Original Article

Clinical Association Factors for Abnormal Cranial CT Scan in Moderate-Risk Patients of Mild Traumatic Brain Injury

Arvemas Watcharakorn, M.D.[1*], Tanaphat Romsaiyut, M.D.[1], Kumpol Amnuaypattanapon, M.D.[2], Varalee Mingkwansook, M.D.[1]

Abstract

Introduction: Moderate-risk patients with mild traumatic brain injury have not needed routine cranial CT scans. The management can be observed after presentation or undergoing a cranial CT scan. A cranial CT scan in this group is warranted in selected cases. This study aims to find clinical association factors for abnormal cranial CT scan in moderate-risk patients of mild traumatic brain injury for identifying the patients who may need a cranial CT scan to reduce unnecessary cranial CT scans and the cost of treatment.

Objective: This study's purpose is to evaluate clinical association factors for abnormal cranial CT scan in moderate-risk patients of mild traumatic brain injury.

Methods: Data of moderate-risk patients with mild traumatic brain injury of Thammasat University Hospital with age ≥ 18 years and ≤ 64 years who underwent a cranial CT scan within the first 24 hours after the onset of the injury were collected. Multivariable logistic regression was used to determine positive CTs' adjusted odds ratio (OR).

Results: Of all 225 patients, 134 (59.6%) had negative cranial CT findings, and 91 (40.4%) had positive cranial CT findings. There were three independent clinical presentations associated with abnormal cranial CT findings including GCS, vomiting and post-traumatic amnesia, the adjusted OR (95% CI) of which were 2.32 (1.04-5.20) (*P*-value = .040), 4.86 (1.04-22.69) (*P*-value = .045) and 2.30 (1.12-4.35) (*P*-value = .010), respectively.

Conclusions: Clinical association factors for abnormal cranial CT scan in moderate-risk patients of mild traumatic brain injury, including GCS lower than 15, vomiting, and post-traumatic amnesia.

Keywords: Clinical factor, Abnormal cranial CT scan, Mild traumatic brain injury, Moderate risk.

Received: 21 February 2022 **Revised: 14 March 2022** **Accepted: 22 March 2022**

[1] Department of Radiology, Faculty of Medicine, Thammasat University, Pathum Thani, Thailand
[2] Department of Emergency Medicine, Faculty of Medicine, Thammasat University, Pathum Thani, Thailand
***Corresponding author:** Arvemas Watcharakorn, M.D., Department of Radiology, Faculty of Medicine, Thammasat University, Pathum Thani, Thailand
Email: arvemas@yahoo.com

Introduction

Traumatic brain injury is a common health problem worldwide.[1] In Thailand, approximately 9,285 patients died from road traffic injury in 2017 and 9,443 patients in 2018. The number of patients who have road traffic injuries is also increased from 360,275 patients in 2017 to 383,238 patients in 2018.[2]

Traumatic brain injury can be classified into three categories according to the Glasgow Coma Scale (GCS): mild (GCS 13-15), moderate (GCS 9-12), and severe (GCS < 8). Mild traumatic brain injury is the most common and accounts for 80% of all brain injury cases at the ER.[3] The main theme in mild traumatic injury cases is early detection of intracranial hemorrhage. However, recent studies reveal only 15% of patients with mild traumatic brain injuries patients had abnormal cranial CT scans, and only 1% of patients required brain surgery.[4,5]

Patients with mild traumatic brain injury are further classified into low-risk, moderate-risk, and high-risk groups. According to the Canadian CT Head Rule (CCHR), which was presented in 2001 by Stiell et al., the high-risk criteria include GCS < 15 at 2 hours after injury, suspected open or depressed skull fracture, any sign of skull base fracture (hemotympanum, raccoon eye, cerebrospinal fluid rhinorrhea, and otorrhea, Battle's sign), vomiting ≥ 2 episodes and age ≥ 65 years. The moderate-risk criteria include GCS = 15, short-term loss of consciousness, amnesia after trauma, vomiting, headache, and toxicity. The low-risk criteria are characterized by being asymptomatic at the time, no other injuries and focal neurological deficit and change in the level of consciousness, normal pupils, normal memory, GCS = 15, detailed history, mild injury mechanism, injury in less than 24 hours, no headache or a mild headache, no vomiting, and no high-risk factors.[6]

For patients classified as high-risk mild traumatic brain injury, a cranial CT scan should be performed due to the higher likelihood of clinically important intracranial injury. In contrast, patients classified as low-risk mild traumatic brain injury are not required further investigation. Nevertheless, patients classified as moderate-risk mild traumatic brain injury have not needed routine cranial CT scans. A cranial CT scan in this group is warranted in selected cases.[7] The management can be observed for a period following presentation or undergoing a cranial CT scan.

