ORIGINAL RESEARCH

Rotterdam computed tomography score as a predictor of early death among patients with traumatic brain injury at a tertiary hospital in Kampala, Uganda: A prospective study

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Abstract

Background
Noncontrast computed tomography (CT) plays a crucial role in the assessment and triage of traumatic brain injured (TBI) patients. This study aimed to determine whether the Rotterdam CT score (RS) had good predictive value for short-term mortality among TBI patients in Uganda.

Methods
This was a hospital-based, prospective study of TBI treated in a tertiary, private hospital in Kampala, Uganda. A total of 108 TBI patients were consecutively enrolled from September 2017 through May 2018 and followed up from admission to either in-hospital death or discharge. Noncontrast CT brain imaging was conducted, and parameters of CT findings were used to calculate the RS. An area under the receiver operating characteristic (AUROC) plot of sensitivity vs specificity was generated to determine the discriminative power of the RS to predict in-hospital mortality.

Results
In total, 38% of TBI patients were aged 20 to 29 years, 25.9 % were aged 30 to 39 years, and 11% were over 50 years of age. Most patients were male (81.4%), while 19% were female. Six deaths occurred among study participants. Study mortality (5.6%) was lower than that predicted by the RS (11.1%). The AUROC for the RS was 68% (95% CI, 48% to 90%), indicating that it had poor to moderate power to predict short-term death in patients with TBI.

Conclusions
The Rotterdam CT score is a poor predictor for mortality of TBI in the short term.

Keywords: Rotterdam CT score, neuroimaging, traumatic brain injury, Glasgow Coma Scale, mortality, prognosis, Uganda

Introduction

Globally, traumatic brain injury (TBI) is an important cause of disability and death.[1] TBI is frequently associated with road traffic accidents, which accounted for an estimated 1.35 million deaths worldwide in 2016.[2] Most TBI occurs in low- and middle-income countries, where resources are limited and case fatality rates are highest.[3] The mortality rate for severe TBI in Uganda is 25.8%.[4] Most TBI deaths occurred in males aged 15 to 29 years,[2],[3] with motorcycle road traffic accidents being the primary cause of injury.[3],[4]

The Glasgow Coma Scale (GCS) is the most widely used tool to assess the severity of head injuries within the first few posttraumatic hours.[5] However, GCS is insensitive to subtle derangements in consciousness and frequently has to be interpreted in sedated patients.[5] In addition, it is difficult to determine the GCS verbal score in intubated patients.

Table 1. Demographic and baseline clinical variables among patients treated for traumatic brain injury at a tertiary hospital in Kampala, Uganda, September 2017 through August 2018 (N=108)

Variable	n (%)
Age, years	
<30	49 (45.4)
30-39	28 (25.9)
40-49	20 (18.5)
≥50	11 (10.2)
Gender	
Male	88 (81.5)
Female	20 (18.5)
Cause of injury	
Fall	5 (4.6)
RTC	69 (63.9)
Assault	34 (31.5)
Convulsions	
No	93 (86.1)
Yes	15 (13.9)
Loss of consciousness	
No	33 (30.6)
Yes	75 (69.4)
Vomiting	
No	76 (70.4)
Yes	32 (29.6)
Ear or nose bleeding	
No	68 (63.0)
Yes	40 (37.0)
Referral	
No	61 (56.5)
Yes	47 (43.5)
TBI severity	
Mild (GCS 13-15)	81 (75.0)
Moderate (GCS 9-12)	16 (14.8)
Severe (GCS 3-8)	11 (10.2)
Basal cisterns	
Normal	82 (75.9)
Compressed	26 (24.1)
Midline shift	
No shift or ≤5mm	93 (86.1)
>5 mm	15 (13.9)
Epidural mass lesion	
No	89 (82.4)
Yes	19 (17.6)
Intraventricular blood or traumatic SAH	
No	83 (76.9)
Yes	25 (23.1)

GCS; Glasgow Coma Scale score; RTC, road traffic crash; SAH, subarachnoid haemorrhage; TBI, traumatic brain injury

