The Study of the Characters of Traumatic Brain Injuries (TBI) in Blunt Head Trauma Caused by Velocity-Related Injuries

Nathathai Suvitsakulwong MD[1,2]
Peerayuht Phuangphung MD, PhD[2*]
[1] Sakon Nakhon Hospital, Ministry of Public Health, Sakon Nakhon province, Thailand
[2] Department of Forensic Medicine, Faculty of Medicine, Siriraj Hospital, Mahidol University, Bangkok, Thailand
* Corresponding author, e-mail address: peerayuht.phu@mahidol.ac.th
Vajira Med J. 2022; 66(3): 199-210
http://dx.doi.org/10.14456/vmj.2022.20

Abstract

Objectives: To determine the characters of traumatic brain injuries (TBI) related to the occurrence of coup-contrecoup phenomenon in blunt head trauma from velocity-related injuries

Methods: The prospective case control study was conducted in Thai postmortem cases sent for autopsies at the Department of Forensic Medicine, Siriraj Hospital, Mahidol University between 11th February 2021 and 31st December 2021. Subjects recruited had the age of 18 years old or over and were dead from traffic accident or falling from height. Data including sex, age, height and weight, configurations of skull, sites of scalp contusion, skull and skull base fracture, brain weight, epidural and subdural hemorrhage, coup-contrecoup contusion and macroscopic spot hemorrhage in white matter were recorded. The comparison of the characters of TBI between the presence and the absence of coup-contrecoup phenomenon was analyzed using descriptive statistics, independent sample t-test, Mann-Whitney U test and contingency table Chi-square test.

Results: There were 60 subjects recruited in this study (30 subjects with coup-contrecoup contusion and 30 subjects without coup-contrecoup contusion). The mean age and body mass index (BMI) between these two groups were not significantly different. The configurations of skull were also not significantly different for both temporal and occipital impacts. Brain weight in coup-contrecoup group was significantly greater than that in no coup-contrecoup group (1366.33 ± 84.42 g vs 1275.33 ± 105.63 g, p=0.001). Skull fracture with simple pattern, base of skull fracture without sella turcica involvement and subdural hemorrhage were significantly associated with the presence of coup-contrecoup contusion (p=0.027, p<0.001 and p=0.002, respectively).

Conclusion: Brain with coup-contrecoup contusion had significantly higher brain weight than brain without coup-contrecoup contusion. The presence of coup-contrecoup contusion was influenced by the characters of skull and base of skull fracture and the presence of subdural hemorrhage.

Keywords: traumatic brain injuries (TBI), coup-contrecoup, Thai, autopsy

Received: 23 February 2022, **Revised:** 20 April 2022, **Accepted:** 26 April 2022

การศึกษาลักษณะการบาดเจ็บของสมองที่เกิดจากศีรษะได้รับบาดเจ็บจากการกระแทกกับวัตถุแข็งไม่มีคมซึ่งเกิดจากการบาดเจ็บที่สัมพันธ์กับความเร็ว

ณัฐหทัย สุวิทย์สกุลวงศ์ พ.บ.[1,2]

พีรยุทธ เฟื่องฟุ้ง พ.บ. ปร.ด.[2*]

[1] โรงพยาบาลสกลนคร กระทรวงสาธารณสุข สกลนคร ประเทศไทย

[2] ภาควิชานิติเวชศาสตร์ คณะแพทยศาสตร์ศิริราชพยาบาล มหาวิทยาลัยมหิดล กรุงเทพมหานคร ประเทศไทย

* ผู้ติดต่อ, อีเมล: peerayuht.phu@mahidol.ac.th

Vajira Med J. 2022; 66(3): 199-210

http://dx.doi.org/10.14456/vmj.2022.20

บทคัดย่อ

วัตถุประสงค์: เพื่อศึกษาลักษณะของการบาดเจ็บของสมองซึ่งสัมพันธ์กับการเกิดภาวะสมองบาดเจ็บในด้านตรงกันข้ามกับการกระแทก เมื่อศีรษะได้รับบาดเจ็บจากการกระแทกกับวัตถุแข็งไม่มีคมซึ่งเกิดจากการบาดเจ็บที่สัมพันธ์กับความเร็ว

