Validity of mild TBI risk score to predict intracranial hemorrhage in cases of mild traumatic brain injury in Thailand

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ABSTRACT

Background Patients with mild traumatic brain injury (TBI) will receive a brain CT scan based on risk of injury. A previous study established a scoring system for patients with mild TBI that assigned <3 points for the low-risk group, 3–6 points for the moderate-risk group, and ≥6 points for the high-risk group. The purpose of this study was to evaluate the external validity of mild TBI risk scores for predicting intracranial hemorrhage in patients with mild TBI who had been transferred to receive a brain CT scan at the 10 nationwide CT scan–capable facilities in Thailand.

Methods The study was a retrospective cross-sectional review of patients with mild TBI who received a brain CT scan in 10 nationwide hospitals of Thailand. Risk factors were observed and points calculated for predicting mild TBI scores based on patient records. Injured patients were divided into two groups: CT scans indicating normal and abnormal brain images. After this, the accuracy of mild TBI score for predicting the presence of intracranial hemorrhage was investigated.

Results The study included a total of 999 patients, comprising 461 (46.15%) patients with abnormal brain CT scans indicating intracranial hemorrhage and 538 (53.85%) indicating no intracranial hemorrhage. In the low-risk group (mild TBI risk score <3), moderate-risk group (mild TBI risk score 3–6), and high-risk group (mild TBI risk score >6), the likelihood ratio positive of brain CT scans were 0.41, 3.53, and 77.3, respectively.

Discussion Mild TBI risk score may assist healthcare providers to select patients with mild TBI for brain CT scan referral, particularly in hospitals without CT scan facilities. In such cases, based on the proposed scoring system, immediate transfer of moderate-risk and high-risk patients with mild TBI to a CT scan–capable facility is necessary.

BACKGROUND

Annually, there are 1.4 million patients with traumatic brain injury (TBI) who visit emergency departments (EDs) in the USA. The cost of taking care of patients with TBI was US$60 billion annually.[1] Assessment of patients with TBI in ED was affected by using the Glasgow Coma Scale (GCS) score. Mild TBI, with total GCS scores ranging from 13 to 15, the largest number of patients with TBI, accounted for 80%.[2] Only 15% of patients with a GCS score of 15 demonstrated an abnormality on CT and only 1% of these patients required cranial surgery.[3 4] This group of patients was usually neglected from observation and closed monitoring when comparing with patients with moderate and severe TBI.[5] A GCS score of 13 was associated with 100% risk for intracranial hemorrhage.[6]

Patients with mild TBI were divided into three groups: a high-risk group, a moderate-risk group, and a low-risk group.[3 7–9] Clinical factors for high-risk group included male gender, age ≥60 years, baseline GCS score, clinical signs of skull fracture, clinical signs of basilar skull fracture, a GCS score drop ≥2 points, post-traumatic vomiting, focal neurological signs, seizure, headache, severe headache (visual analog scale score >7), post-traumatic amnesia (<1 hour), transient loss of consciousness, large extracranial hematoma/severe maxillofacial injury, coagulopathy, trauma mechanisms, and drug/alcohol intoxication.[10] Per the guidelines developed by the Royal College of Surgeons of Thailand and the College of Neurological Surgeons of Thailand, patients with mild TBI who are considered high risk should undergo a brain CT scan within 1 hour of ED admission.

The study in Ramathibodi Hospital, a university-affiliated super tertiary care hospital in Bangkok, Thailand, was conducted to develop the clinical prediction score to predict intracranial hemorrhage in patients with mild TBI. The mild TBI risk scores were categorized into three groups: scores <3 (low risk), scores 3–6 (moderate risk), and scores >6 (high risk). The likelihood ratio of positive head CT scan was 20.61 (95% CI 12.74 to 33.33) in the high-risk group.[10]

Therefore, the objective of this study was to evaluate the external validity of mild TBI risk scores for predicting intracranial hemorrhage in patients with mild TBI who had been transferred to receive a brain CT scan at the 10 nationwide CT scan–capable facilities in Thailand.

PATIENTS AND METHODS

The study was a retrospective cross-sectional review of patients with isolated mild TBI who had been transferred to receive a brain CT at the 10 nationwide CT scan–capable facilities in Thailand. The inclusion criteria were age ≥15 years. Those patients who had been transferred to receive a brain CT scan without medical records were

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excluded. The study period was between June and December 2016.