Increasing referrals to the radiology department complicate the management and imaging procedures. Therefore, the guidelines should be set with high sensitivity to help physicians triage the patients who need emergency cranial CT scans to reduce the economic burden of the health system and the exposure to radiation.

According to prior reports, a 10% decrease in the number of scans due to mild brain injury can reduce the expenditure of the US health system by about 20 million dollars.[8] Thus, this study's purpose is to find clinical association factors for abnormal cranial CT scan in moderate-risk patients of mild traumatic brain injury for identifying the patients who may need a cranial CT scan.

Methods

We performed a retrospective observational study conducted at Thammasat University Hospital in Pathum Thani, Thailand. This retrospective observational study was approved by the Research Ethics Board of the Faculty of Medicine, Thammasat University. According to G*Power version 3.1.7 with alpha = 0.05 and power = 0.8, the total sample size was 225 patients. The inclusion criteria were mild traumatic brain injury, moderate risk for intracranial hemorrhage (using modified criteria as below), age between 18 and 64 years, and a cranial CT scan was performed within the first 24 hours after the onset of the injury. In addition, the patients with poor imaging quality of a cranial CT scan or history of previous brain trauma/brain surgery were excluded. The study period was between June 1, 2019 and September 30, 2020.

We reviewed the literature about the moderate-risk patient with mild traumatic brain injury from Canadian CT Head Rule (CCHR)[7], Advanced Traumatic Life Support (ATLS) 10th edition,[9] and the latest version (2019) of Clinical Practice Guidelines for Traumatic Brain Injury, which was published in Thailand.[1] We modified the risk factors from these three guidelines then defined moderate risk of mild traumatic brain injury in our study as a GCS score of 13-14 (without any high risk criteria according to CCHR) or a GCS score of 15 accompanied by at least one sign or symptom of the following:

vomiting < 2 episodes, loss of consciousness, headache, post-traumatic amnesia, drug/alcohol intoxication, risk of bleeding tendency, and history of dangerous mechanism.

Operational clarifications of the studied symptoms were as follows: vomiting was defined as vomiting less than two interval episodes after head injury,[1] loss of consciousness was defined by loss of consciousness over 15 minutes or observed/witnessed loss of consciousness, the headache was any degree of headache after head injuries not related to the wound, post-traumatic amnesia was defined as a deficit in short term memory[5] or amnesia before impact (more than 30 minutes),[9] drug/alcohol intoxication was defined by any history of drug/alcohol consumption, risk of bleeding tendency was defined as a history of using antiplatelet drugs or the diseases that related to a bleeding disorder, and the dangerous mechanism was defined by fall from > 0.9 meters or 3 feet, direct blunt head injury, motorcycle accident, traffic accident that patient falls out from the vehicle/other patient died/overturned vehicle and pedestrian injury.

Clinical data of all included patients were recorded, including baseline characteristics, Glasgow Coma Scale, comorbidities, medications, symptoms, and mechanism of the head injury. The non-contrast cranial CT scans were performed by multidetector CT scanners (Philips Brilliance iCT 256-Slice Scanner, Siemens Somatom definition AS 128-Slice CT scanner, and Philips Iqon spectral Multidetector 128-Slice CT scanner). Multiplanar reconstructions were done in 5-mm slice thickness in the axial plane and 3-mm slice thickness in the coronal and sagittal planes for the brain window, and 3-mm slice thickness in the axial, coronal, and sagittal planes for the bone window. The positive results of the cranial CT scan (Figures 1-4) included a skull fracture, epidural hematoma (EDH), subdural hematoma (SDH), subarachnoid hemorrhage (SAH), parenchymal injury (cerebral contusion and intracerebral hemorrhage (ICH)), intraventricular hemorrhage (IVH), and pneumocephalus. These cranial CT findings were reviewed by two neuroradiologists. The equivocal findings were made consensus.

