OPEN ACCESS *Original Article*

A retrospective analysis of the skull base fractures: demographic characteristics, causes and imaging findings

Hüseyin Kafadar[1], Safiye Kafadar[2*], ŞeyhoCem Yücetaş[3], Hakan Kaya[4]

[1]Department of Forensic Medicine, Adiyaman University Education and Research Hospital, Adiyaman, Turkey;
[2]Department of Radiology, Adiyaman University Education and Research Hospital, Adiyaman, Turkey;
[3]Department of Neurosurgery, Adiyaman University Education and Research Hospital, Adiyaman, Turkey;
[4]Department of Cardiology, Adiyaman University Education and Research Hospital, Adiyaman, Turkey

Abstract

***Background and objectives*:** Skull base fractures have high mortality and morbidity rates and constitute a significant medical issue. The aim of the present study was to review the demographic characteristics, common locations and causes of the skull base fractures retrospectively.

***Methods*:** This retrospective study was conducted on patients who attended the Intensive Care Unit/Radiology Clinic of Adiyaman University Training and Research Hospital between 2015 and 2018 and were found to have skull base fractures. The data were accessed via PACS system of the hospital database. Age, gender, cause of the trauma, type of the skull base fracture, imaging findings and outcome of the enrolled patients were analyzed.

***Results*:** Total 138 cases who met the study criteria were enrolled in the study. The causes of the skull base fracture were as follows: fall 52.2%, traffic accident 36.2%, pounding 3.6%, firearm injury 0.7%, sharp object injury 0.7%, and other causes 6.5%. There was a statistically significant ($p<0.001$) difference in rate of skull base fracture caused by traffic accident between the ≤18-year group and 19-45 age group. The difference between the types of epidural hematoma was not significant in all age groups ($p= 0.156$); however, there was a statistically significant difference for gender (female vs. male 26.1%73.9%, $p=0.025$).

***Conclusion*:** Skull base fractures were more common in fall from height and traffic accidents. In order to reduce skull base fractures, it is recommended to take preventive precautions for falls from height and traffic accidents.

IMC J Med Sci 2022; 16(2): 002. DOI: https://doi.org/10.55010/imcjms.16.012

Introduction

Skull base fractures are defined as fracture of any bones that consist of the skull base due to any reason. Since skull base fractures have high mortality and morbidity rates, they constitute a significant public health issue [1]. It is recognized that skull base fractures appear in approximately 25% of the head trauma cases [2]. Almost 90% of these fractures occur due to closed head trauma whereas approximately 10% of the cases appear in the form of penetrating injuries [3]. In skull base fractures, severe complications may occur as a result of injury to the blood vessels and nerves. Mortality is high, and therefore diagnosis and treatment require urgent intervention. The most important factors that affect the mortality include trauma severity, cerebral hemorrhage and cerebral damage concomitant to skull base fractures [4]. A destructive neurological pathology or possibly fatal vascular injuries accompany the

***Correspondence**: *Safiye Kafadar, Department of Radiology, Adiyaman University Education and Research Hospital, Adiyaman, Turkey. Email: safiyekafadar@gmail.com, ORCID: 0000-0003-4070-9615*

clinical presentation in approximately 50% of the patients with skull base fracture [5]. Cranial computed tomography (CT) is used as a sensitive imaging method to diagnose skull base fracture and to determine concomitant cerebral hemorrhages [6]. Although skull base fractures commonly involve the temporal bone, fractures of the occipital, sphenoid, ethmoid and frontal bones may also be detected [7].

The aim of the present study was to analyze the demographic characteristics, the events that caused fracture (i.e. traffic accident, falling, pounding, firearm injury), types of skull base fracture, imaging findings and outcome of the enrolled patients.

Methods

This retrospective study was approved by the Clinical / Human Research Ethics Committee (2019/7-4) of Medical Faculty, Adiyaman University. Helsinki Declaration rules were followed to conduct the study. Patients who attended the Intensive Care Unit/Radiology Clinic of Adiyaman University Training and Research Hospital between June 1, 2015 and June 30, 2018 and were found to have skull base fractures were included in the study. The data were accessed via PACS system of the hospital database. The enrolled patients with skull base fracture were reviewed for age, gender, the event that caused fracture (i.e. traffic accident, falling, pounding), type of the skull fracture on the imaging studies (i.e. direct X-ray, computed tomography and magnetic resonance imaging), hospitalization period, clinical features and the outcome.

