



Contents lists available at ScienceDirect

Chinese Journal of Traumatology

journal homepage: <http://www.elsevier.com/locate/CJTEE>

Original Article

Correlation between the skull base fracture and the incidence of intracranial hemorrhage in patients with traumatic brain injury

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ARTICLE INFO

Article history:

Received 11 March 2019

Received in revised form

9 June 2019

Accepted 31 July 2019

Available online 16 August 2019

Keywords:

Skull base fracture

Intracranial hemorrhage

Traumatic brain injury

ABSTRACT

Purpose: A head injury (HI) may cause a skull fracture, which may or may not be associated with injury to the brain. In essence, a skull base fracture (SBF) is a linear fracture at the base of the skull. Loss of consciousness and Glasgow coma score (GCS) may vary depending on an associated intracranial pathology. The pathomechanism is believed to be caused by high energy impact directly to the mastoid and supraorbital bone or indirectly from the cranial vault. Aim of this study is to define the correlation between SBF and intracranial hemorrhage (ICH) in patients with HI.

Methods: Analysis of data obtained from a retrospective review of medical records and from a systematized database pertaining to diagnostic criteria of SBF patients based only on clinical symptoms associated with ICH caused by HI treated in the Department of Neurosurgery at Dr. Hasan Sadikin Hospital, Bandung, Indonesia from January 1, 2012 to December 31, 2017. The exclusion criteria included age less than 15 years and no head computed tomography (CT) scan examination provided.

Results: A total of 9006 patients were included into this study in which they were divided into 3 groups: group 1, HI with no ICH; group 2, HI with single ICH and group 3, HI with multiple ICH. In all the SBF cases, SBF at anterior fossa accounted for 69.40% of them, which were mostly accompanied with mild HI (64.70%). Severity of HI and site of SBF correlated with the existence of traumatic brain lesions on CT scan, thus these factors were able to predict whether there were traumatic brain lesions or not. Most of the patients with epidural hemorrhage (EDH) has single traumatic lesion on CT scan, whereas most of the patients with cerebral contusion (CC) has multiple traumatic lesions on CT scan. On patients with both traumatic brain injury and SBF, most of the patients with anterior fossa SBF has EDH; whereas most of the patients with middle fossa SBF were accompanied with CC. Surgery was not required for most of the patients with SBF.

Conclusion: SBFs were strongly correlated with traumatic ICH lesions patients with anterior fossa SBF were more likely to suffer EDH whereas with middle fossa SBF were more likely to suffer CC.

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Introduction

Skull base fracture (SBF) may be caused by direct impact or propagation of high energy force waves through the skull as a result of remote impact or impact to facial bone.^{1–3} In clinical settings, patients may present with mild to severe head injury (HI) in which deterioration of these patients is common.^{4,5}

It seems that the high degree of applied energy causing these fractures may also lead to injury of delicate intracranial structures.^{6,7} Although high energy is required but there is no clear correlation between these type of fractures and intracranial hemorrhage (ICH). This study was undertaken to address this issue.

Methods

Patient population and data collection

There were 9006 cases of documented HI treated in our department from January 1, 2012 until December 31, 2017. The

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Peer review under responsibility of Chinese Medical Association.

amount of patients in each category (mild HI, moderate HI and severe HI) were 5846 (64.91%), 2111 (23.44%) and 1049 (11.65%) patients, respectively.

Patients' demographic, clinical and neuroimaging data, including age, sex, admission Glasgow coma score (GCS), severity of HI, type of SBF and type of ICH were collected. Of the 9006 patients admitted in our emergency unit during the study period, diagnostic criteria of SBF patients based only on clinical symptoms associated with ICH caused by HI, clinical symptoms for diagnosis of SBF were used on initial interventions in 987 patients (10.96%). The final study population consisted of 9006 patients with 6783 males (75.32%) and 2223 females (24.68%), divided into three groups, group 1, HI with no ICH; group 2, HI with single ICH and group 3, HI with multiple ICH. The exclusion criteria included age less than 15 years and patient with no head computed tomography (CT) scan examination provided. Based only on clinical symptoms, we categorized the lesions into SBF anterior, SBF medial and both SBF anterior and medial fossa.