วิธีดำเนินการวิจัย: ทำการศึกษาไปข้างหน้าแบบควบคุมกรณี โดยศึกษาในศพคนไทยที่ส่งมาผ่าศพที่ภาควิชานิติเวชศาสตร์ คณะแพทยศาสตร์ศิริราชพยาบาล มหาวิทยาลัยมหิดล ตั้งแต่วันที่ 11 กุมภาพันธ์ 2564 ถึง 31 ธันวาคม 2564 โดยศพมีอายุตั้งแต่ 18 ปีขึ้นไปและเสียชีวิตจากอุบัติเหตุจราจรหรือตกจากที่สูง ทำการบันทึกข้อมูล ได้แก่ เพศ, อายุ, ส่วนสูงและน้ำหนัก, ขนาดของกะโหลกศีรษะ, ตำแหน่งที่มีรอยช้ำที่ศีรษะ, ลักษณะของกะโหลกศีรษะและฐานกะโหลกศีรษะแตก, น้ำหนักสมอง, การมีเลือดออกเหนือและใต้เยื่อหุ้มสมองชั้นหนา, การมีสมองช้ำในด้านตรงกันข้ามกับการกระแทก และการบาดเจ็บภายในเนื้อสมองชั้นใน ทำการเปรียบเทียบลักษณะของการบาดเจ็บของสมองในกลุ่มที่มีและไม่มีสมองช้ำในด้านตรงกันข้ามกับการกระแทกกับปัจจัยต่างๆ โดยใช้สถิติเชิงพรรณา, การทดสอบ ที-เทสต์, แมน-วิทนีย์ ยู เทสต์ และไค-สแควร์เทสต์

ผลการวิจัย: งานวิจัยนี้มีศพทั้งหมด 60 ราย (แบ่งเป็น 30 รายมีสมองช้ำในด้านตรงกันข้ามกับการกระแทก และ 30 รายไม่มีสมองช้ำในด้านตรงกันข้ามกับการกระแทก) อายุและดัชนีมวลกายระหว่างสองกลุ่มนี้ไม่มีความแตกต่างกันอย่างมีนัยสำคัญ ขนาดของกะโหลกศีรษะระหว่างสองกลุ่มนี้ไม่มีความแตกต่างกันอย่างมีนัยสำคัญทั้งการกระแทกทางด้านข้างและด้านหลัง น้ำหนักสมองในกลุ่มที่มีสมองช้ำในด้านตรงกันข้ามกับการกระแทกมีน้ำหนักมากกว่ากลุ่มที่ไม่มีสมองช้ำในด้านตรงกันข้ามกับการกระแทกอย่างมีนัยสำคัญ (1366.33 ± 84.42 กรัม และ 1275.33 ± 105.63 กรัม, p=0.001) กะโหลกศีรษะที่แตกร้าวแบบไม่ซับซ้อน, ฐานกะโหลกศีรษะที่แตกร้าวไม่ผ่านแนวกึ่งกลาง และการมีเลือดออกใต้เยื่อหุ้มสมองชั้นหนา มีความสัมพันธ์กับการเกิดสมองช้ำในด้านตรงกันข้ามกับการกระแทกอย่างมีนัยสำคัญ (p=0.027, p<0.001 และ p=0.002 ตามลำดับ)

สรุปผลการวิจัย: สมองที่มีการบาดเจ็บในด้านตรงกันข้ามกับการกระแทกมีน้ำหนักสมองที่มากกว่าสมองที่ไม่มีการบาดเจ็บในด้านตรงกันข้ามกับการกระแทก ลักษณะการแตกร้าวของกะโหลกศีรษะและฐานกะโหลกศีรษะรวมถึงการมีเลือดออกใต้เยื่อหุ้มสมองชั้นหนามีผลต่อการเกิดสมองช้ำในด้านตรงกันข้ามกับการกระแทก

คำสำคัญ: การบาดเจ็บของสมอง สมองบาดเจ็บในด้านตรงกันข้ามกับการกระแทก คนไทย การผ่าศพ

วันที่รับบทความ 23 กุมภาพันธ์ 2565 **วันแก้ไขบทความ** 20 เมษายน 2565 **วันตอบรับบทความ** 26 เมษายน 2565

Introduction

Traumatic brain injury (TBI) is one of the leading causes of death worldwide. In Thailand, TBI frequently results from blunt head trauma from road traffic accident[1]. According to World Health Organization (WHO) report 2018, it was found that Thailand had estimated fatality rate per 100000 population from road traffic accident at 32.7% and this fatality rate is in the top ten countries where people died from road traffic accident[2]. Blunt head trauma can result from contact head injury or acceleration-deceleration (inertial) head injury[3-4]. Acceleration-deceleration head injury is mainly related to velocity-related injuries like road traffic accident and falling from height because it deals with either head movement after impact injury or moving head colliding with objects[3-4]. Acceleration-deceleration head injury can produce several brain pathologies including subdural hemorrhage, traumatic axonal injury and coup-contrecoup phenomenon[5]. Coup-contrecoup contusion is commonly encountered in medico-legal autopsy. This phenomenon can be described as coup contusion for cerebral contusion occurring at the area of head impact and contrecoup contusion for cerebral contusion occurring at the opposite site of head impact[6]. Contrecoup contusion mostly has greater severity than coup contusion[6].