The data of eligible patients were recorded, including baseline characteristic and potential risk factors for intracranial hemorrhage. Risk factors included post-traumatic vomiting more than two times (1.5 points), severe headache (7.5 points), transient loss of consciousness (3 points), post-traumatic amnesia (1 point), focal neurological signs (4 points), clinical signs of skull fracture (6 points), and base of skull fracture (8 points).[10] All eligible patients were divided into two groups according to CT scan results: CT positive, indicating intracranial hemorrhage; and CT negative, indicating no intracranial hemorrhage. The outcome of this study was accuracy of mild TBI risk score for predicting the presence of intracranial hemorrhage.

Statistical analysis

Baseline characteristics of eligible patients were compared for difference between two groups divided by brain CT results. Exact probability test was used to analyze the difference in categorical variables, whereas an independent t-test or Wilcoxon rank-sum test was used in continuous variables.

Assessing discrimination of studied risk factors for positive CT results presented as an area under receiving operating characteristic (AuROC) curve, 95% CI, and significance level (p value). The patient's risk of intracranial hemorrhage was categorized into low, moderate, and high risk according to mild TBI risk score calculation. Diagnostic indices including sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and likelihood ratio positive (LR+) were examined to assess the validity of mild TBI score.

Results

In this study, there were 999 patients with mild TBI who had been transferred to 10 nationwide CT scan–capable facilities to receive a brain CT scan. Of those, 461 patients (46%) indicated the presence of intracranial hemorrhage (CT positive), and 538 patients (54%) resulted in normal brain imaging (CT negative). According to the type of incidents, motorcycle crash and assault had higher result significantly in CT positive (237 (51.41%) vs 137 (25.46%), p<0.001 and 38 (8.24%) vs 16 (2.97%), p<0.001, respectively) (table 1).

Regarding the univariable analysis, there were nine potential risk factors that had significantly higher proportion in positive CT findings and high discriminative performance (AuROC) (table 2). The potential risk factors are suspicion of skull fracture (20.82% vs 0.37%, p<0.001) (AuROC curve of 0.60 and 95% CI 0.57 to 0.63), neurological deficit (12.36% vs 5.39%, p<0.001) (AuROC curve of 0.60 and 95% CI 0.53 to 0.57), experiencing of post-traumatic amnesia (58.83% vs 24.35%, p<0.001) (AuROC curve of 0.66 and 95% CI 0.63 to 0.69), and history of loss of consciousness (67.68% vs 16.17%, p<0.001) (AuROC curve of 0.76 and 95% CI 0.73 to 0.78).

The accuracy of mild TBI risk score for predicting intracranial hemorrhage was investigated (table 3). In low-risk patients, sensitivity was 8.24%, specificity 79.74%, PPV 25.85%, NPV 50.35%, and LR+ 0.41. In moderate-risk patients, sensitivity was 57.05%, specificity 83.83%, PPV 75.14%, NPV 69.50%, and LR+ 3.53. For those of high risk, sensitivity was 28.63%, specificity 99.63%, PPV 98.51%, NPV 61.97%, and LR+ 77.3.

The discrimination performance of mild TBI risk score for predicting intracranial hemorrhage was presented as AuROC curve of 0.89 and 95% CI 0.87 to 0.91.

Table 1 Baseline prognostic factors of patients with mild TBI categorized by brain CT scan results

Characteristics	CT positive (n=461)		CT negative (n=538)		P value
Age (mean±SD)	46.3±24.1		54.9±25.0		<0.001
Admission systolic blood pressure (mean±SD)	125.3±34.8		110.1±28.8		0.225
ED triage level					
Level 1	14	3.1%	9	1.7%	0.416
Level 2	247	54.3%	211	39.5%	
Level 3	186	40.9%	296	55.4%	
Level 4	7	1.5%	17	3.2%	
Level 5	1	0.2%	1	0.2%	
Type of injury					
Motorcycle crash	237	51.4%	137	25.5%	<0.001
Motor vehicle crash	31	6.7%	23	4.3%	0.094
Falling	108	23.4%	286	53.2%	<0.001
Blunt object	24	5.2%	26	4.8%	0.884
Assault	38	8.2%	16	3.0%	<0.001
Fainting/syncope	28	6.1%	43	8.0%	0.267
Laboratory results*					
Platelet (×10³)	222.6	836.8	243.2	119.2	0.088
INR	1.1	0.3	1.1	0.1	0.785
Type of TBI					
EDH	105	22.8%			
SDH	91	19.7%			
SAH	88	19.1%			
Brain contusion	72	15.6%			
IPH	105	23.0%			
Hospital stay (days)	4.5±6.9		2.7±3.1		<0.001
Disposition					
Discharge	446	96.8%	536	99.6%	<0.001
Dead	15	3.3%	2	0.4%	

*Laboratory results: platelet concentration and INR reported as mean and SD.
ED, emergency department; EDH, epidural hematoma; INR, international normalized ratio; IPH, intraparenchymal hemorrhage; SAH, subarachnoid hemorrhage; SDH, subdural hematoma; TBI, traumatic brain injury.