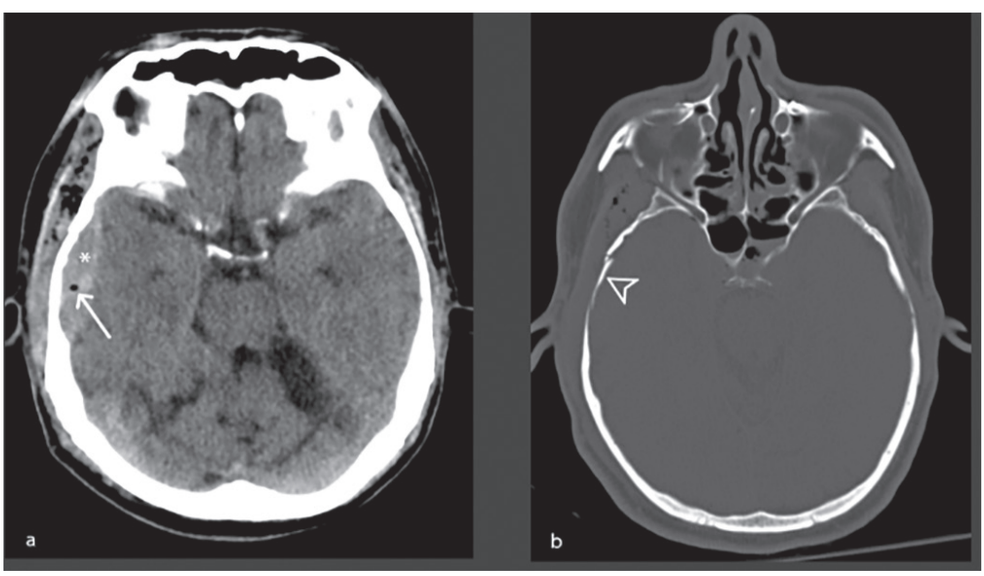

Figure 1 (a) Axial cranial CT scan (brain window) shows extra-axial, lens-shaped hyperdense lesion along the right temporal convexity (*), compatible with epidural hematoma, with internal pneumocephalus (arrow). Overlying soft tissue swelling and subcutaneous emphysema at the right temporal region are seen. Encephalomalacia at bilateral cerebellar hemispheres is also noted. (b) Axial cranial CT scan (bone window) shows fractures at the squamous part of the right temporal bone (arrowhead).

Figure 2 Axial cranial CT scan (brain window) shows extra-axial, crescent-shaped hyperdense lesion along the left fronto-parietal convexity (arrow), compatible with acute subdural hematoma.

Figure 3 Axial cranial CT scan (brain window) shows a well-defined hyperdense lesion with mild perilesional edema at the inferior aspect of right frontal lobe (arrow), compatible with cerebral contusion.

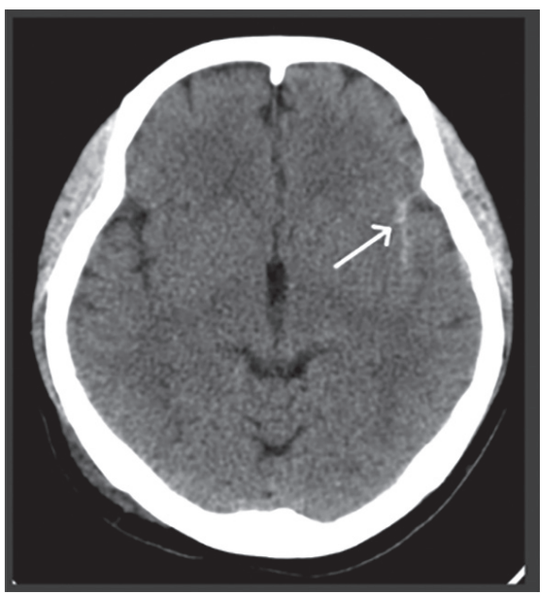

Figure 4 Axial cranial CT scan (brain window) shows an extra-axial, curvilinear hyperdense lesion in the left Sylvian fissure (arrow), compatible with subarachnoid hemorrhage.