Although there are many theories proposed for brain pathologies in acceleration-deceleration head injury, the pathogenesis of these brain pathologies are still not clearly elucidated. It was suggested that subdural hemorrhage was related to head movement with higher rate of angular acceleration in short interval[7]. In contrast, traumatic axonal injury was attributed to head movement with relatively lower rate of angular acceleration in longer interval[7]. In addition, the experiment in the finite element model of the human head showed that maximal principal strain in the brain for acceleration and deceleration pulse force was relatively high at corpus callosum and basal ganglia area which were common locations for traumatic axonal injury[8]. For coup-contrecoup phenomenon, there were several proposed theories including rotational shear stress theory, angular acceleration theory, theory of wave of transmitted force, negative pressure (intracranial cavitation) theory, and positive pressure theory[6,9]. In addition, the effect of brain displacement along rough base of skull and the effect of cerebro-spinal fluid (CSF) might involve in coup-contrecoup phenomenon[6,9]. Skull geometry was the other factor that was hypothesized for the other important parameter involved in the occurrence of coup-contrecoup contusion[9-10]. It was found that the percentage of cerebral contusion occurring at the opposite area of impact site was relatively higher in temporal and occipital impact than frontal impact[9-10]. However, there is no single theory that can completely explain coup-contrecoup phenomenon.

Due to the importance of blunt head trauma from velocity-related injuries as stated above that can be commonly found in forensic autopsy in Thailand, this study aims to determine the characters of TBI in blunt head trauma resulting from velocity-related injuries including road traffic accident and falling from height using the presence or absence of coup-contrecoup phenomenon as the model for comparison. This study also aims to indicate factors influencing coup-contrecoup contusion and other brain pathologies. These data will be useful for case interpretation in road traffic accident and falling from height when considered with crime scene evidence.

Methods

Prospective case control study was conducted and case data were collected from medico-legal cases who were sent for the autopsy to the Department of Forensic Medicine, Siriraj Hospital, Mahidol University, Thailand between 11th February 2021 and 31st December 2021. Inclusion criteria in this study were Thai postmortem cases who were at the age of 18 years old or over and were dead at the crime scene from traffic accident or falling from height which were classified as velocity-related injuries. The causes of death in all cases were head injuries and there was only single impact site at the head which was divided into two categories: temporal impact and occipital impact. The impact site was considered by external wound at head and scalp contusion beneath. This study was concentrated only on temporal impact and occipital impact because these two sites were more commonly associated with the presence of coup-contrecoup contusion than frontal impact[9-10]. Exclusion criteria in this study were dead cases with open skull fracture with brain exposure and comminuted skull fracture.

Fundamental subject data including sex, age, height, weight, and type of injuries (traffic accident and fall from height) were recorded. Body mass index (BMI) was calculated from height and weight for each case. Detailed data of head injuries related to head impact including the impact site, the configuration of skull (maximal lateral diameter and maximal anterior-posterior (AP) diameter of skull), and the characters of skull and base of skull fracture were collected. Maximal lateral diameter and maximal AP diameter of skull were measured as described in **figure 1**.

The characters of skull fracture were divided into two types (as shown in **figure 2**):

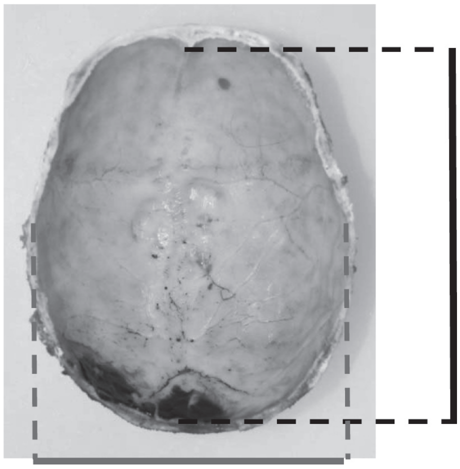
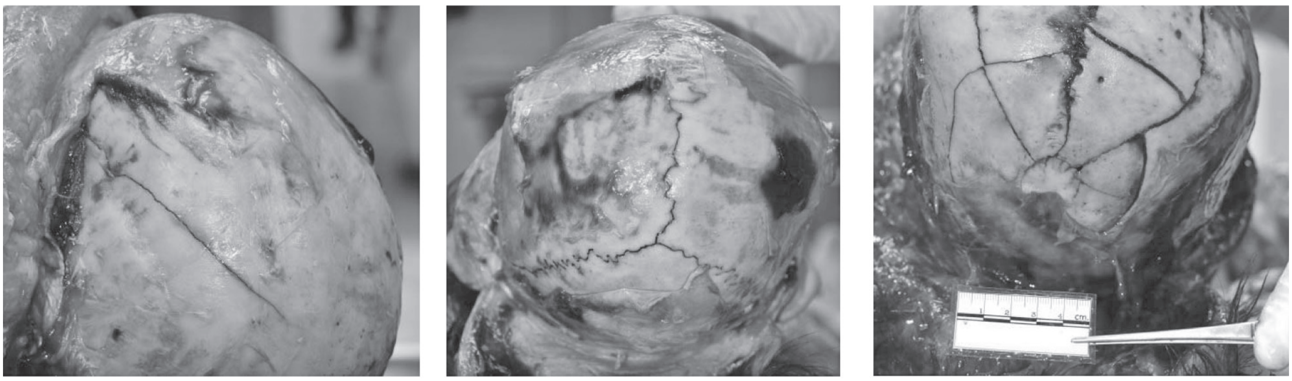


