Original Article

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

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A B S T R A C T

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. © 2019 Chinese Medical Association, Production and hosting by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

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. In clinical settings, patients may present with mild to severe head injury (HI) in which deterioration of these patients is common.6,7

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
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 at anterior fossa 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 with both SBF anterior and medial had moderate HI. Most of the patients with SBF at anterior fossa had EDH; whereas most of the patients with SBF at middle fossa were accompanied with the CC.

The various incidence of correlation between type of hemorrhage and SBF lesion is shown in Table 2. 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 bone. The various incidence of correlation between type of hemorrhage and SBF lesion \((p = 0.008)\) with the CT scan results, including epidural hemorrhage (EDH), subdural hemorrhage (SDH), intracerebral 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\%).

| 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 | 185 (27.20) | 98 (36.20) | 16 (51.60) | 300 (30.40) |
| Severe HI | 56 (8.10) | 43 (15.80) | 6 (18.00) | 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 | | | |
| Male | 4779 (74.87) | 1138 (77.46) | 866 (75.04) | 0.018 |
| Female | 1604 (25.13) | 331 (22.53) | 288 (24.95) | |
| Age | | | |
| <40 years old | 4549 (71.27) | 1074 (73.12) | 683 (59.18) | 0.000 |
| >40 years old | 1834 (28.73) | 395 (26.88) | 471 (40.82) | |
| HI Severity | | | |
| Mild | 5172 (81.02) | 514 (36.20) | 160 (13.86) | 0.000 |
| Moderate | 647 (10.13) | 754 (51.32) | 710 (61.52) | |
| Severe | 564 (8.85) | 201 (13.70) | 284 (24.62) | |
| SBF | | | |
| Anterior | 479 (74.96) | 107 (64.07) | 96 (53.04) | 0.013 |
| 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.

| 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.
bone. Such fractures can tear 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 rhinorrhea) in fractures of the skull base, yielding a salty sign. These signs are pathognomonic for SBF. SBF are harder to document on plain X-ray and dribble out through a perforated eardrum (CSF otorrhea) or CSF rhinorrhea in fractures of the skull base. 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. 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. The manifestation of intradural hemorrhages such as CC (p = 0), SDH (p = 0), intracerebral 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. This wide variation also results from both differences in study population and from difficulty of obtaining radiographic verification of the fractures. 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.

**Table 4**

| Variables                      | Location of the skull base fracture (n) | p value |
|-------------------------------|----------------------------------------|---------|
|                               | 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**

| Variables                  | Therapy, n (%) | Total (n) | p value |
|----------------------------|----------------|-----------|---------|
| Skull base fracture location | Operation | No operation |           |
| Anterior                   | 78 (63.90) | 607 (70.20) | 685 | 0.202 |
| 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 |         |

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**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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