Statistical analysis: Analysis of the variables was performed through SPSS 25.0 (IBM Corporation, Armonk, New York, United States) program. Pearson's Chi-Square and Fisher's exact tests were used to compare categorical variables with each other; results of the exact test were used for Fisher-Freeman-Holton test and Monte Carlo simulation technique; column ratios were compared with each other, and the values were expressed according to Benjamini-Hochberg corrected p value. The odds ratio was used along with confidence interval of 95% to demonstrate the number of the patients with or without a risk factor. Quantitative variables were expressed in mean ± SD (standard deviation) and median (minimum / maximum); categorical variables were demonstrated as number (n) and percent (%). The variables were reviewed at a confidence interval of 95%, and a p value smaller than 0.05 was accepted as significant.

Results

Total 138 patients with skull base fracture were enrolled in the study. The cases were reviewed in four groups namely ≤18, 19-45, 45-65 and ≥66 years. Furthermore, a comparison was performed by gender. Of the total cases, 26.1% were female and 73.9% were male with a mean age of 25.4 years. The comparisons according to the months within the year revealed no statistically significant ($p>0.05$) difference between gender and age groups for skull base fractures (Table-1).

Skull base fracture according to the causes of the incidents is shown in Table-2. The causes of the skull base fracture were by traffic accident 36.2%, fall 52.2%, firearm injury 0.7%, pounding 3.6%, sharp object injury 0.7%, and other causes 6.5%. Fall as the cause for skull base fractures was detected more in the ≤18 years of age (76.5%) and female gender ($p<0.001$). The skull base fractures due to traffic accidents were observed more in the 19-45 and 46-65 age groups than in the ≤ 18 years group, and in male than female gender ($p<0.001$).

Out of total fracture cases, 44.2% of skull base fractures were on single site whereas 55.8% of them were on multiple sites. In addition to the skull base fracture, 22.5% of the cases had cerebral edema, and contusion was detected in 19.6% of the cases. It was detected that cerebral contusion together with skull base fracture was more in 19-45 age group than ≤18 age group, and the fractures without contusion were more in the 19-45 age group than ≤18 age group ($p=0.003$). Epidural, subdural and intracranial hematomas were present in 31.9%, 14.5%, and 6.5% cases respectively. Subarachnoid hemorrhage was found in 24.6%, patients (Table-3). Anatomic locations of the skull base fractures were detected on the following locations: right frontal region 7.9%, left frontal

Table-1: *Month wise incidence of skull base fractures according to age groups and gender of the study patients (n=138)*

Month of the incident	Age in years, n (%)						Gender, n (%)		
	≤18	19-45	45-65	≥66	p	Total	Female	Male	p
	68 (48.3)	39 (29.3)	21 (15.2)	10 (7.2)		138	36 (26.1)	102 (73.9)	
January	0	2 (5.1)	0	0	0.769[ff]	2 (1.4)	0	2 (2)	0.576[ff]
February	1 (1.5)	2 (5.1)	0	0		3 (2.2)	0	3 (2.9)	
March	4 (5.9)	4 (10.3)	2. (9.5)	1 (10)		11 (8)	2 (5.6)	9 (8.8)	
April	3 (4.4)	2 (5.1)	4 (19.0)	2 (20.0)		11 (8)	2 (5.6)	9 (8.8)	
May	9 (13.2)	4 (10.3)	1 (4.8)	0		14(10.1)	6 (16.7)	8 (7.8)	
June	11 (16.2)	4 (10.3)	3 (14.3)	2 (20.0)		20(14.5)	6 (16.7)	14 (13.7)	
July	15 (22.1)	7 (17.9)	2 (9.5)	1 (10)		25(18.1)	9 (25)	16 (15.7)	
August	10 (14.7)	4 (10.3)	3 (14.3)	1 (10)		18 (13)	2 (5.6)	16 (15.7)	
September	6 (8.8)	2 (5.1)	1 (4.8)	1 (10)		10 (7.2)	4 (11.1)	6 (5.9)	
October	5 (7.4)	2 (5.1)	1 (4.8)	1 (10)		9 (6.5)	2 (5.6)	7 (6.9)	
November	1 (1.5)	3 (7.7)	2 (9.5)	0		6 (4.3)	2(5.6)	4 (3.9)	
December	3 (4.4)	3 (7.7)	2 (9.5)	1 (10)		9 (6.5)	1 (2.8)	8 (7.8)	

Note: *[ff]Fisher Freeman Halton test (Monte Carlo).*

Table-2: ***C****auses of the skull base fracture according to age and gender groups (n=138)*