Figure 1: Maximal AP diameter of skull was measured from the distance between the inner surface of the midline of frontal bone and occipital bone (black line) whereas maximal lateral diameter of skull was measured between the inner surface of the broadest point at both parietal areas (blue line)



(A) (B) (C)

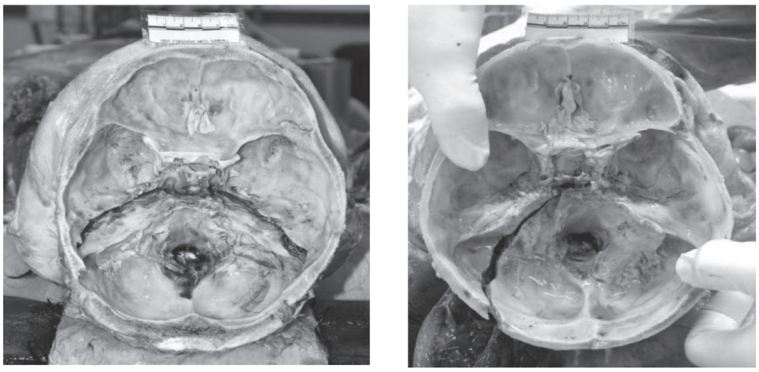
Figure 2: Skull fracture: (A) linear skull fracture, (B) diastatic skull fracture (C) spider web fracture

1) Skull fracture with simple pattern: linear skull fracture involving single or two skull bones

2) Skull fracture with complex pattern: linear skull fracture involving more than two skull bones or depressed skull fracture or diastatic fracture or other complex pattern of skull fracture, for example, spider web fracture (which was not broken into multiple separated fragments).

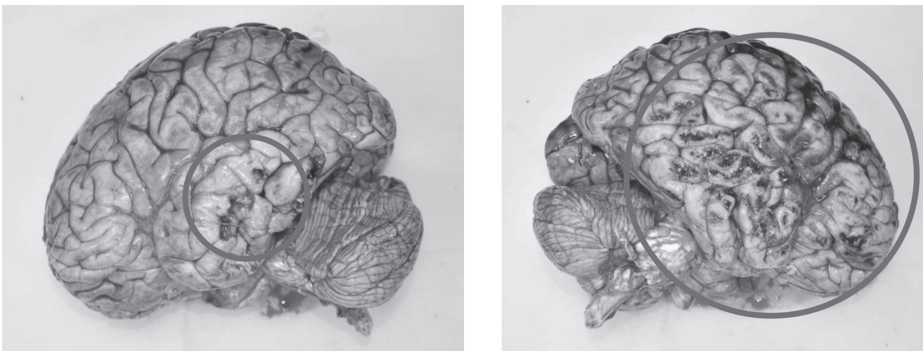
The character of base of skull fracture was also divided into two categories: skull base fracture involving sella turcica (such as Hinge type I fracture) (as shown in **figure 3**) and skull base fracture without sella turcica involvement.

Then, detailed data of brain injuries were collected including brain weight, the presence of epidural hemorrhage and subdural hemorrhage, and the presence of coup-contrecoup contusion. The definition of the presence of coup-contrecoup contusion was defined as the contusional area at the opposite site of impact was greater than that at the impact site. For temporal impact, the presence of coup-contrecoup contusion meant that contrecoup contusion was found mainly on the temporal lobe opposite to the impact site (as shown in **figure 4**). For occipital impact, the presence of coup-contrecoup contusion was defined as the presence of contrecoup contusion mainly on either frontal or temporal lobes. In addition, the presence of macroscopic spot hemorrhage in white matter and the area of white matter where macroscopic spot hemorrhage belonged to were recorded. The area of white matter considered in this study included common three areas: corpus callosum, deep gray matter including basal ganglia and thalamus and midbrain/brainstem area (**figure 5**). The presence of macroscopic spot hemorrhage in white matter was also confirmed by histological findings.



