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Indicators of abnormal CT Scan findings in clinically mild traumatic brain injury patients

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Abstract

Background & Objective: Various clinical guidelines have been developed to predict intracranial findings and minimize the unnecessary head CT scans in mild traumatic brain injury (MTBI) patients. However, the most appropriate guideline for routine practices might be highly dependent on the emergency department policies, qualifications of medical staff, and the level of infrastructure availability. This study aims to identify various indicators that can predict abnormal CT scan findings in clinically MTBI patients. *Methods:* Our retrospective analytical study included patients diagnosed with MTBI admitted to the Emergency Department of Prof. Dr. R. D. Kandou General Hospital, Manado, Indonesia, from November 2022 to February 2023, age ≥18 years, and having undergone a brain CT scan. Multivariate analyses of several indicators were performed to identify the strongest indicators of abnormal CT scan findings. *Results:* Among 112 subjects, abnormal CT scan findings were identified in 38 subjects (33.9%). The proportion of men is greater (63.4%), with a median age of 33 (18-88) years. The most common mechanism was traffic accidents (83.0%). Logistic regression analysis revealed that skull fracture (OR 8.144, 95% CI 3.110-21.326) and signs of skull base fracture (OR 7.059, 95% CI 2.217-22.475) were the two strongest indicators in predicting abnormal CT scan findings.
Conclusions: Skull fracture and signs of skull base fracture were the two strongest indicators of abnormal CT scan findings in clinically MTBI patients. Therefore, skull X-rays in the setting of limited CT scans and thorough clinical examination are recommended.

Keywords: Head computed tomography scan, mild traumatic brain injury, skull fracture, skull base fracture, traumatic intracranial lesion

INTRODUCTION

Traumatic brain injury (TBI) remains a subject of significant research focus due to its substantial contribution to illness, fatalities, and visits to the emergency department (ED).[1] The global burden of TBI has increased in recent years as prevalence rates increased by 8.4% between 1990 and 2016.[2] More than 2 million annual visits of TBI patients to emergency departments in North America, 800,000 to 2 million in the United States, and over 400,000 visits in the UK have been reported.[3-5] In Indonesia, the National Institute of Health Research and Development in 2018 showed a TBI incidence of 11.9%.[6]

In TBI cases, 70-97.5% are mild (MTBI).[5,7-10] The majority (80-90%) do not require hospitalization and can be discharged with proper instructions.[3,7,11] However, some MTBI patients are found to have intracranial bleeding, known as complicated MTBI, with incidence rates of 4.7% - 38.9%, which have a higher risk of cognitive impairments and worse functional outcomes.[4,7,8,10-14]

Cranial CT scans are the most commonly used clinical imaging technique to assess head injuries.[2,5,7] However, approximately one-third of head injury patients are subjected to unnecessary CT scans.[3] In cases of MTBI, it is advisable to consider whether to perform imaging to avoid unnecessary waste.[9,10] Furthermore, performing CT scans increases the exposure to X-rays and the financial burden on the patient.[5,7,8,13,15,16]

Several guidelines assist in prescribing CT scans for patients with MTBI.[14-16] However,

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the proper and efficient implementation of this remains challenging in small healthcare centers.[11] Therefore, this study aims to identify various indicators that can predict abnormal CT scan findings in clinically MTBI patients.

METHODS

Study design and patient selection

This research was conducted with a cross-sectional retrospective design on patients with MTBI Glasgow Coma Scale (GCS) 13-15, loss of consciousness <30 minutes, altered mental status or memory loss <24 hours), aged over 18, without associated injuries, and with CT brain scans ordered by the emergency physician, neurologist, and diagnostic imaging physician in the Emergency Department of Professor Dr. R.D. Kandou General Hospital, a tertiary healthcare center in Manado, Indonesia, from March to August 2023.

The sampling method is consecutive non-random sampling from medical records with a minimum sample size of 120 (according to the formula). The approval number from the Ethics Committee of Professor Dr. R.D. Kandou General Hospital is 095/EC/KEPK-KANDOU/VII/2023.