Table 2. Clinical signs at baseline and hospitalization duration among patients treated for traumatic brain injury at a tertiary hospital in Kampala, Uganda, September 2017 through August 2018 (N=108)

Variable	Mean ± SD	Median (IQR)
Pulse rate, beats per min	78.2±19.0	76 (64-90)
Systolic BP, mmHg	132.0±20.2	130 (120-146)
Diastolic BP, mmHg	76.9±14.2	78 (69-84)
Respiratory rate, breaths per min	20.4±8.3	20 (18-22)
SpO2, %	97.2±3.0	98 (96-99)
Temperature, °C		
Length of stay, days	4.6±3.3	4 (2-6)

BP, blood pressure; IQR, interquartile range; SD, standard deviation

Radiological imaging offers an objective method of assessing patients with acute severe TBI.[6] Noncontrast computed tomography (CT) for imaging enables rapid image acquisition and is now widely used in most trauma centres. Statistical models of imaging results can complement clinical judgment in predicting outcomes of TBI. Prognostic scores based on the findings of radiological imaging can help guide clinical decision-making for TBI patients, including regarding the need for immediate surgical intervention and patient placement in an intensive care unit. These clinical decisions imply the allocation of medical resources that are scarce in resource-limited settings. Most prognostic scores based on findings from radiological imaging have been developed and validated in high-income countries,[6],[7] which limits their generalizability to resource-poor settings.

The Rotterdam CT score (RS), developed in 2005 by Maas et al.,[7] is a scoring system that uses CT findings at ad-

Table 3. Bivariate analysis of computed tomography findings among patients treated for traumatic brain injury at a tertiary hospital in Kampala, Uganda, September 2017 through August 2018 (N=108)

Computed tomography finding	n (%)	Survived, n (%)	Died, n (%)	OR (95%CI)	*P* value
Basal cisterns					
Normal	82 (75.9)	79 (96.3)	3 (3.7)	Reference	0.15
Compressed	26 (24.1)	23 (88.5)	3 (11.5)	3.43 (0.65-18.18)	
Midline shift					
No shift or ≤5 mm	93 (86.1)	89 (95.7)	4 (4.3)	Reference	0.18
>5 mm	15 (13.9)	13 (86.7)	2 (13.3)	3.42 (0.57-20.59)	
Epidural mass lesion					
No	89 (82.4)	84 (94.4)	5 (5.6)	1.07 (0.12-9.73)	0.95
Yes	19 (17.6)	18 (94.74)	1(5.26)	Reference	
Intraventricular blood or traumatic SAH					
No	83 (76.9)	79 (95.2)	4 (4.8)	Reference	0.55
Yes	25 (23.1)	23 (92.0)	2 (8.0)	1.72 (0.30-9.98)	

OR, unadjusted odds ratio or in-hospital death; SAH, subarachnoid haemorrhage

Table 4. Observed vs predicted deaths[a] among patients treated for traumatic brain injury at a tertiary hospital in Kampala, Uganda, September 2017 through August 2018 (N=108)

RS	Patients in RS risk category, n (%)	Predicted deaths by RS risk category, n (%[b])	Observed deaths by RS risk category, n (%[c])
1	7 (6.5)	0 (0)	0 (0.0)
2	67 (62.0)	5 (7)	2 (3.0)
3	16 (14.8)	3 (16)	2 (13)
4	16 (14.8)	4 (26)	2 (12.5)
5	2 (1.9)	1 (53)	0 (0.0)
6	0 (0.0)	0 (61)	0 (0.0)
Total	108	13 (11.1)	6 (5.6)

[a]Predicted by the Rotterdam score (RS); 6 represents the highest risk

[b]Predetermined percentages for each RS risk category used to calculate the whole numbers of predicted deaths

[c]Percentages calculated from observed deaths in each RS risk category

mission to improve accuracy in predicting patient outcomes. In the current study, we aimed to determine whether the RS could predict mortality among TBI patients at a tertiary hospital in Kampala, Uganda.