Statistical analysis

Statistical analysis was performed using R 3.6.0 and GraphPad Prism 7.03. Correlation between patient characteristics (sex, age, severity of HI and SBF location) and ICH were analyzed using binary logistic. The same binary logistic process were also done to analyze the relationship between type of hemorrhage and CT scan results and the correlation between SBF type and surgery therapy. It was considered statistically significant when $p < 0.05$.

Results

The population of SBF was divided into three groups. Group 1, SBF at anterior fossa ($n = 685$, 69.40%). Group 2, SBF at middle fossa ($n = 271$, 27.50%) and group 3, SBF at both anterior and middle fossa ($n = 31$, 3.10%). As shown in Table 1, most of the patients with SBF were diagnosed with mild HI ($n = 582$, 59%); SBF at anterior fossa accounting for most of the cases ($n = 685$, 69.40%). Most of the patients with SBF medial had mild HI, whereas most of the patients with both SBF anterior and medial had moderate HI.

The various characteristics of patients according to their sex, age, HI severity and SBF location in accordance of the ICH are shown in Table 2 as follows: (1) no lesion: male 4779 (74.87%), female 1604 (25.13%), <40 years old 4549 (71.27%), ≥40 years old 1834 (28.73%), mild HI 5172 (81.02%), moderate HI 647 (10.13%), severe HI 564 (8.85%), SBF anterior fossa 479 (75.0%), SBF middle fossa 144 (22.5%) and SBF anterior-middle fossa 16 (2.5%); (2) single lesion: male 1138 (77.46%), female 331 (22.53%), <40 years old 1074 (73.12%), ≥40 years old 395 (26.88%), mild HI 514 (34.98%), moderate HI 754 (51.32%), severe HI 201 (13.7%), SBF anterior fossa 107 (64.1%), SBF middle fossa 54 (32.3%) and SBF anterior-middle fossa 6 (3.6%); (3) multiple lesion: male 866 (75.04%), female 288 (24.95%), <40 years old 683 (59.18%), ≥40 years old 471 (40.82%), mild HI 160 (13.86%), moderate HI 710 (61.52%), severe HI 284 (24.62%), SBF anterior fossa

Table 1
Severity of head injury and skull base fracture location, n (%).

Variables	Location of the skull base fracture			Total
	Anterior	Middle	Anterior-middle	
Mild HI	443 (64.70)	130 (48.00)	9 (29.00)	582 (59.00)
Moderate HI	186 (27.20)	98 (36.20)	16 (51.60)	300 (30.40)
Severe HI	56 (8.10)	43 (15.80)	6 (19.40)	105 (10.60)
Total	685 (69.40)	271 (27.50)	31 (3.10)	987 (100.00)

HI: head injury.

Table 2
Correlation between patient characteristics and intracranial hemorrhage.

Variables	Intracranial hemorrhage, n (%)			p value
	No lesion	Single lesion	Multiple lesions	
Sex				0.018
Male	4779 (74.87)	1138 (77.46)	866 (75.04)	
Female	1604 (25.13)	331 (22.53)	288 (24.95)	
Age				0.000
<40 years old	4549 (71.27)	1074 (73.12)	683 (59.18)	
≥40 years old	1834 (28.73)	395 (26.88%)	471 (40.82)	
HI Severity				0.000
Mild	5172 (81.02)	514 (34.98)	160 (13.86)	
Moderate	647 (10.13)	754 (51.32)	710 (61.52)	
Severe	564 (8.85)	201 (13.70)	284 (24.62)	
SBF				0.013
Anterior	479 (74.96)	107 (64.07)	96 (53.04)	
Middle	144 (22.54)	54 (32.34)	70 (38.67)	
Anterior-middle	16 (2.50)	6 (3.59)	15 (8.29)	

HI: head injury, SBF: skull base fracture.