Potential predictors

The independent variables include age, gender, mechanism of injury (related to traffic or other causes), consciousness status, post-injury memory loss (The Galveston Orientation and Amnesia Test (GOAT) $\leq$ 75), headache (based on Numeric Pain Rating Scale (NPRS)), persistent vomiting ($\geq$ 2 episodes), post-traumatic seizures (PTS), history of alcohol/drug addiction, antiplatelet/anticoagulant medication, GCS score (15 and 13-14), focal neurological signs, signs of skull base fracture (periorbital ecchymosis, ecchymosis behind the ear, cerebrospinal fluid leakage), severe head skin injuries, skull fractures (X-ray or CT), and coagulation disorders.[17-24]

Outcome

Dependent variables are the outcomes of CT scans (normal or abnormal), including epidural hematoma, subdural hematoma, subarachnoid hemorrhage, intracerebral hematoma, cerebral contusion, and cerebral edema, with the results aimed at determining various parameters that can predict abnormal CT scan outcomes in clinical cases of MTBI patients and identifying the strongest parameter.

Statistical analysis

Data were examined utilizing IBM SPSS (Statistics) software 26.0 (IBM Corp., Armonk, NY, USA). We provided descriptive statistics with frequency and percentage to describe categorical data. We expressed the normally distributed data as mean and standard deviation; otherwise, we presented them as median and the range from the minimum to the maximum value. To determine and compare differences in both numerical and categorical factors between the groups with normal and abnormal CT scans, we conducted univariate analysis using descriptive statistics, and the Chi-square test or Fisher's exact test to compare two independent groups. Meanwhile, for continuous data, we employed an Independent t-test or Mann-Whitney U test. A *P*-value of $\leq$0.05 was considered indicative of statistical significance.

We performed a logistic regression analysis to determine the potential of an abnormal CT scan based on the indicators and reveal the strongest indicator that predicts abnormal CT scan; the results are reported in Odds Ratio (OR). All variables with a *P*-value $\leq$0.05 were included for analysis, and we used the backward stepwise method.

RESULTS

In the study, 112 patients were surveyed (Table 1), with the majority being under 40 years of age, predominantly related to traffic accidents and having a GCS score of 15. The male-to-female ratio was 1.7/1, and a greater number of patients had a history of loss of consciousness, mild headache, and scalp wounds. Signs of skull base fractures, skull fractures, and focal neurological deficits were less common.

The proportion of abnormal cranial computed tomography (CT) findings is 33.9% (Table 2). Among these, the proportion of moderate to severe headaches, persistent vomiting, localized neurological signs, skull fracture, and signs of skull base fracture are significantly higher compared to the normal CT group (Table 3).

The analysis in Table 4 indicate that skull fracture is the most significant (*P* <0.001) in cases of abnormal CT scans. Reanalysis in Table 5 by excluding skull fracture which is a radiological indicator, showed that signs of skull base fracture is the most significant clinical indicators of abnormal CT scans (*P* 0.001).

Table 1: Baseline and clinical characteristics

Indicators (n=112)	Group	Frequency n (%)
Age in years	Median (min – max)	33 (18 – 88)
	≤40	68 (60.7%)
	41-60	33 (29.5%)
	>60	11 (9.8%)
Sex	Female	41 (36.6%)
	Male	71 (63.4%)
Mechanism of injury	Others	19 (17.0%)
	Traffic-related	93 (83.0%)
Loss of consciousness	Absent	49 (43.8%)
	Present	63 (56.3%)
Post-traumatic amnesia (PTA)	Absent	108 (96.4%)
	Present	4 (3.6%)
Headache	No / unknown	14 (12.5%)
	Mild	59 (52.7%)
	Moderate-severe	39 (34.8%)
Persistent vomiting	Absent	94 (83.9%)
	Present	18 (16.1%)
Post-traumatic seizure (PTS)	Absent	109 (97.3%)
	Present	3 (2.7%)
History of using	Alcohol	0 (0%)
	Antiplatelet	0 (0%)
	Anticoagulant	0 (0%)
Glasgow Coma Scale (GCS)	15	102 (91.1%)
	13-14	10 (8.9%)
Focal neurological deficits	Absent	105 (93.8%)
	Present	7 (6.3%)
Signs of skull base fracture	Absent	93 (83.0%)
	Present	19 (17.0%)
Significant wound on the head	Absent	44 (39.3%)
	Present	68 (60.7%)
Skull fracture	Absent	80 (71.4%)
	Present	32 (28.6%)
Coagulopathy	Absent	111 (99.1%)
	Present	1 (0.9%)