Causes of fracture	Age in years								P	Gender				P
	≤18 (n=68)		19-45 (n=39)		46-65 (n=21)		≥66 (n=10)			Female (n-36)		Male (n-102)		
	n	(%)	n	%	n	%	n	%	<0.001[ff]	n	%	n	%	<0.001[ff]
TA (n= 50, 36.2%)	15	22.1	23[a]	59.0	8	38.1	4	40.0		7	19.4	43[X]	42.2	
Fall (n= 72, 52.2%)	52[bc]	76.5	8	20.5	7	33.3	5	50.0		29	80.6	43[X]	42.2	
FAI (n= 1, 0.7%)	0	0.0	1	2.6	0	0.0	0	0.0		0	0.0	1	1.0	
Pounding (n= 5, 3.6%)	0	0.0	3	7.7	1	4.8	1	10.0		0	0.0	5	4.9	
SOI (n=1, 0.7%)	0	0.0	1	2.6	0	0.0	0	0.0		0	0.0	1	1.0	
Others (n= 9, 6.5%)	1	1.5	3	7.7	5[a]	23.8	0	0.0		0	0.0	9	8.8	

Note: TA: *Traffic accident,* ***FAI:*** *Firearm injury,* ***SOI: S****harp object injury, [ff]Fisher Freeman Halton test (Monte Carlo), [a]significant for ≤18 age group, [b]Significant for 19-45 age group, [c]Significant for 46-55 age group, [x]Significant for female group,.*

Table-3: *Analysis of imaging findings and outcome of the patients with skull base fractures (n=138)*

Variables	Age groups (years)									Gender				
	≤18 n = 68		19-45 n = 39		45-65 n = 21		≥66 n = 10		P	Female n = 36		Male n = 102		P
Injury type														
Single (n= 61, 44.2%)	35	51.5	13	33.3	10	47.6	3	30.0	0.232[ff]	19	52.8	42	41.2	0.247[pe]
Multiple (n= 77, 55.8%)	33	48.5	26	66.7	11	52.4	7	70.0		17	47.2	60	58.8	
Fracture														
Linear (29, 21%)	14	20.6	6	15.4	8	38.1	1	10.0	0.196[ff]	7	19.4	22	21.6	0.819[pe]
Collapse (n= 109, 79%)	54	79.4	33	84.6	13	61.9	9	90.0		29	80.6	80	78.4	
Edema														
None (n= 107, 77.5%)	57	83.8	24	61.5	18	85.7	8	80.0	0.053[ff]	28	77.8	79	77.5	0.999[pe]
Yes (n= 31, 22.5%)	11	16.2	15	38.5	3	14.3	2	20.0		8	22.2	23	22.5	
Contusion														
None (n= 111, 80.4%)	61[b]	89.7	27	69.2	17	81.0	6	60.0	0.017[ff]	32	88.9	79	77.5	0.153[pe]
Yes (n= 27, 19.6%)	7	10.3	12[a]	30,8	4	19.0	4	40.0	3.9 (1.4-0.9)[OR]	4	11.1	23	22.5	
Epidural hematoma														
None (n= 94, 68.1%)	41	60.3	30	76.9	17	81.0	6	60.0	0.156[ff]	19	52.8	75[X]	73,5	0.025
Yes (n= 44, 31.9%)	27	39.7	9	23.1	4	19.0	4	40.0		17[Y]	47.2	27	26.5	2.5 (1.1-5,5)[OR]
Subdural hematoma														
No (118, 85.5%)	61	89.7	33	84.6	16	76.2	8	80.0	0.335[ff]	34	94.4	84	82.4	0.100[pe]
Yes (n= 20, 14.5%	7	10.3	6	15.4	5	23.8	2	20.0		2	5.6	18	17.6	
Subarachnoid bleeding														
No (n= 104, 75.4%)	59[c]	86.8	28	71.8	13	61.9	4	40.0	0.003	32[Y]	88,9	72	70.6	0.041
Yes (n= 34, 24.6%)	9	13.2	11	28.	8	38.1	6[a]	60.0	9.8 (2.3-41.8)[OR]	4	11.1	30[X]	29.4	3.3 (1,1-10,2) [OR]
Intracranial hematoma														
No (n= 129, 93.5%)	66	97.1	35	89.7	19	90.5	9	90.0	0.247[pe]	34	94.4	95	93.1	0.999[fe]
Yes (n= 9, 6.5%)	2	2.9	4	10.3	2	9.5	1	10.0		2	5.6	7	6.9	
Outcome														
Alive (n= 104, 97.1%)	67	98.5	37	94.9	21	100.0	9	90.0	0.228[ff]	35	97.2	99	97.1	0.999[fe]
Expired (n= 4, 2.9%)	1	1.5	2	5.1	0	0.0	1	10.0		1	2.8	3	2.9	