96 (53.0%), SBF middle fossa 70 (38.7%) and SBF anterior-middle fossa 15 (8.3%).

There is a significant correlation between HI severity and SBF locations towards the ICH as seen on CT scan of these patients. Most of the patients with single and multiple ICH(s) had anterior SBF. It's shown that incidence of SBF at anterior fossa was more common than middle fossa, and SBF strongly correlates ($p < 0.05$) with the incidence of ICH(s), as shown in Table 3. There were strong correlation between the type of hemorrhage with CT scan results, including epidural hemorrhage (EDH), subdural hemorrhage (SDH), intra-cerebral hemorrhage, cerebral contusion (CC), subarachnoid hemorrhage (SAH) and intraventricular hemorrhage (IVH), as follow: (1) in single lesion, EDH 622 (42.3%), SDH 179 (12.2%), intracerebral hemorrhage 157 (10.7%), CC 379 (25.8%), SAH 119 (8.1%) and IVH 13 (0.9%); (2) in multiple lesions, EDH 433 (15.3%), SDH 579 (20.4%), ICH 476 (16.8%), CC 766 (27.0%), SAH 484 (17.1%) and IVH 97 (3.4%).

The various incidence of correlation between type of hemorrhage and SBF lesion(s) are shown in Table 4. Most of the patients with anterior fossa SBF had EDH; whereas most of the patients with middle fossa SBF were accompanied with the CC.

The management of SBF clearly depends on the existence of the intra-cranial pathology. The correlation of SBF location and the management of the patients are shown in Table 5, most of the patients ($n = 865$, 87.64%) were treated conservatively (i.e. without surgery). However, operative procedures were common on patients experiencing of anterior fossa SBF (63.90%), although this was not statistically significant ($p = 0.202$).

Discussion

A SBF is a base fracture of the skull, typically involving the area of temporal bone, occipital bone, sphenoid bone and/or ethmoid

Table 3
Relationship between type of hemorrhage and CT scan results.

Variable	CT scan, n (%)		p value
	Single lesion	Multiple lesions	
Epidural hemorrhage	622 (42.3)	433 (15.3)	0.012
Subdural hemorrhage	179 (12.2)	579 (20.4)	0.000
Intracerebral hemorrhage	157 (10.7)	476 (16.8)	0.000
Cerebral contusion	379 (25.8)	766 (27.0)	0.000
Subarachnoid hemorrhage	119 (8.1)	484 (17.1)	0.000
Intraventricular hemorrhage	13 (0.9)	97 (3.4)	0.000

CT: computed tomography.

Table 4
The type of hemorrhage and skull base fracture location.

Variables	Location of the skull base fracture (n)		
	Anterior	Middle	Anterior-middle
Epidural hemorrhage	55	25	6
Subdural hemorrhage	30	29	6
Intracerebral hemorrhage	38	20	1
Cerebral contusion	49	31	4
Subarachnoid hemorrhage	22	18	3
Intraventricular hemorrhage	9	1	1

Table 5
Correlation of SBF location and management of the patients.

Variables	Therapy, n (%)		Total (n)	p value
	Operation	No operation		
Skull base fracture location				0.202
Anterior	78 (63.90)	607 (70.20)	685	
Middle	40 (32.80)	232 (26.80)	272	
Anterior-middle	4 (3.30)	26 (3.00)	30	
Total	122 (12.36)	865 (87.64)	987	

bone.^{1–3} Such fractures can tears the membranes surrounding the brain, or meninges, with resultant leakage of the cerebrospinal fluid (CSF). The leaking fluid may accumulate in the middle ear space, and dribble out through a perforated eardrum (CSF otorrhea) or into the nasopharynx via the eustachian tube, causing a salty taste. CSF may also drip from the nose (CSF rhinorrhea) in fractures of the anterior skull base, yielding a halo sign. These signs are pathognomonic for SBF. SBF are harder to document on plain X-ray films and usually require CT scanning with bone window settings for identification.^{5,6,9–13}