Table 2: Characteristics of abnormal CT scan findings

Characters	n (%)
Abnormal CT scan findings (n=38, 33.9%)	
Subdural hematoma	17 (44.7%)
Subarachnoid hemorrhage	13 (34.2%)
Epidural hematoma	12 (31.6%)
Cerebral contusion	12 (31.6%)
Intracerebral hematoma	9 (23.7%)
Cerebral edema	2 (5.3%)

Table 3: Comparison of variables between normal and abnormal computed tomography scan

Indicators	Normal CT n=74	Abnormal CT n=38	P-value
Age in years, Median (min – max)	30 (18 – 88)	39 (18 – 87)	0.536*
Age groups (years)			0.305
≤40	47 (63.5%)	21 (55.3%)	
41-60	22 (29.7%)	11 (28.9%)	
>60	5 (6.8%)	6 (15.8%)	
Sex			0.105
Female	31 (41.9%)	10 (26.3%)	
Male	43 (58.1%)	28 (73.7%)	
Mechanism of injury			0.193
Others	15 (20.3%)	4 (10.5%)	
Traffic-related	59 (79.7%)	34 (89.5%)	
Loss of consciousness	37 (50.0%)	26 (68.4%)	0.063
Posttraumatic amnesia (PTA)	2 (2.7%)	2 (5.3%)	0.489†
Moderate-severe headache	17 (23.0%)	22 (57.9%)	**<0.001**
Persistent vomiting	8 (10.8%)	10 (26.3%)	**0.034**
Post-traumatic seizure (PTS)	1 (1.4%)	2 (5.3%)	0.265 †
Glasgow Coma Scale (GCS) 13-14	4 (5.4%)	6 (15.8%)	0.086 †
Focal neurological deficits	2 (2.7%)	5 (13.2%)	**0.043** †
Signs of skull base fracture	5 (6.8%)	14 (36.8%)	**<0.001**
Significant wound on the head	43 (58.1%)	25 (65.8%)	0.431
Skull fracture	10 (13.5%)	22 (57.9%)	**<0.001**
Coagulopathy	1 (1.4%)	0 (0%)	1.000 †

Note: analyzed using Chi-square test, except *=T-test and †=Fisher's exact test.

Table 4. Multivariate analysis of indicators of abnormal CT scan findings

Indicators	OR	95% CI	P-value
Step 1			
Moderate-severe headache	1.72	0.80-3.71	0.164
Persistent vomiting	1.74	0.96-3.16	0.066
Focal neurological deficits	1.46	0.20-10.64	0.708
Signs of skull base fracture	2.26	0.57-8.96	0.246
Skull fracture	5.79	1.86-17,99	**0.002**
Step 2			
Moderate-severe headache	1.72	0.80-3.71	0.164
Persistent vomiting	1.73	0.96-3.13	0.071
Signs of skull base fracture	2.22	0.56-8.77	0.256
Skull fracture	6.30	2.21-18.01	**0.001**
Step 3			
Moderate-severe headache	2.01	0.98-4.13	0.059
Persistent vomiting	1.78	0.99-3.19	0.055
Skull fracture	8.14	3.11-21.33	**<0.001**

Abbreviation: OR: odds ratio; CI: confidence interval

Table 5: Multivariate analysis of clinical indicators of abnormal CT scan findings

Indicators	OR	95% CI	P-value
Step 1			
Moderate-severe headache	1.57	0.75-3.28	0.231
Persistent vomiting	1.76	0.99-3.11	0.052
Focal neurological deficits	5.00	0.75-33.27	0.096
Signs of skull base fracture	5.43	1.60-18.46	**0.007**
Step 2			
Persistent vomiting	1.69	0.96-2.97	0.067
Focal neurological deficits	4.73	0.74-30.11	0.100
Signs of skull base fracture	7.06	2.22-22.48	**0.001**

