Factors associated with intracranial injury in blast-induced traumatic brain injury

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Abstract

Background: Blast-induced traumatic brain injury (bTBI) is one of the major causes of death from traumatic brain injury (TBI) in southern Thailand. However, no consensus has been proposed for the indication of cranial computed tomography (CCT) in bTBI. Therefore, this study aimed to identify the factors associated with intracranial injury after CCT.

Methods: A retrospective cohort study was performed on patients with bTBI. Clinical and radiologic characteristics were collected. The outcome of the present study was intracranial injury after CCT that included any type of skull fracture, epidural hematoma, subdural hematoma, coup contusion, contrecoup contusion, intraventricular hemorrhage, subarachnoid hemorrhage, or diffuse axonal injury. Binary logistic regression analysis was performed to identify the factors associated with intracranial injury following CCT.

Results: There were 80 patients in the present study with a median age of 32.5 years (IQR 19). According to the severity of bTBI, the majority of patients had mild TBI in 66.3% of all cases. Moderate TBI was found in 10%, where 23.8% of the present cohort comprised severe TBI. Therefore, intracranial injuries were found in 62.5% of all cases. Using multiple logistic regression analysis with a backward stepwise procedure, one factor associated with intracranial injury following CCT was the severity of bTBI (OR of moderate TBI 2.9, 95%CI 0.53-15.63 and OR of severe TBI 8.2, 95%CI 1.71-38.99, Reference mild TBI).

Conclusion: The severity of bTBI associated with intracranial injury after CCT should be considered for the development of guidelines concerning CCT for implicating mass causality triage and setting priorities for investigation in the future.

Keywords: Blast-induced traumatic brain injury, Intracranial injury, Traumatic brain injury

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Abbreviations used in this paper:
bTBI: Blast-induced traumatic brain injury, CCT: cranial computed tomography, DAI: diffuse axonal injury, GCS: Glasgow Coma Scale, IQR: interquartile range, OR: odds ratio, TBI: traumatic brain injury

บทคัดย่อ

ปัจจัยที่สัมพันธ์กับการบาดเจ็บสมองในผู้บาดเจ็บสมองจากระเบิด

คณิศร สังฆะโร, ธาราณ์ ตันธนาธิป

ที่มาและความสำคัญ: การบาดเจ็บสมองจากระเบิด เป็นสาเหตุหนึ่งของการเสียชีวิตจากการบาดเจ็บสมองในภาคใต้ ประเทศไทย อย่างไรก็ตาม ปัจจุบันยังไม่มีข้อบ่งชี้ที่ชัดเจนในการส่งตรวจเอกซเรย์คอมพิวเตอร์สมองจากการบาดเจ็บสมองจากระเบิด ดังนั้นการศึกษานี้มีวัตถุประสงค์เพื่อศึกษาปัจจัยที่สัมพันธ์กับการเกิดการบาดเจ็บสมองหลังการส่งตรวจเอกซเรย์คอมพิวเตอร์ในผู้บาดเจ็บกลุ่มดังกล่าว

วิธีการ: การศึกษานี้เป็นการศึกษาแบบย้อนหลังในผู้บาดเจ็บสมองจากระเบิด โดยทำการเก็บข้อมูลทางคลินิกและทางภาพถ่ายรังสีจากการทบทวนเวชระเบียน โดยผลลัพธ์ของการศึกษานี้ ประกอบด้วย การมีพยาธิสภาพการบาดเจ็บสมอง ดังนี้ กะโหลกแตก epidural hematoma, subdural hematoma, coup contusion, contrecoup contusion, intraventricular hemorrhage, subarachnoid hemorrhage และ diffuse axonal injury การวิเคราะห์ปัจจัยที่สัมพันธ์กับการเกิดการบาดเจ็บสมองหลังการส่งตรวจเอกซเรย์คอมพิวเตอร์โดยใช้สถิติ binary logistic regression

ผลการศึกษา: ผู้บาดเจ็บสมองจากระเบิดจำนวน 80 รายมีค่ามัธยฐานอายุ 32.5 ปี (Interquartile range (IQR) 19) เมื่อพิจารณาตามระดับความรุนแรง พบว่าส่วนใหญ่ร้อยละ 66.3 มีความรุนแรงระดับ mild TBI ความรุนแรงระดับ moderate TBI และ severe TBI พบได้ร้อยละ 23.8 และ 62.5 ตามลำดับ เมื่อวิเคราะห์ทางสถิติโดยวิธี multiple logistic regression analysis with a backward stepwise procedure พบว่าปัจจัยที่สัมพันธ์กับการเกิดการบาดเจ็บสมอง คือ ระดับความรุนแรง (Odds ratio(OR) ของ moderate TBI 2.9 95%CI 0.53-15.63 และ OR ของ severe TBI 8.2, 95%CI 1.71-38.99, กลุ่มอ้างอิง mild TBI)