(A) (B)

Figure 3: Skull base fracture involving sella turcica (A) Hinge type I fracture from temporal impact and (B) Fracture of left posterior cranial fossa involving sella turcica



(A) Left temporal impact with small area of coup brain contusion at left temporal lobe (blue circle)

(B) Contrecoup contusion at all four lobes of right hemisphere (blue circle)

Figure 4: Coup-contrecoup contusion in temporal impact: (A) coup contusion (B) contrecoup contusion

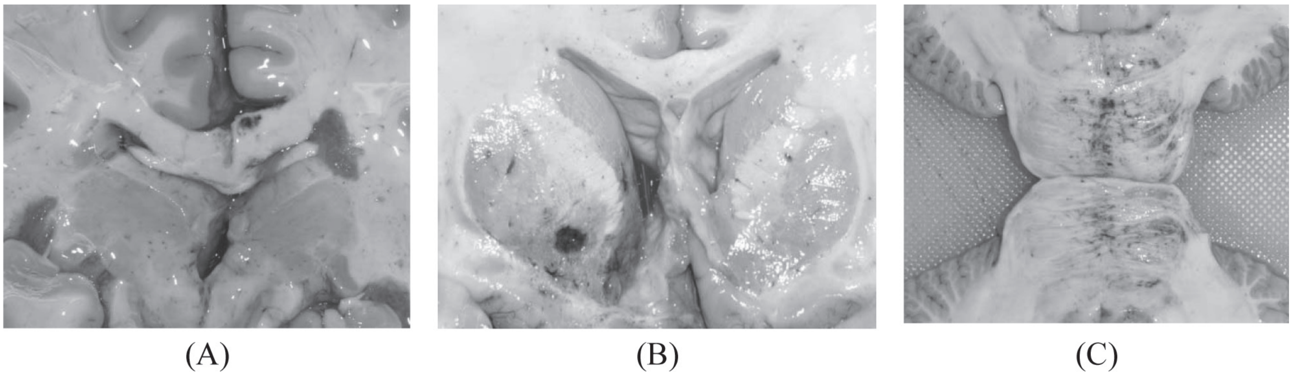


Figure 5: Macroscopic spot hemorrhage in white matter presented in three main locations: (A) corpus callosum, (B) basal ganglia and (C) brainstem (pons)

The statistical analysis was performed using program IBM SPSS® Statistics for Window version 21. Descriptive statistics including mean, median and standard deviation (SD) were analyzed. Then, Kolmogorov-Smirnov test and Levene's test for equality of variance were tested for continuous variables. Independent sample t-test and Mann-Whitney U test were used where it was appropriate. For categorical data, contingency table chi-square test was employed for analysis. The statistical significance was set at p<0.05.

This study was approved by the Siriraj Institutional Review Board, Faculty of Medicine, Siriraj Hospital, Mahidol University (Certificate of Approval Number Si 121/2021, Research Project Number 1083/2563).

Results

There were 60 subjects recruited in this study and all subjects were divided into 30 cases who had coup-contrecoup phenomenon and the other 30 cases who had no coup-contrecoup phenomenon. The demographic data in this study was shown in **table 1**. Age and BMI between coup-contrecoup group and no coup-contrecoup group were tested by independent sample t-test and both parameters in these two groups were not significantly different.

The configurations of skull between coup-contrecoup group and no coup-contrecoup group were analyzed using independent sample t-test. The statistical testing was performed both in total case analysis and the analysis for each impact site. It was found that maximal lateral diameter and maximal AP diameter between coup-contrecoup group and no coup-contrecoup group were not significantly different both in total case analysis and each impact site as shown in **table 2**.

Then, the comparison of the character of skull and base of skull fracture between coup-contrecoup group and no coup-contrecoup group was analyzed using contingency table chi-square test as shown in **table 3** and **table 4**. Skull fracture with simple pattern and base of skull fracture without sella turcica involvement were significantly associated with the occurrence of coup-contrecoup contusion.

The comparison of brain weight between coup-contrecoup group and no coup-contrecoup group was tested both in total case analysis and each impact analysis. The statistical analysis for total case and temporal impact was performed using independent sample t-test. However, Mann-Whitney U test was employed for the analysis of occipital impact because data for brain weight in occipital impact was not normally distributed and was not passed for Levene's test for equality of variance. It was found that brain weight in coup-contrecoup group was significantly higher than that in no coup-contrecoup group as show in **table 5**.