Methods

This prospective study enrolled patients treated at the departments of surgery, radiology, and emergency medicine of St. Francis Hospital Nsambya, a 361-bed, private Catholic teaching hospital in Kampala, Uganda. From September 2017 through August 2018, we prospectively enrolled consecutive patients who were aged 15 years or older, had a clinical diagnosis of TBI, and had undergone a brain CT scan within 24 hours of the injury. We enrolled only patients who consented to the study or who were consented by their next of kin; patients with polytrauma were excluded.

In all patients, we performed standard resuscitation procedures as recommended by the Advanced Trauma and Life Support course[8] before performing a noncontrast CT scan of the brain using a Siemens Somatom Perspective 128-slice CT scanner. Two independent radiologists interpreted the scans and conferred with one another before issuing a final report of radiological findings. RS values were calculated for all enrolled patients as follows: (a) The basal cistern status was scored as 0 if normal, 1 if compressed, and 2 if absent. (b) The midline shift of the brain was scored as 0 if within the range of 0 to 5 mm and as 1 if greater than 5 mm. (c) Epidural hematoma was scored as 0 if present and 1 if absent. (d) The presence of a subarachnoid haemorrhage or an intraventricular hematoma was scored as 1; the absence of both was scored as 0.[9] Data on demographic and clinical factors were obtained from emergency department admission records, transcribed into a standardized case report form, and entered into Stata, version 13.0 (StataCorp, College Station, TX, USA) for analysis. CT imaging data were exported from the CT scanner into Excel for data cleaning and then imported into the study database.

We evaluated patient outcomes from admission until death in the hospital or discharge from the hospital. Bivariate tests were conducted to estimate associations between factors derived from CT findings and patient vital status at

Table 5. Association between injury severity and Rotterdam score categories among patients treated for traumatic brain injury at a tertiary hospital in Kampala, Uganda, September 2017 through August 2018 (N=108)

TBI severity	Rotterdam score, n (%)		*P* value
	1-3	4-6	
Mild (GCS 13-15)	63 (77.8)	18 (22.2)	
Moderate (GCS 9-12)	8 (50.0)	8 (50.0)	0.001
Severe (GCS 3-8)	3 (27.3)	8 (72.7)	

GCS, Glasgow Coma Scale score; TBI, traumatic brain injury

discharge (i.e. alive being 0 and dead being 1); factors with a *P* value <0.05 were included in multivariable logistic regression analysis. An area under the receiver operating characteristic (AUROC) plot of sensitivity vs specificity was generated to determine the discriminative power of the RS.[10] Our analysis determined which RS severity category had the poorest predictive value.

According to the Krejcie and Morgan table for determining sample sizes for finite populations,[4],[9] the required sample size for a population of 1 million or more is 384. The surgery department at Nsambya Hospital admits about 25 patients per month. We anticipated that the data collection would take about 6 months to complete, yielding a population of approximately 300 patients. We, therefore, employed the following formula to calculate our target sample size in a finite population (where the population is less than 50 000):

$$\text{New SS} = \frac{\text{SS}}{1 + (\frac{\text{SS} - 1}{\text{Pop}})}$$

Where SS is the required sample size for the study, and Pop is the population at the hospital.

$$\text{New SS} = \frac{384}{1 + (\frac{384 - 1}{25 * 6})} = 108 \text{ patients}$$

Therefore, the target sample size for this study was 108.

Approval for this study was obtained from the Nsambya Hospital Research and Ethics Committee (Nsambya REC No., UG-REC-020). Informed consent was obtained from patients' relatives or guardians before starting any study procedure.

Results

Road traffic crashes were the most common cause of injury (accounting for 63.9% of TBI), followed by assaults (31.5% of TBI); only 4.6% of TBI resulted from falls. Patients aged 20 to 29 years accounted for the largest proportion of TBI patients (38%), followed by those aged 30 to 39 years (25.9%); patients aged 10 to 19 and those aged over 50 accounted for 5.5% and 11.0% of TBI patients, respectively. Most TBI patients were male (n=88, 81.5%), and 20 (18.5%) were female (Table 1). At admission, most patients had vital signs that were within the normal ranges. The average length of stay in hospital was 4.6±3.3 days (Table 2).