Discussion

According to the guidelines developed by the Royal College of Surgeons of Thailand and the College of Neurological Surgeons of Thailand, patients with mild TBI can be categorized into three groups: high-risk, moderate-risk, and low-risk groups. Of those, patients with mild TBI who are considered high risk should undergo an expedited brain CT.[3 7–9]

Delays in obtaining this CT scan in high-risk patients with mild TBI may lead to worse outcomes including increased disability and mortality.[10] In contrast, patients with mild TBI who are low risk are unlikely to have an intracranial hemorrhage and should avoid a CT scan to prevent unnecessary radiation and costs.[11]

Regarding the study, overall, 46% of eligible patients who underwent brain CT demonstrated intracranial hemorrhage. For low-risk patients with mild TBI, the LR+ of positive CT findings (intracranial hemorrhage) was only 0.41. Management of these patients for non-CT scan–capable facilities should be neurological observation and transport to appropriate facility if neurological deficit develops.

Patient with moderate risk were found that the LR+ increased to 3.35 times and increased to 77.3 times for patients with high risk. Management of these patients for non-CT scan–capable facilities should be rapid transport to the closest appropriate

Table 2 Potential risk factors of patients with mild TBI categorized by brain CT scan results

Risk factors	CT positive (n=461)		CT negative (n=538)		P value	AuROC (95% CI)
	N	%	N	%		
Gender—male	176	38.2	226	42.0	0.220	0.52 (0.49 to 0.55)
Age >60 years	145	31.5	306	56.9	<0.001	0.37 (0.34 to 0.40)
Admission GCS score						
GCS 15	385	83.5	490	91.1	0.001	0.46 (0.43 to 0.49)
GCS 14	51	11.1	33	6.1		
GCS 13	25	5.4	15	2.8		
Skull fracture	96	20.8	2	0.4	<0.001	0.60 (0.57 to 0.63)
Basilar skull fracture	10	2.2	0	0	<0.001	0.51 (0.48 to 0.54)
GCS score drop ≥2 points	20	4.3	8	1.5	0.007	0.51 (0.48 to 0.55)
Penetrating skull injury	3	0.7	0	0	0.098	0.50 (0.47 to 0.53)
Vomiting ≥2 times	40	8.7	47	8.7	0.999	0.50 (0.47 to 0.53)
Neurological deficit	57	12.4	29	5.4	<0.001	0.53 (0.50 to 0.57)
Post-traumatic seizure	17	3.7	14	2.6	0.363	0.51 (0.47 to 0.54)
Headache	164	35.6	131	24.4	<0.001	0.56 (0.53 to 0.59)
Severe headache	33	7.2	0	0	<0.001	0.53 (0.50 to 0.57)
Post-traumatic amnesia	262	58.8	131	24.4	<0.001	0.66 (0.63 to 0.69)
History of LOCs	312	67.7	87	16.2	<0.001	0.76 (0.73 to 0.78)
Scalp/facial hematoma	85	18.4	41	7.6	<0.001	0.55 (0.52 to 0.59)
Intoxication	89	25.9	35	22.6	0.502	0.52 (0.47 to 0.56)

AuROC, area under receiving operating characteristic curve; GCS, Glasgow Coma Scale; LOC, loss of consciousness; TBI, traumatic brain injury.

Table 3 Diagnostic indices of mild TBI risk score categorized by risk category

Risk factors	CT positive	CT negative	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	LR+
Low risk	38	109	8.2	79.7	25.9	50.4	0.4
Moderate risk	263	87	57.1	83.8	75.1	69.5	3.5
High risk	132	2	28.6	99.6	98.5	62.0	77.3

Low risk, mild TBI score <3 points; moderate risk, mild TBI score 3–6 points; high risk, mild TBI score ≥7 points.
LR+, likelihood ratio positive; 0.89 and 95% CI 0.87 to 0.91; NPV, negative predictive value; PPV, positive predictive value; TBI, traumatic brain injury.

facility to provided them a brain CT scan. And for CT scan–capable facilities, patients with mild TBI should be prioritized for receiving brain imaging based on their risk category.

The study had a number of limitations including the retrospective nature of the data reviewed. Some of the background data were excluded because they were incomplete. Not all high-risk patients with mild TBI were transferred for a CT scan.

In conclusion, for patients with mild TBI, a risk score can help predict the presence of intracranial hemorrhage which can be used to determine and prioritize the patients who require a brain CT. Those patients with mild TBI with high-risk and moderate-risk scores should undergo immediate CT scans.

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