Table 1:
Demographic data in this study

Parameters		Presence of coup-contrecoup contusion	Absence of coup-contrecoup contusion	p-value
Number of case		30	30	
Sex	Male	26 (86.67%)	23 (76.67%)	
	Female	4 (13.33%)	7 (23.33%)	
Type	Traffic accident	27 (90%)	25 (83.33%)	
	Fall from height	3 (10%)	5 (16.67%)	
Impact site	Temporal area	15 (50%)	15 (50%)	
	Occipital area	15 (50%)	15 (50%)	
Age (years old) (range)		42.07 ± 16.88 (19-78)	41.60 ± 19.63 (19-76)	>0.05
BMI (kg/m^2) (range)		24.23 ± 3.95 (18.30-32.70)	23.00 ± 4.37 (16.60-34.20)	>0.05

Table 2:
The comparison of the configuration of skull between coup-contrecoup group and no coup-contrecoup group

Skull Parameters	Presence of coup-contrecoup contusion Mean ± SD (Range)	Absence of coup-contrecoup contusion Mean ± SD (Range)	p-value
Total case			
Maximal AP diameter (cm)	15.54 ± 0.59 (14.3-16.6)	15.86 ± 0.91 (14.3-18.0)	>0.05
Maximal Lateral diameter (cm)	13.70 ± 0.66 (12.3-15.5)	13.55 ± 0.88 (11.5-15.6)	>0.05
Temporal impact			
Maximal AP diameter (cm)	15.56 ± 0.69 (14.3-16.5)	15.98 ± 0.92 (14.6-17.7)	>0.05
Maximal Lateral diameter (cm)	13.97 ± 0.58 (13.0-15.5)	13.48 ± 0.84 (11.5-14.8)	>0.05
Occipital impact			
Maximal AP diameter (cm)	15.52 ± 0.50 (14.7-16.6)	15.74 ± 0.92 (14.3-18.0)	>0.05
Maximal Lateral diameter (cm)	13.43 ± 0.63 (12.3-14.8)	13.63 ± 0.94 (12.0-15.6)	>0.05

Table 3:
The association between patterns of skull fracture and coup-contrecoup contusion

Skull fracture		Presence of coup-contrecoup contusion	Absence of coup-contrecoup contusion	p-value
Total	Simple pattern	27	18	0.027
	Complex pattern	4	11	
Temporal	Simple pattern	15	7	0.048
	Complex pattern	2	6	
Occipital	Simple pattern	12	11	>0.05
	Complex pattern	2	5	

Table 4:
The association between patterns of base of skull fracture and coup-contrecoup contusion

Base of skull fracture		Presence of coup-contrecoup contusion	Absence of coup-contrecoup contusion	p-value
Total	Without sella turcica	27	12	<0.001
	With Sella turcica	4	17	
Temporal	Without sella turcica	11	6	0.003
	With Sella turcica	2	11	
Occipital	Without sella turcica	16	6	0.003
	With Sella turcica	2	6	

Table 5:
The comparison of brain weight between coup-contrecoup group and no coup-contrecoup group

Brain weight (grams)	Presence of coup-contrecoup contusion Mean ± SD	Absence of coup-contrecoup contusion Mean ± SD	p-value
Total case	1366.33 ± 84.42	1275.33 ± 105.63	0.001
Temporal impact	1394.67 ± 87.58	1300.67 ± 89.80	0.007
Occipital impact	1338.00 ± 73.31	1250.00 ± 116.93	0.041

Then, the chi-square test was performed to determine the relationship between the presence of intracranial hemorrhage and the presence of coup-contrecoup contusion. It was found that epidural hemorrhage had no association with the presence of coup-contrecoup contusion (p>0.05). In contrast, there was significant association between the presence of subdural hemorrhage and the presence of coup-contrecoup contusion (p=0.002). However, when impact site was considered, the significant association between subdural hemorrhage and the presence of coup-contrecoup contusion was presented only in temporal impact (p=0.003). The presence of macroscopic spot hemorrhage in white matter also presented no significant association with the presence of coup-contrecoup contusion both in overall case and in each impact site (p>0.05).

However, when the white matter area of macroscopic spot hemorrhage was considered, the analysis was performed for three sites including corpus callosum, deep gray matter including basal ganglia and thalamus and midbrain/brainstem area. It was found that midbrain/brainstem area had significant association with the absence of coup-contrecoup contusion in overall case (p=0.017). Then, each impact site was analyzed and it was found that there was significant association between the presence of macroscopic spot hemorrhage in midbrain/brainstem area and the absence of coup-contrecoup contusion only in temporal impact (p=0.008).

Discussion

This study demonstrated some characters of TBI in blunt head trauma from traffic accident and fall from height which were velocity-related injuries. Firstly, the age and BMI did not play any significant roles in the presence of coup-contrecoup contusion in this study. Then, it was found that the configurations of skull diameter were also not significantly associated with the presence or absence of coup-contrecoup contusion. However, previous studies showed that the geometry of skull had a significant effect on the presence of coup-contrecoup contusion[9-10]. It could be speculated that there were other parameters of skull geometry that had an effect on the occurrence of coup-contrecoup contusion and the maximal AP and lateral diameter of skull might not be the main factors. Other skull parameters such as skull volume and skull thickness should be further studied to elucidate the effect of skull geometry on coup-contrecoup phenomenon.