สรุป: ระดับความรุนแรงเป็นปัจจัยที่สัมพันธ์กับการเกิดการบาดเจ็บสมอง ที่อาจนำมาใช้พิจารณาหรือพัฒนาแนวทางการส่งตรวจเอกซเรย์คอมพิวเตอร์สมอง การจัดการอุบัติภัยหมู่และจัดลำดับความสำคัญในการส่งตรวจวินิจฉัยเพิ่มเติมในผู้บาดเจ็บเหตุการณ์ระเบิด ต่อไปในอนาคต

Introduction

Blast-induced traumatic brain injury (bTBI) is one of the major causes of death from traumatic brain injury (TBI) in southern Thailand. The unrest in southern Thailand has persisted since 2001, with terrorist bombings having occurred more than 2,000 times[1]; cumulate mortality from the unrest was reported at 7,233 persons.[2] From a prior study, a mortality rate of bTBI was 11.4% of cases, with an unfavorable outcome being observed in 24.3%. Tunthanathip et al. reported that the factors associated with outcomes comprised midline shift ≥ 5 mm and coagulopathy.[3]

Cranial computed tomography (CCT) is the standard tool for the diagnosis and evaluation of intracranial injury following TBI with a blunt mechanism. From the literature review, various clinical decision rules have been proposed in mild TBI. The Canadian CT Head Rule and the New Orleans Criteria have been used as criteria for CCT.[4,5] The Canadian CT Head Rule showed sensitivity and specificity for intracranial lesion detection at 87% and 39%, respectively, whereas the New Orleans Criteria showed 99% and 5% for sensitivity and specificity, respectively.[6]

CCT is the gold standard diagnostic tool for detecting intracranial injury following TBI. However, triage requires the selection of those patients who are predicted to have an intracranial injury in a mass casualty situation. From the literature review, no consensus has been proposed for the indication of CCT in bTBI. From expert opinions, the Defense and Veterans' Brain Injury Center questionnaire was used for screening when making the decision to perform CCT.[7-9]

There is a lack of evidence mentioning the predictors related to intracranial injury in patients suffering from bTBI. Therefore, this study aimed to identify the factors associated with intracranial injury after CCT.

Materials and Methods

Study design and population

The bTBI cases were retrospectively selected from a database between January 2009 and July 2021. Patients who did not undergo CCT, had died within the first 24 hours, had inaccessible or incomplete medical records during admission, or could not assess update outcomes were excluded. The study was approved by the Human Research Ethics Committee of the Faculty of Medicine, Songklanagarind Hospital, Prince of Songkla University (REC 64-405-10-1).

Clinical and radiological data were collected for analysis. bTBI cases were divided into three groups according to severity. In detail, mild TBI comprised patients with a Glasgow Coma Scale (GCS) score of 13–15, while patients with a GCS score of 9–12 were classed as moderate TBI. Finally, patients who had GCS scores of 3–8 were classed as severe TBI.[10] The radiological findings were reviewed by two neurosurgeons. Moreover, diffuse axonal injury (DAI) was defined as a patient with severe TBI who had CCT or magnetic resonance imaging showing either normal outcomes or signs of DAI, following Vieira et al.[11]

The outcome of the present study was intracranial injury after CCT that included any type of skull fracture, epidural hematoma, subdural hematoma, coup contusion, contrecoup contusion, intraventricular hemorrhage, subarachnoid hemorrhage, or DAI. Moreover, the location and lateralization of the main positive findings were evaluated.

Statistical analysis

All demographic variables were analyzed using descriptive statistics as follows: median with interquartile range (IQR) was used for describing continuous variables, while the categorical variables were described in percentages.

The differences in results of CCT were compared by the chi-square test and independent t-test. For the categorical variable, the chi-square test was performed to test the difference in the distribution of each variable across outcome groups. An independent t-test was also used to show the difference in the binary outcomes in the continuous variables. *P*-values < 0.05 were regarded as statistically significant. Therefore, the factors that were associated with intracranial injury after CCT were shown in univariate analysis. Therefore, we performed multiple logistic regression with the initial model performed by all clinical characteristics. A backward stepwise method was used, and the factors with a p-value less than 0.05 were kept for the final model. Statistical analysis was done using R-version 3.6.2 software (R Foundation, Vienna, Austria).