Statistical Analysis

Eligible patients were categorized with negative and positive CT findings. The positive CT findings included a skull fracture, EDH, SDH, SAH, parenchymal injury, IVH, and pneumocephalus. Numerical variables with normally distributed data are presented as the mean (standard deviation) and compared using Student's t-test, while non-normally distributed data were presented as the median (interquartile range) and compared using the Mann-Whitney U test. Categorical variables were expressed as number and percentage and compared using the chi-square test or Fisher's exact test, as appropriate. In moderate-risk patients of mild traumatic brain injury, clinical association factors for abnormal cranial CT scans were analyzed using univariable and multivariable logistic regression analyses.

According to univariable logistic analysis, factors with a *P*-value of less than 0.1 and factors that may be related to abnormal cranial CT findings were included in the multivariable logistic analysis. Results of the model were reported as adjusted odds ratio (OR) and 95% confidence interval (CI). A *P*-value of < .05 was considered statistically significant. The entire analysis was performed using STATA software, version 12.0 (College Station, Texas, USA).

Results

Two hundred and twenty-five patients were enrolled in this study. Most of the patients were male (n = 171, 76%), and the rest were female (n = 54, 24%). The median patients' age was 32 years old (IQR = 22 - 44). According to the K-Means method, all patients were further classified into three age groups like 18 to 33 years old, 34 to 48 years old, and 49 to 64 years old.[10] The peak age group of moderate-risk patients with mild traumatic brain injury was in the youngest group, about 123 (54.7%). As shown in Table 1, most of all patients had GCS = 15 (n = 192, 85.3%). While the most common clinical presentation in moderate-risk patients with mild traumatic brain injury was the history of dangerous mechanism (n = 205, 91.1%) followed by post-traumatic amnesia (n = 120, 53.3%) and loss of consciousness (n = 110, 48.9%). Of all 225 patients, 134 (59.6%) had negative cranial CT findings, and 91 (40.4%) had positive cranial CT findings. The most common positive cranial CT finding was skull fracture (n = 61, 27.1%) followed by SAH (n = 54, 22.7%), SDH (n = 19, 8.4%), parenchymal injury (n = 17, 7.6%), pneumocephalus (n = 11, 4.9%), EDH and IVH (n = 6, 2.7% each). Table 2 shows no statistical differences in general characteristics of the moderate-risk patients with mild traumatic brain injury, whereas GCS was the only clinical presentation with a significantly higher proportion of patients with abnormal cranial CT findings (*P*-value = .030). There were three independent clinical presentations associated with abnormal cranial CT findings including GCS, vomiting, and post-traumatic amnesia, the adjusted OR (95% CI) of which were 2.32 (1.04-5.20) (*P*-value = .040), 4.86 (1.04-22.69) (*P*-value = .045), and 2.30 (1.12-4.35) (*P*-value = .010), respectively (Table 3).

Table 1 Number and percentage of general characteristics, clinical presentations, and cranial CT findings of moderate-risk patients with mild traumatic brain injury (n = 225)

Factors	n (%)
General characteristics	
Gender	
Male	171 (76.0)
Female	54 (24.0)
Median age [IQR]; year	32 [22 - 44]
Age group	
18-33	123 (54.7)
34-48	65 (28.9)
49-64	37 (16.4)
Clinical presentation	
Glasgow coma scale (GCS)	
13	4 (1.8)
14	29 (12.9)
15	192 (85.3)
Vomiting	13 (5.8)
Loss of consciousness (LOC)	110 (48.9)
Headache	9 (4.0)
Post-traumatic amnesia	120 (53.3)
Drug/Alcohol intoxication	65 (28.9)
Risk of bleeding tendency	2 (0.9)
Dangerous mechanism	205 (91.1)
Cranial CT finding	
Negative finding	134 (59.6)
Positive finding	91 (40.4)
Skull fracture	61 (27.1)
Epidural hematoma (EDH)	6 (2.7)
Subdural hematoma (SDH)	19 (8.4)
Subarachnoid hemorrhage (SAH)	51 (22.7)
Parenchymal injury	17 (7.6)
Intraventricular hemorrhage (IVH)	6 (2.7)
Pneumocephalus	11 (4.9)

Note: Data presented as number (percentage) unless indicated otherwise, IQR: Interquartile range.