The skull base can be defined as those bony structures below a plane drawn from the glabella to theinion. Bones of the skull base are relatively fragile and more prone to fracture than those of the vault. Fractures of the skull base have been reported to occur in 3.5%–24.0% of HI patients.^{4,5,14} In our series, most of the patients that had HI were less than 40 years old which is believed appropriate with high mortality and morbidity of HI in this age group. The sutures of neurocranium fuse completely with surrounding bone between 20 and 40 years of age, furthermore, this progressive closure of the skull changes the mechanical characteristics of the skull and probably contributes to a different mechanical response of the skull and its contents to injury impact.^{7,15}

From our study population, we found that most cases presented with mild HI with anterior fossa SBF which accounting for 64.70% of these cases. We believe that might be caused by the anatomical basis of the anterior cranial fossa which contains thin bones of the cribriform plate and the roof of orbits. Besides causing bony disruption of the skull base, high energy impact also results in ICHs. This might be initiated by higher energy needed to cause SBF than linear fracture of the convexity. Chan et al.¹⁶ investigates the correlation between skull fractures and intracranial lesions showing that linear fractures may lead to CC or ICH.¹⁰ As shown multiple lesions tend to occur with mild HI patients compare with moderate and severe HI.

Interestingly, our data showed that the incidence of ICH was higher in moderate HI group compared to mild and severe HI patients. We believe that this might be caused by a noteworthy difference of patient population between these two groups. We found that anterior fossa SBF was more likely to result in single lesion of traumatic ICH (64.10%) compared to other groups ($p = 0.013$). The floor sections of the anterior cranial fossa are richly sculptured by impressiones gyrorum (poorly defined depressions on the inner

surface of the cranium, corresponding to the sulci of the brain) and bony grooves for the meningeal vessels.¹⁷ Although there are other places prone to fracture such as the thin squamous bone and the areas between the mastoid, the incidence of cortical damage in these groups was not high.^{8,18,19} The manifestation of intradural hemorrhages such as CC ($p = 0$), SDH ($p = 0$), intra-cerebral hemorrhage ($p = 0$), SAH ($p = 0$) and IVH ($p = 0$) is higher in multiple lesions compared to extradural ($p > 0.93$). This might be aided to the fact that most CCs are multiple and tend to enlarge to become intra-cerebral hemorrhages. These contusions are potential to develop to become intra-cerebral hemorrhage, SDH also SAH and IVH due to the high velocity caused by the trauma.

In the study of phylogenetic development of the frontal floor of the skull base it was noticed that this platform does not have a stationary form and structure but changes throughout the course of life.²⁰ This wide variation also results from both differences in study patient populations and from difficulty of obtaining radiographic verification of the fractures.^{5,8,14} The limitations of our study especially regarding population size and since the most injury mechanism is accelerated-decelerated results from vehicle crashes, most of our cases is multiple fractures. Nevertheless, we believe that this study might be helpful in creating prompt awareness in patients with SBFs. Closed observation of these head injured patients and head CT scan is the core of diagnosis and management.

Based on our study we conclude that SBFs were strongly correlated with traumatic ICH lesion(s); patients with anterior fossa SBF most likely to had an epidural hemorrhage whereas patients with middle fossa SBF tended to had CC. Further larger study is needed for confirm of these findings.

Funding

This work was supported by the Grants-in-Aid from the Ministry of Research, Technology and Higher Education of the Republic of Indonesia “DIKTI” 05/E/KPT/2019 for Faried A.

Acknowledgements

We thank to all residents in neurotrauma-team for data collecting and technical assistance.

Ethical statement

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

Conflicts of interest

The authors declare that they have no conflicts of interest.

Authors' contributions

All authors had examined, operated, observed, followed up the subject and participated in writing manuscript, has read and approved of the manuscript.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.cjtee.2019.05.006>.

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