In the bivariate analysis, no single variable used to calculate the RS was a statistically significant predictor of in-hospital mortality (Table 3). In total, 6 TBI patients (5.6%) died, which was fewer than the number predicted by the RS (predicted mortality, 11.1%; n=12 deaths) (Table 4). Further, the number of observed deaths corresponding to each possible RS was consistently lower than the number of RS-predicted deaths. The GCS was significantly and positively correlated with the RS (Pearson's correlation coefficient, ; *P*<0.001; Table 5).

Among TBI patients who died in hospital, the most common RS pathology was compressed basal cistern (in 3 of 6 patients who died; Table 6), while the most common non-RS pathology was raised intracranial pressure with brain oedema. The discriminatory power of the RS as determined by

Table 6. Computed tomography findings of the 6 patients who died while being managed for traumatic brain injury at a tertiary hospital in Kampala, Uganda, September 2017 through August 2018 (N=108)

Form code	Basal cisterns	Midline shift	Epidural mass lesion	Intraventricular blood or traumatic SAH	Rotterdam score	Other computed tomography findings
2	Compressed	>5 mm	Absent	Absent	4	Midline intracerebral contusions, cerebral oedema with raised ICP, medial maxillary sinus fracture with sinus effusion
30	Compressed	>5 mm	Absent	Absent	4	Subdural haemorrhage, raised ICP, brain oedema
50	Normal	None	Absent	Present	3	Brain oedema, raised ICP, fracture of base of skull
62	Normal	None	Absent	Absent	2	Left temporal depressed fracture and left haemorrhagic contusions
73	Compressed	None	Present	Present	3	Depressed skull fracture and pneumocranium
101	Normal	None	Absent	Absent	2	Extensive left cerebellar hypodensity

ICP, intracranial pressure; SAH, subarachnoid haemorrhage

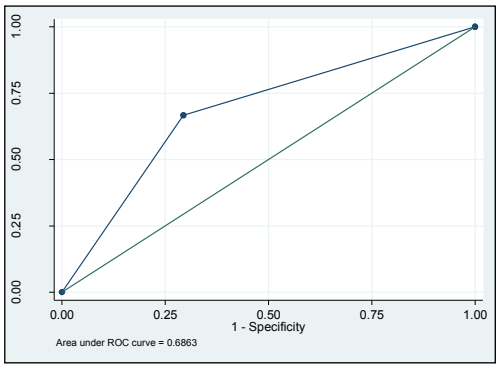

Figure 1. Area under the receiver operating characteristic (AUROC) curve for Rotterdam scores among patients treated for traumatic brain injury at a tertiary hospital in Kampala, Uganda, September 2017 through August 2018 (N=108)

The discriminatory power of the Rotterdam score, as determined by the AUROC plot of sensitivity vs specificity was 0.68 (95% CI, 0.48 to 0.90), where a value of 0.50 indicates that the test is uninformative, and a value of 1 indicates that the test is perfectly predictive.

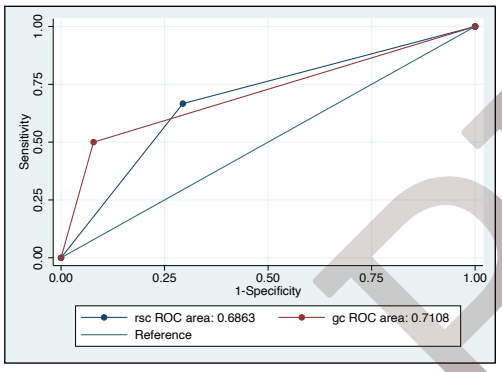

Figure 2. Area under the receiver operating characteristic (AUROC) curve for Rotterdam scores among patients treated for traumatic brain injury at a tertiary hospital in Kampala, Uganda, September 2017 through August 2018 (N=108)

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the AUROC plot of sensitivity vs specificity was 0.68 (95% CI, 0.48 to 0.90), where a value of 0.50 indicates that the test is uninformative, and a value of 1 indicates that the test is perfectly predictive (Figure 1). In an analysis stratifying TBI severity, the predictive value of the RS was poorest for patients with mild TBI.