Table 2 Comparing general characteristics and clinical presentations between cranial CT findings (positive and negative studies) in moderate-risk patients with mild traumatic brain injury

Factors	CT positive n (%)	CT negative n (%)	*P*-value
General characteristics			
Gender			
Male	71 (78.0)	100 (74.6)	.558
Female	20 (22.0)	34 (25.4)	
Median age [IQR]; year[M]	28 [22-40]	33.5 [22.8-45.3]	.072
Age group; year			
18-33	56 (61.5)	67 (50.0)	.181
34-48	24 (26.4)	41 (30.6)	
49-64	11 (12.1)	26 (19.4)	
Clinical presentation			
Glasgow coma scale (GCS)			
13-14	19 (20.9)	14 (10.4)	.030*
15	72 (79.1)	120 (89.6)	
Vomiting	8 (8.8)	5 (3.7)	.110
Loss of consciousness (LOC)	42 (46.2)	68 (50.7)	.499
Headache[F]	4 (4.4)	5 (3.7)	.803
Post-traumatic amnesia	55 (60.4)	65 (48.5)	.078
Drug/Alcohol intoxication	26 (28.6)	39 (29.1)	.931
Risk of bleeding tendency[F]	-	2 (1.5)	.516
Dangerous mechanism[F]	87 (95.6)	118 (88.1)	.058

*Statistically significant at *P*-value < .05 determined by Chi-square test, F Fisher's exact test and M Mann-Whitney U test.

Table 3 Multivariable logistic regression analysis to identify the independent factors associated with abnormal cranial CT finding among 225 moderate-risk patients with mild traumatic brain injury

Factors	Adjusted OR (95% CI)	*P* -value
General characteristics		
Gender		
Male	1.23 (0.61-2.46)	.568
Female	Ref	
Age group; year		
18-33	2.15 (0.93-4.94)	.072
34-48	1.62 (0.65-4.07)	.302
49-64	Ref	
Clinical presentation		
Glasgow coma scale (GCS)		
13-14	2.32 (1.04-5.20)	.040*
15	Ref	
Vomiting	4.86 (1.04-22.69)	.045*
Loss of consciousness	0.71 (0.38-1.31)	.268
Headache	0.67 (0.11-4.11)	.664
Post-traumatic amnesia	2.30 (1.12-4.35)	.010*
Drug/Alcohol intoxication	0.95 (0.48-1.88)	.883
Dangerous mechanism	2.85 (0.88-9.21)	.080

*Statistically significant at *P*-value < .05 determined by logistic regression. (OR: Odds ratio, Ref: Reference).

Discussion

After the adjustment for clinical presentation, three independent factors were associated with the presence of abnormal cranial CT findings in moderate-risk patients of mild traumatic brain injury, including GCS, vomiting, and post-traumatic amnesia.

Vomiting was one of the independent factors associated with abnormal cranial CT findings. In this study, patients with vomiting in case of mild traumatic brain injury were accompanied by about the fourfold more significant risk for abnormal cranial CT findings (adjusted OR = 4.86, 95% CI of 1.04-22.69). Similarly, Srichaikul[11] found that vomiting was one of the clinical factors related to abnormal brain lesions in mild traumatic brain injuries. Alhoseini et al.[12] also said that vomiting was separately associated with abnormal brain CT scans related to the trauma. In the same way, Mishra et al.[13] found that vomiting after head injury was significantly associated with abnormal CT scans. In contrast, Yuksen et al.[14] showed that vomiting was not significantly associated with the presence of intracranial hemorrhage in patients who were diagnosed as a mild head injury with moderate risk. This result may be explained by differences in the positive CT finding focusing on an intracranial hemorrhage only and interval time from the onset of head injury to cranial CT scan. Langroudi et al.[15] and Limsuriyakan et al.[16] noted that vomiting was not significantly associated with abnormal brain CT scans in patients with mild brain trauma. The results may be from the differences in the definition of vomiting that our study clearly defined the frequency of vomiting as less than two episodes. Moreover, the difference in the study population may cause these different results. Nevertheless, Rafay et al.[17] said that in mild head injury with one or multiple episodes of vomiting, most patients had normal CT scan brain while around one-third of the patients had positive CT scan findings. So, the use of CT scan in the mild head trauma patient with vomiting is still debatable and need more evidence and studies in this regard.