Results

Eighty-five patients suffering from bTBI were included in the present study. Five patients were excluded because they did not perform CCTs. Thus, the present study included 80 patients; their baseline characteristics are presented in Table 1. The median age was 32.5 years (IQR 19), and two-thirds of patients were male. More than two-thirds of patients with bTBI had a scalp hematoma/injury, and post-traumatic seizure was observed in 2.5%. According to the severity of TBI, the majority of patients had mild TBI, comprising 66.3% of all cases. Moderate TBI was found in 10%, whereas 23.8% of the present cohort had severe TBI.

Intracranial injuries were found in 62.5% (50/80). From the radiological findings, intracranial injuries were demonstrated as shown in Table 2. Coup contusion, subdural hematoma and subarachnoid hemorrhage were common findings following CCT. Moreover, DAI was found in 8.8%, with the frontal lobe being the most common location of injury.

Table 1. Demographic data following the results of cranial CT (N=80)

Factor	Results of cranial CT		Total	*p*-value
	Negative finding (%)	Intracranial injury (%)		
Gender				0.12
Male	26 (35.1)	48 (64.9)	74	
Female	4 (66.7)	2 (33.3)	6	
Median age (IQR)-years	31 (23.0)	34 (18.0)	32.5 (19)	0.71*
Age group-years				0.44
< 30	14 (42.4)	19 (57.6)		
≥ 30	16 (34.0)	31 (66.0)		
Military personnel	24 (41.4)	34 (58.6)	58	0.24
Signs and symptoms				
Loss of consciousness	9 (47.4)	10 (52.6)	19	0.30
Amnesia	10 (41.7)	14 (58.3)	24	0.61
Scalp hematoma/injury	22 (42.3)	30 (57.7)	52	0.22
Seizure	1 (50.0)	1 (5.00)	2	0.71
Weakness	2 (66.7)	1 (33.3)	3	0.28
Bleeding from nose/ears	1 (25.0)	3 (75.0)	4	0.59
Episode of hypotension	5 (27.8)	13 (72.2)	18	0.33
Episode of hypoxia	3 (33.3)	6 (66.7)	9	0.78
Coagulopathy	3 (18.8)	13 (81.3)	16	0.08
Pupillary light reflex				0.19
Fixed both eyes	1 (20.0)	4 (80.0)	5	
Fixed one eye	1 (12.5)	7 (87.5)	9	
React both eyes	28 (41.8)	39 (58.2)	67	
Severity				0.009
GCS 13-15	26 (49.1)	27 (50.9)	53	
GCS 9-12	2 (25.0)	6 (75.0)	8	
GCS 3-8	2 (10.5)	16 (89.5)	19	

**p*-value of independent t-test

Table 2 Characteristics of intracranial injury (N=50)

Intracranial injury	N (%)
Skull fracture	
Depressed skull fracture	23 (28.8)
Non-depressed skull fracture	7 (8.8)
Basilar skull fracture	9 (11.3)
Epidural hematoma	10 (12.5)
Subdural hematoma	25 (31.3)
Coup contusion	32 (40.0)
Contrecoup contusion	2 (2.5)
Subarachnoid hemorrhage	26 (32.5)
Diffuse axonal injury	7 (8.8)
Lateralization	
Left	31 (28.8)
Right	16 (20.0)
Bilateral	25 (31.3)
Midline	2 (2.5)
Location of major injury	
Frontal	18 (22.5)
Temporal	17 (21.3)
Parietal	11 (13.8)
Occipital	8 (10)
Other	4 (5.0)

Factors associated with intracranial injury

The severity of bTBI showed a significant difference between negative findings and positive findings groups. The majority of patients with negative findings after CCT had mild TBI in 32% (26/80), while severe TBI had negative results in 2.5% (2/80). Moreover, other clinical characteristics such as median age and pupillary light reflex showed no differences between the two groups. Therefore, binary logistic regression was performed for both univariate and multivariable analysis with the backward stepwise procedure.

The crude odds ratios (OR) were revealed using univariate analysis, as shown in Figure 1. Only severity of bTBI significantly related to intracranial injury after CCT (OR of moderate TBI 2.9, 95%CI 0.53-15.63 and OR of severe TBI 8.2, 95%CI 1.71-38.99, Reference mild TBI). Therefore, multivariable analysis with the backward stepwise procedure was initiated from