This study showed that skull fracture with simple pattern was significantly associated with the presence of coup-contrecoup contusion compared with skull fracture with complex pattern. These findings indicated that coup-contrecoup phenomenon might be partly related to character of force applied to the head at the time of injury. The previous study suggested one hypothesis about impulse wave generating from skull vibration after head impact[11]. In case of skull fracture, the energy was absorbed by skull fracture after impact and the frequency of skull vibration which caused coup-contrecoup contusion was reduced[11]. The previous study suggested that head impact location and impact velocity had an effect on patterns of fracture and brain contusion index in non-fracture model was relatively higher than that in fracture model in the same impact velocity because fracture could absorb some impact energy and reduce pressure wave transmission[12-13]. In addition, the previous study suggested that short duration impact was potentially related to coup-contrecoup phenomenon because it produced high pressure gradient[14] and short duration impact was more associated with linear skull fracture than depressed skull fracture[15]. Furthermore, the previous study suggested that intracranial lesions were found in the higher rate in linear skull fracture compared to depressed skull fracture[16]. These data implied that skull fracture with simple pattern produced sufficient energy wave transmitted into brain parenchyma due to relatively lower impact energy absorption compared with skull fracture with complex pattern and led to the association with coup-contrecoup contusion. Future work should be conducted to verify this mechanism.

The presence of coup-contrecoup contusion was also significantly associated with skull base fracture without sella turcica involvement. This finding could be interpreted in the similar way to the association of skull fracture with simple pattern with coup-contrecoup phenomenon because skull base fracture with sella turcica involvement like Hinge type I fracture was associated with greater impact energy absorption. Thus, it could be expected that skull base fracture without sella turcica involvement should be relatively associated with coup-contrecoup contusion.

This study showed that the average brain weight in coup-contrecoup group was higher than that in no coup-contrecoup group. As this study only recruited subjects who were dead at the crime scene, it could be implied that increased brain weight in coup-contrecoup group resulted from the immediate direct effect of brain injury. Previous studies described that TBI caused increased brain tissue osmolarity by shifting of sodium and potassium ion contents followed by increased water content in brain tissue both in intracellular and interstitial areas in the early period of TBI (0-12 hours)[17-18]. This finding occurred both in contusional areas and surrounded areas of contusion[17]. It was proposed that this osmolar/contusional swelling was caused by disruption of cell membrane and blood-brain barrier at this initial stage of TBI[17-18]. Then, vasogenic and cytotoxic edema came to play an important role in the later period of TBI[17-18]. Coup-contrecoup group consisted of greater contusional areas than no coup-contrecoup group. Thus, one explanation for increased brain weight in coup-contrecoup group might result from osmolar/contusional swelling of brain tissue caused by direct effect of greater contusional areas in coup-contrecoup group. However, the impact of other findings like subdural hemorrhage or macroscopic spot hemorrhage in white matter on the degree of cerebral edema should be further studied to verify the effects of these findings on brain weight in TBI.

Subdural hemorrhage was the other parameter that had significant association with the presence of coup-contrecoup contusion. This finding supported the underlying mechanisms of subdural hemorrhage because subdural hemorrhage was originated from two mechanisms. Firstly, subdural hemorrhage was associated with tearing of bridging veins in dynamic head injury[19]. Secondly, subdural hemorrhage could be caused by bleeding from cerebral contusion into subdural space[19]. Coup-contrecoup phenomenon was related to acceleration-deceleration brain injury[4] and contrecoup lesions presented with greater degree of contusional area compared with coup lesions. Thus, these two reasons were main explanations for the association between subdural hemorrhage and the presence of coup-contrecoup contusion.

It was found that the presence of macroscopic spot hemorrhage in white matter was not significantly associated with the presence of coup-contrecoup phenomenon. In addition, this study showed that the majority of white matter areas containing macroscopic spot hemorrhage were not significantly associated with the presence of coup-contrecoup phenomenon. This finding implied that the presence of macroscopic spot hemorrhage in white matter which was related to traumatic axonal injury might result from different mechanisms. This finding was indirectly supported by previous studies showing that physics parameters measured for brain contusion and axonal injury were different[8,13-14]. For axonal injury, principal strain or cumulative strain index were measured for the prediction of location of axonal injury[8,13].

This study consisted of several limitations. Firstly, subjects recruited in this study were mainly dead from traffic accident and there were only minor subjects who were dead from falling from height. The mechanisms of injuries in these two types might be different in the amount and characters of force applied to the head and this might affect study results. Secondly, details of traffic accident like types of injuries and the heights of falling from height were not available in this study and these factors might influence on the characters of TBI. Thirdly, some parameters such as subdural hemorrhage and their relationship with skull/base of skull fracture and brain contusion, and areas of macroscopic spot hemorrhage in white matter could be more classified and more variations could be generated in details of head injuries. Thus, greater sample size was needed in further study to obtain higher extent of statistical analysis. Lastly, other parameters of skull geometry that might potentially have an impact on TBI like skull/brain volume and skull thickness in each location of skull should be included for further study.