GCS was one of the independent factors associated with abnormal cranial CT findings. In this study, the reduction of GCS from 15 to 13-14 in case of mild traumatic brain injury was accompanied by about the twofold greater risk for abnormal cranial CT findings (adjusted OR = 2.32, 95% CI 1.04-5.20). Similarly, Yuksen et al.[14] found that one of the independent factors for intracranial hemorrhage was GCS. Patients with lower GCS got a higher risk for intracranial hemorrhage, and a baseline GCS of 13 carried a 100% risk of intracranial hemorrhage.[14] Likewise, Seddighi et al.[18] found that patients with a GCS of 13-14 were more prone to deterioration compared with those with a GCS of 15. In contrast, Langroudi et al.[15] showed that the GCS was not a statistically significant factor related to positive CT findings. The result may be from that study focusing on GCS 13 and 14, while our study included GCS from 13 to 15. At the same time, the different study populations may also lead to this different result. From our result, we recommend that a cranial CT scan should be performed in patients with mild traumatic brain injury who have GCS lower than 15.

Another independent factor associated with abnormal cranial CT findings was post-traumatic amnesia. In this study, the patients with post-traumatic amnesia in case of mild traumatic brain injury were accompanied by about the twofold greater risk for abnormal cranial CT findings (adjusted OR = 2.30, 95% CI of 1.12-4.35). Srichaikul[11] and Alhoseini et al.[12] also discovered that loss of consciousness or amnesia was one of the clinical factors related to abnormal brain CT scans in patients with mild traumatic brain injuries. On the other hand, Yuksen et al.[14] found that amnesia was not significantly associated with the presence of intracranial hemorrhage in patients who were diagnosed as a mild head injury with moderate risk. Differences in the positive CT findings may explain that this study focused on intracranial hemorrhage only. In contrast, our study included a skull fracture, EDH, SDH, SAH, parenchymal injury, IVH, and pneumocephalus. Interval time from the onset of head injury to cranial CT scan may be another cause leading to the different results. Moreover, Limsuriyakan et al.[16] and Seddighi et al.[18] also said that amnesia was not significantly associated with the presence of intracranial hemorrhage in a mild head injury with moderate risk. The difference in study populations may explain this result. Our study enrolled patients between 18 and 64 years old who met the inclusion criteria, while Limsuriyakan et al.[16] and Seddighi et al.[18] included patients of all ages.

Previous studies have reported several factors predictive for intracranial hemorrhages, such as the history of loss of consciousness[11,12,14] or headache.[12,14] In contrast, these were not independent factors in our study. The results may be explained by some studies' differences in the population, the interval time from the onset of head injury to cranial CT scan, the definition of the positive CT findings, statistical analysis, or the term of loss of consciousness or headache.

Other previous studies found that alcohol intoxication was associated with abnormal brain CT[11,12] but not significant in our study. It may be explained by the differences in the statistical analysis and study population.

The risk of bleeding tendency showed no statistical significance in our study. In contrast, Limsuriyakan et al.[16] and Seddighi et al.[18] found that patients with a history of coagulopathy or anticoagulant drug use were associated with intracerebral hemorrhage in mild head injury with moderate-risk patients. The result may be from a very low incidence of risk of bleeding tendency in our population. Moreover, our study design is a retrospective observational study. Therefore, some data may be lost.

The dangerous mechanism also showed no statistical significance in our study. However, some previous studies showed that the dangerous mechanism was a significant factor associated with intracranial hemorrhage in mild head injury patients.[15,16] The difference in the study population and some of the details of the dangerous mechanism may cause these different results.

In addition, the major difference between our study and most of the previous studies was the reviewer and review's method. In our study, two neuroradiologists reviewed cranial CT findings for both brain and bone windows in axial, coronal, and sagittal planes. In contrast, most of the earlier studies just used the official report. Again, this may cause a difference in some results.