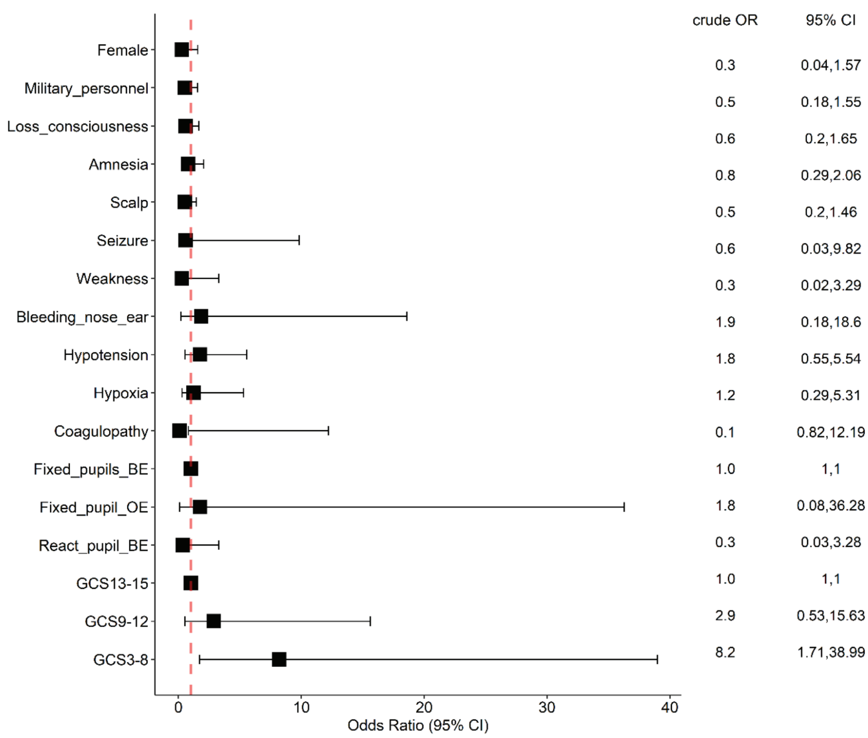

Figure 1 Forest plot of crude odds ratio from univariate analysis of binary logistic regression

the full model with all clinical characteristics, as shown in Figure 2. Further, multiple logistic regression was conducted with a backward stepwise procedure and the final model was demonstrated, as shown in Figure 3.

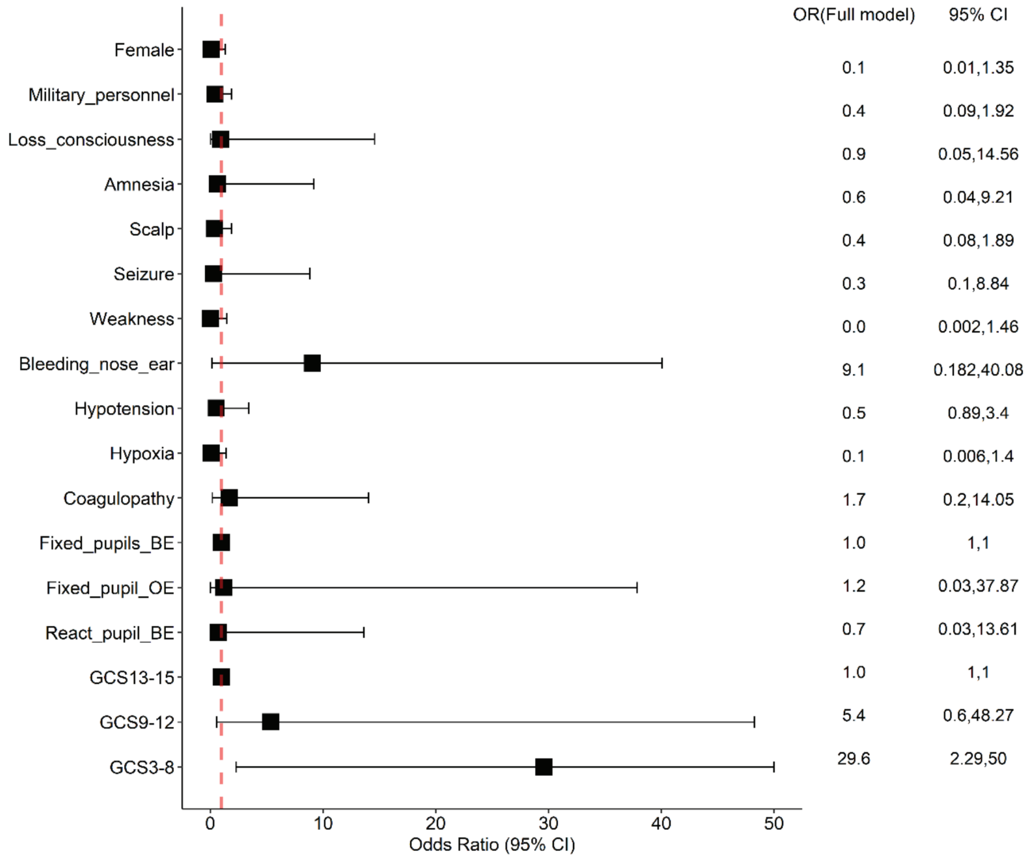

Figure 2 Forest plot of odds ratio from the full model of multiple logistic regression