Discussion

In this hospital-based, prospective study, we evaluated whether the RS predicts short-term mortality following TBI in patients in Uganda, finding that the RS had only a moderately predictive value of 68%. This finding is comparable to that of the initial evaluation of the RS, which assessed 6-month mortality among 2269 TBI patients from preexisting international and North American data sets.[7] Men aged 20 to 29 years accounted for the largest proportion of TBI patients in our study sample, a finding that is consistent with other studies of TBI patients.[2],[4],[10] Road traffic accidents and assault were the main causes of TBI among study participants. This is unsurprising given that road traffic accidents are a leading cause of death among people aged 15 to 29 years,[11] and rates of homicide are increasing in Eastern Africa.[12] Falls accounted for only 4.6% of all traumatic brain injuries in this study. Most TBIs resulting from falls occur in children under 5 years old,[10]-[13] an age bracket excluded from the current study

Table 7. Associations between injury severity and survival outcomes among patients with Rotterdam scores of 2, 3, and 4 who were treated for traumatic brain injury at a tertiary hospital in Kampala, Uganda, September 2017 through August 2018 (N=108)

Rotterdam score and TBI severity	Outcome, n (%)		*P* value
	Survived	Died	
RS 2 (n=68)			
Mild TBI (GCS 14-15)	55 (96.5)	2 (3.5)	
Moderate TBI (GCS 9-14)	7 (100)	0 (0.0)	0.83
Severe TBI (GCS 3-8)	3 (100)	1 (0.0)	
RS 3 (n=16)			
Mild TBI (GCS 14-15)	9 (90)	1 (10.0)	
Moderate TBI (GCS 9-14)	3 (100)	0 (0.0)	0.43
Severe TBI (GCS 3-8)	2 (66.7)	1 (33.3)	
RS 4 (n=16)			
Mild TBI (GCS 14-15)	7 (100)	0 (0.0)	
Moderate TBI (GCS 9-14)	4 (100)	0 (0.0)	0.08
Severe TBI (GCS 3-8)	3 (60)	2 (40)	

GCS, Glasgow Coma Scale score; RS, Rotterdam score; TBI, traumatic brain injury

The number of observed deaths was consistently lower than the number of predicted deaths across the RS scale. The number of deaths observed in our study sample was only about half of the number predicted by the RS. We attribute the discrepancy between observed and predicted deaths to the inclusion of patients with mild TBI in our study, most of whom presented to the hospital within 24 hours of injury. We were unable to identify any other studies of prognostic scores for TBI patients that included patients with mild TBI. Among some patients, we observed a discordance between clinical findings and findings based on CT imaging, which suggests that prognostic scores should use a combination of physiological findings from clinical examination and anatomical findings from brain imaging.[14],[15]

The 6 deaths that occurred in study participants were equally distributed across the risk categories represented by RS 2, 3, and 4. Our finding that compressed basal cistern was the commonest RS pathology in patients who died accords with findings of other studies in which the presence of compressed or absent basal cisterns is a significant predictor of TBI death.[6],[16],[17] However, none of the variables used to calculate the RS were significant independent predictors of mortality; this null finding may have been due to a lack of statistical power resulting from the small number of observed deaths. Our finding of a positive correlation between the RS and the GCS supports the widely accepted use of the GCS as a prognostic scale despite the fact that the GCS was initially developed to grade brain dysfunction.[12]

Limitations

Our study had limitations. Patients were recruited at a tertiary, private hospital where the level of clinician expertise is high, and many patients presented with mild TBI; thus, the generalizability of study findings may be limited. Only 6 deaths occurred among study participants; this limited the study's statistical power to evaluate the predictive value of RS for death in TBI.

Conclusions and Recommendations

Our study showed that the RS had limited power to predict short-term mortality in patients with TBI. Further studies that include patients with a range of injury severity are needed to establish whether the RS is a good prognosticator of TBI mortality.

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