Our study had some limitations. First, our study was based on the data collected retrospectively, which might cause missing some factors. Second, our study was a single-site study conducted in Thailand. Therefore, there might be different results in other centers or other countries.

We recommended that abnormal cranial CT scan in moderate-risk patients of mild traumatic brain injury be predicted by the following clinical association factors: GCS lower than 15, vomiting, and post-traumatic amnesia. Thus, a cranial CT scan should be performed if any patient has these clinical association factors in moderate risk, mild traumatic brain injury.

Acknowledgements

Financial support. None reported.

All authors report no conflicts of interest relevant to this article.

References

1. Phuenpathom N, Srikijvilaikul T. *Clinical Practice Guidelines for Traumatic Brain Injury. 1st ed.* Bangkok: Prosperous Plus; 2019.
2. Thairsc. Road Accident Victims Protection Company Limited. http://www.thairsc.com/. Published 2021. Accessed October 17, 2021.
3. Levin HS, Narayan RK, Wilberger JE, Povlishock JT. *Outcome from mild head injury in Neurotrauma.* New York, NY: McGraw-Hill; 1996.
4. Haydel MJ, Preston CA, Mills TJ, Luber S, Blaudeau E, DeBlieux PMC. Indications for computed tomography in patients with minor head injury. *N Engl J Med.* 2000;343:100-105.
5. Stiell IG, Clement CM, Rowe BH, et al. Comparison of the Canadian CT head rule and the New Orleans criteria in patients with minor head injury. *JAMA.* 2005;294:1511-1518.
6. Haydel MJ. Clinical decision instruments for CT scanning in minor head injury. *JAMA.* 2005;294:1551-1553.
7. Goergen S, Varma D, Tavender E, et al. Adult head trauma, education modules for appropriate imaging referrals. *Royal Australian and New Zealand College of Radiologists.* 2015: 1-32.
8. Mack LR, Chan SB, Silva JC, Hogan TM. The use of head computed tomography in elderly patients sustaining minor head trauma. *J Emerg Med.* 2003;24:157-162.
9. American College of Surgeons. *Advanced Trauma Life Support® Student Course Manual. 10th edition.* Chicago: American College of Surgeons; 2018.
10. Geifman N, Cohen R, Rubin E. Redefining meaningful age groups in the context of disease. *AGE*. 2013;35:2357-2366.

11. Srichaikul P. The prevalence and factors related to abnormal brain lesions in the mild traumatic brain injuries of patients admitted to the emergency room of Banglamung hospital. *J Prapokklao Hosp Clin Med Educat Center.* 2018;35:363-371.
12. Sharif-Alhoseini M, Khodadadi H, Chardoli M, Rahimi-Movaghar V. Indications for brain computed tomography scan after minor head injury. *J Emerg Trauma Shock.* 2011;4:472-476.
13. Mishra RK, Munivenkatappa A, Prathyusha V, Shukla DP, Devi BI. Clinical predictors of abnormal head computed tomography scan in patients who are conscious after head injury. *J Neurosci Rural Pract.* 2017;8:64-67.
14. Yuksen C, Sittichanbuncha Y, Patumanond J, et al. Clinical factors predictive for intracranial hemorrhage in mild head injury. *Hindawi Neurology Research International.* 2017:1-5.
15. Molaei-Langroudi R, Alizadeh A, Kazemnejad-Leili E, Monsef-Kasmaie V, Moshirian S. Evaluation of clinical criteria for performing brain CT-Scan in patients with mild traumatic brain injury. *Bull Emerg Trauma.* 2019;7:269-277.
16. Limsuriyakan W, Lorwanich P. Factors associated with intracranial hemorrhage in mild traumatic brain injury moderated risk patients at Phra Nakhon Si Ayutthaya Hospital. *TUH Journal online.* 2019;4:1-10.
17. Rafay M, Hussain F, Gulzar F, Ain N, Sharif S. Vomiting in mild head injury, an indicator for CT scan. *Surgery Curr Res.* 2019;9:331.
18. Seddighi AS, Motiei-Langroudi R, Sadeghian H, et al. Factors predicting early deterioration in mild brain trauma: A prospective study. *Brain Inj.* 2013;27:1666-1670.