***Note**: [ff]Fisher Freeman Halton test (Monte Carlo), [fe] Fisher exact Test (Exact), [pe] Pearson Chi-Square test (Exact), [OR] Odss Ratio (95% Confidence intervall),[a]significant for ≤18 age group, [b]19-45 Significant for age group, [c]Significant for ≥66 age group, [X]Significant for female group,[Y]Significant for male group.*

region 6.9%, right temporal region 11.5%, left temporal region 19.6%, right occipital region 33.1%, left occipital region 4%, sphenoidal region 7.4%, and ethmoidal region 9.5%. Only 4 patients died in the present study. It was concluded that deaths occurred at the scene of occurrence or before arrival to the hospital, and for this reason, all deaths might not have been registered in the hospital records (Table-3). There was no statistically significant difference between other traumatic causes and mortality, fracture types, anatomic region and edema. Review of hematoma and hemorrhages that accompanied skull base fractures revealed no significant association between the age groups, but it was more in male patients than females (p=0.025). There was no significant association between gender and the age groups for subdural and intracranial hematoma (p>0.05). Subarachnoid bleeding was more common in the ≤18 age group than other age groups (p=0.003), and more prevalent in male patients than female patients (p=0.004; Table -3).

Discussion

Skull base fractures are evaluated as basic fractures that are present at the skull base including temporal, occipital, sphenoid or ethmoid bones [1-3]. Such fractures may cause rupture of the meninges and leakage of cerebrospinal fluid (CSF) [8]. The leaked CSF may accumulate in the middle ear space and may cause neurological and hearing loss [9]. Direct X-ray has limited value for confirmation of the skull base fractures, and CT or MRI is required for final diagnosis [10]. In the present study, 138 patients who presented with skull base fracture due to different reasons were reviewed with justification of the diagnosis by X ray, CT and MRI.

A previous study reported that 78.6% of the cases with skull base fracture were male with a male to female ratio of 3.6 to 1 [11]. We also detected in our group that the male patients with skull base fracture was relatively higher than female patients. Our results comply with the literature information that skull base fractures usually occur on males. The cause for higher number of male cases may be the vulnerability of men to severe traumas due to working in hazardous professions.

Approximately 30% of skull base fractures are known to be caused by motor vehicle accidents, fall, physical assaults and close contact sports. The prevalence of skull base fractures in the patients with head injury was reported from 3.5% to 24.0% [12]. Basillary skull fractures are more common in younger individuals due to their tendency to perform risky activities [13]. A previous study demonstrated that 64.7% cases of skull base fractures had injury to the anterior fossa of the skull [14]. An earlier study reported that the most common causes of skull injuries were traffic accidents (59%), fall (13%) and bicycle accident (12%) [15]. It is a noticeable assessment that motor vehicle accidents are the most common cause of skull base fractures, and majority of these cases are pedestrians [12]. In the present study, we observed that fall (52.2%) were the most common cause of skull base fractures followed by traffic accidents (36.2%).

In the present study, the correlation between skull base fractures and intracranial lesions were evaluated. Intracranial hemorrhages in skull base fractures occur due to linear breakage of the skull convexity [16]. It was also demonstrated that linear fractures may cause cerebral contusion or intracranial hemorrhage [17]. It was detected that skull base fractures were anatomically on a single site in 44.2% of the cases, on multiple sites in 55.8% of the cases; no edema was detected in 77.5% of the patients; contusion was observed in 19.6% of the cases; epidural hematoma, subdural hematoma, subarachnoid bleeding and intracranial hematoma were detected in 31.9%, 14.5%, 24.6% and 6.5% of the cases respectively. A previous research on skull base fracture reported higher incidence of intracranial hemorrhage in the moderate head injury group than mild and severe head injury groups [14]. It was found in the same study that skull base fractures appeared on the anterior fossa were more likely to cause single lesion of traumatic intracranial hemorrhage when compared with other groups. Furthermore, subdural hemorrhages were reported to be higher than cerebral, subarachnoid and extradural hemorrhages in multiple lesions. In the present study, there was no significant association between the age groups and skull base fractures caused by trauma for the cases without epidural hematoma;

however, number of male patients was higher than females. A statistically significant association was not detected for age and gender in the patients with and without subdural and intracranial hematoma. Subarachnoid hemorrhage in patients with skull base fracture was found lower in ≤18 year's age group than other groups, and in men than women. We observed contusion in 19.6% cases. These contusions have the potential to progress to cerebral bleeding, subdural, subarachnoid hemorrhage or intraventricular hemorrhages.

The limitations of the study were that the study had small number of cases (total 138 cases), conducted in a single center and the lack of late-period follow up findings of the patients (after 2 years). We believe that this study on skull base fracture would raise the awareness of the healthcare providers about the approach to the patients. It was also observed that skull base fractures were strongly correlated with traumatic intracranial lesions, while age gender had positive or negative effect.

Conflict of interest

All authors declare no conflicts of interest.

Financial disclosure

No funding or financial support was received.

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Cite this article as:
Kafadar H, Kafadar S, Yücetaş S, Kaya H. A retrospective analysis of the skull base fractures: demographic characteristics, causes and imaging findings. *IMC J Med Sci*. 2022; 16(2):002.
DOI: https://doi.org/10.55010/imcjms.16.012