Abbreviation: OR: odds ratio; CI: confidence interval

DISCUSSION

Throughout the years, numerous clinical prediction models have been created and tested to determine which MTBI patients should undergo a Head CT scan. However, there was significant diversity in clinical practices and research methods among these studies. Furthermore, due to the absence of a universally accepted definition for MTBI patients, each authors established their own criteria based on local preferences. This variability has limited the applicability to different healthcare settings.[11]

Among baseline characteristics, no variable was considered an independent factor for abnormal CT scans. Various clinical guidelines use the cutoff of age >60 or >65 years to predict abnormal CT scan findings.[17-22] Age (>60 years) is an independent risk factor that can be used to predict abnormal CT scan outcomes. Conversely, a younger age is often associated with high-energy trauma and correlates with findings of skull fractures and intracranial hemorrhages.[12,23]

Generally, Vaniyapong reported that the Asian populations have similar clinical indicators as the Western population, although there are differences in the primary mechanism of injury.[11] According to Teeratakulpisarn and colleagues, intracranial hemorrhage is often a result of trauma related to traffic accidents. Traffic injury-related factors such as the type of vehicle used (car, motorbike, bicycle, or pedestrian) and whether the patient was a passenger or driver were also included in the analysis, but none of these factors was statistically significant.[15] A more detailed analysis of several factors related to injury mechanisms, including the presence of dangerous injury mechanism features, was not carried out in this study due to limited data.

There are five significant prognostic factors of abnormal CT scan findings, including moderate to severe headaches, persistent vomiting, focal neurological deficits, signs of skull fracture, and signs of a basal skull fracture. According to Langroudi and colleagues, moderate to severe headaches suggest a higher likelihood of abnormal findings on CT scans, and persistent vomiting on at least two occasions is considered a crucial sign of intracranial injury.[4,22,25] Focal neurological deficits are considered a robust predictor for the development of intracranial hemorrhage, although they are less common in mild traumatic brain injury (MTBI) patients.[19,21–24] The detection of a skull fracture in MTBI patients significantly increases the risk of intracranial injury, with Leitner and colleagues indicating that a skull fracture is an independent risk factor for intracranial hemorrhage in MTBI patients over 65 years old or under 35 years old with a high-energy mechanism of injury.[23] A metaanalysis reported that the risk of intracranial hemorrhage was estimated to be 12 times higher in patients with radiographically detected skull fractures.[22]

Our study supported the previous findings. Skull fracture was the only significant indicator ($p < 0.001$) in the final step of multivariate analysis (Table 4), with an OR of 8.14 (95% CI; 3.11 – 21.33). When the medical facility lacks the capacity for CT scans, skull X-rays are used to classify MTBI patients into high and low-risk groups, with a sensitivity of 38% and a specificity of 95%.[22,26] While skull X-rays cannot rule out intracranial hemorrhage, the risk increases up to 4.9 times in the group with skull fractures.[26] Therefore, skull X-rays still provide valuable information for MTBI patients.

We performed a reanalysis of four clinical indicators that predict abnormal CT scan findings with the exclusion of skull fracture (Table 5), only signs of skull base fracture were considered statistically significant (p = 0.001), with an OR of 7.06 (95% CI; 2.22 – 22.48). The prevalence of patients with fractures of the cranial base on clinical examination showing intracranial hemorrhage on CT ranges from 19% to 82%.[25] Therefore, this is a favorable prognostic factor on CT following MTBI. Hence, a thorough clinical examination is of utmost importance, including the evaluation of the GCS. The rate of detecting abnormal CT findings in patients with GCS < 14 is twice as high, and for GCS < 13, it is four times higher compared to GCS 15.[21]

Overall, the value of our research is that it provides some references for emergency room physicians to determine whether to order a CT scan of the brain in patients with MTBI. Nevertheless, some limitations of our study include: (1) The data collection is not comprehensive as it is a retrospective study; (2) Non-probabilistic sampling method; (3) Lack of clarity in the initial CT scan criteria; (4) The study was conducted at a single center, which may not be sufficiently representative.

In summary, the presence of a skull fracture on X-ray and clinical signs of a basilar skull fracture can be utilized as reference points for predicting abnormal CT scan results in patients with Mild Traumatic Brain Injury (MTBI).

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DISCLOSURE

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