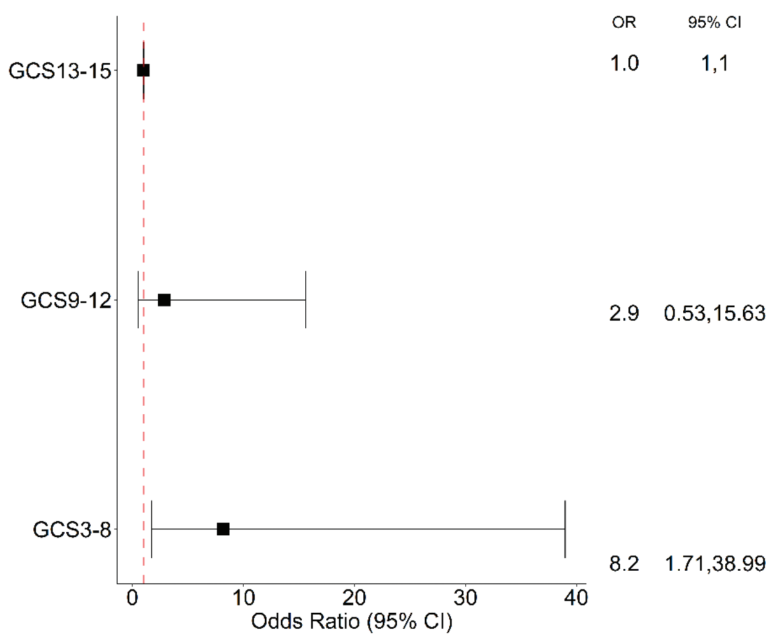

Figure 3 Forest plot of odds ratio from the final model of multiple logistic regression

Discussion

Intracranial injuries have been caused by the unrest and bombings in southern Thailand. Commonly, the blast wave from an explosion leads to primary blast injury via the Friedländer waveform. A shrapnel or bone fragment penetrating the brain causes secondary blast injury, while a tertiary blast injury develops from the acceleration-deceleration injury, producing coup and contrecoup contusion.[7,8,12] In the present study, almost two-thirds of bTBI cases had an intracranial injury.

The bombings in the present study occurred in civilian situations, making mass casualty triage a challenge to manage. As a result, the severity of bTBI by GCS was associated with intracranial injury. In severe TBI, intracranial injury was found in 89.5%, whereas positive findings in mild TBI accounted for 50.9%. These results are in concordance with other research reports. MacGregor et al. studied intracranial injury in combat-related TBI during Operation Iraqi Freedom. They found that intracranial injury accounted for 99.6%, 58.8%, and 69.5% for mild, moderate, and severe TBI, respectively.[13] Hence, the priority that should be investigated by CCT is the patients who had GCS less than 9. However, mild and moderate TBI still needs CCT because positive results for CCT are commonly found in these groups. When triage in the emergency department has been controlled, these patients should undergo CCT based on recommendations.

From prior studies, Tunthanathip et al. reported that bleeding per nose/ear and pupillary light reflex were the potential factors predicting the intracranial injuries after CCT in pediatric TBI.[14] However, these factors were not significantly associated with intracranial injury following CCT in the present study because a limitation of a small sample size was observed. Multi-center studies or systematic reviews and meta-analysis should be conducted in the future for mitigating the limitation. Moreover, another limitation of this study should be acknowledged: The retrospective design of the present study may have led to certain biases and confounders.[15-17] However, we were concerned about this limitation and used multivariable analysis to account for this problem.[18,19]

Finally, the present study is the first paper that proposed the factors associated with intracranial injury, which may be further explored and developed for clinical prediction rules to use in real-world situations in the future.

Conclusion

The severity of bTBI associated with intracranial injury after CCT should be considered for the development of guidelines concerning CCT for implicating mass causality triage and setting priorities for investigation in the future.

Conflicts of Interest

None.

Ethical Clearance

All procedures performed in the study that involved studies concerning human participants followed the ethical standards as set by the institutional and/or national research committee or both, as well as the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Study was performed with exemption determination from the Ethics Committee of the Faculty of Medicine, Songklanagarind Hospital, Prince of Songkla University (REC 64-405-10-1).

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