modified treatment algorithms which in itself can change the outcome measures. We tried to nullify this with validation of the score from two trained radiologist and inclusion of the highest score in the data. In order to prevent the *post hoc* effect, we performed the prospective study among the selected cohort group.

Proper dichotomization of the patients with a head injury has an immense impact on the outcome as well as the
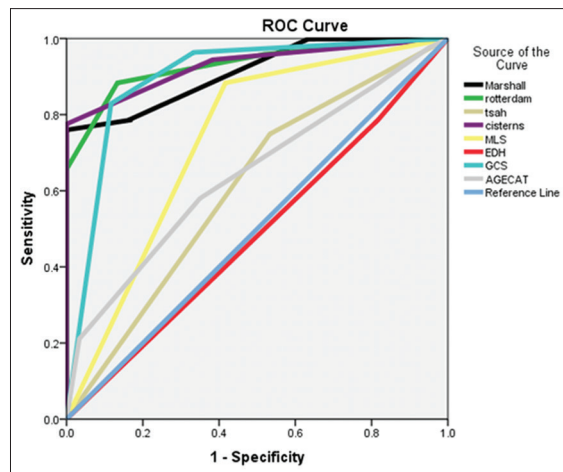

Figure 7: Area under curve for different variables in the study

proper allocation of the available resources in developing countries like ours. Prognostication models should provide a mirror image of the life in the long run for both the patients and their caregivers. Dichotomizing into "good" or "poor" may though be helpful for the immediate care decisions, but it may be just covering the loopholes for correctly projecting the real scenario in the long-term.

SUMMARY AND CONCLUSION

This study concludes that the radiological Marshall CT score has a strong predictive power for predicting the outcome after TBI, but greater discrimination and more relevant interpretation can be ascertained with the application of clinical scores utilizing individual CT parameters as attempted in the Rotterdam scoring model. Consequently, for prognostication purposes, this study recommends the use of a set of specific imaging characteristics obtained in individuals rather than using broad categories derived from the existing CT classification systems alone. In the future, it will therefore be important to develop prognostic models that are applicable for the majority of patients in the world they live in, and not just a privileged few who can use resources not necessarily representative of their societal environment.

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Conflicts of interest
There are no conflicts of interest.

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