Conclusion

Brain with coup-contrecoup contusion presented with significantly higher brain weight than brain without coup-contrecoup contusion. In addition, coup-contrecoup phenomenon was associated with skull fracture with simple pattern, skull base fracture without sella turcica involvement and the presence of subdural hemorrhage. However, there was no significant association between the configurations of skull or the presence of macroscopic spot hemorrhage and the presence of coup-contrecoup contusion.

Conflict of interest

The authors declare no conflict of interest.

References

1. Siripituphum D, Songwathana P, Khupantavee N, Williams I. Caring for Thai Traumatic Brain Injury Survivors in a Transitional Period: What Are the Barriers? J Health Sci Med Res 2020; 38:43-52.
2. World Health Organization (WHO). Global status report on road safety [internet]. 2018 [cited 2021 December 7]. Available from https://www.who.int/publications/i/item/9789241565684.
3. Graham DI, Adams JH, Nicoll JA, Maxwell WL, Gennarelli TA. The nature, distribution and causes of traumatic brain injury. Brain Pathol 1995;5(4):397-406.
4. Davceva N, Janevska V, Ilievski B, Petrushevska G, Popeska Z. The occurrence of acute subdural haematoma and diffuse axonal injury as two typical acceleration injuries. J Forensic Leg Med 2012;19(8):480-4.
5. Kleiven S. Why most traumatic brain injuries are not caused by linear acceleration but skull fractures are. Front Bioeng Biotechnol 2013;1:15.
6. Drew LB, Drew WE. The contrecoup-coup phenomenon: a new understanding of the mechanism of closed head injury. Neurocrit Care 2004;1(3):385-90.
7. Gennarelli TA. Head injury in man and experimental animals: clinical aspects. Acta Neurochir Suppl (Wien) 1983;32:1-13.
8. Yoganandan N, Li J, Zhang J, Pintar FA, Gennarelli TA. Influence of angular acceleration-deceleration pulse shapes on regional brain strains. J Biomech 2008;41(10):2253-62.
9. Cepeda S, Gómez PA, Castaño-Leon AM, Munarriz PM, Paredes I, Lagares A. Contrecoup Traumatic Intracerebral Hemorrhage: A Geometric Study of the Impact Site and Association with Hemorrhagic Progression. J Neurotrauma 2016;33(11):1034-46.
10. Ratnaike TE, Hastie H, Gregson B, Mitchell P. The geometry of brain contusion: relationship between site of contusion and direction of injury. Br J Neurosurg 2011;25(3):410-3.
11. Martin G. Traumatic brain injury: The first 15 milliseconds. Brain Inj 2016;30(13-14):1517-24.
12. Ren L, Wang D, Liu X, Yu H, Jiang C, Hu Y. Influence of Skull Fracture on Traumatic Brain Injury Risk Induced by Blunt Impact. Int J Environ Res Public Health 2020;17(7):2392.
13. Barbosa A, Fernandes FAO, Alves de Sousa RJ, Ptak M, Wilhelm J. Computational Modeling of Skull Bone Structures and Simulation of Skull Fractures Using the YEAHM Head Model. Biology (Basel) 2020;9(9):267.

14. Pearce CW, Young PG. On the pressure response in the brain due to short duration blunt impacts. PLoS One 2014;9(12):e114292. doi: 10.1371/journal.pone.0114292.
15. Yoganandan N, Pintar FA, Sances A Jr, Walsh PR, Ewing CL, Thomas DJ, et al. Biomechanics of skull fracture. J Neurotrauma 1995;12(4):659-68.
16. Yavuz MS, Asirdizer M, Cetin G, Günay Balci Y, Altinkok M. The correlation between skull fractures and intracranial lesions due to traffic accidents. Am J Forensic Med Pathol 2003;24(4):339-45.
17. Kawamata T, Mori T, Sato S, Katayama Y. Tissue hyperosmolality and brain edema in cerebral contusion. Neurosurg Focus 2007;22(5):E5. doi: 10.3171/foc.2007.22.5.6.
18. Jha RM, Kochanek PM, Simard JM. Pathophysiology and treatment of cerebral edema in traumatic brain injury. Neuropharmacology 2019;145(Pt B):230-46.
19. Evaggelakos CI, Alexandri M, Tsellou M, Dona A, Spiliopoulou CA, Papadodima SA. Subdural and epidural hematoma occurrence in relation to the head impact site: An autopsy study. J Forensic Leg Med 2022;85:102283. doi: 10.1016/j.jflm.2021.102283.