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Original Article

Traumatic brain injury in patients with facial fracture – A challenge for the clinician?

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Objective: This study aimed to evaluate the occurrence and clinical predictors for missed traumatic brain injury (TBI) diagnosis at primary evaluation in facial fracture patients. The specific aim was to compare the risk between adults and elderly patients.
Materials and methods: A retrospective study was performed, and data were collected from medical records. All adult facial fracture patients with associated TBI and a primary Glasgow Coma Scale score of 13 or more diagnosed and treated between 2013 and 2018 were included. The elderly group comprised patients aged at least 65 years at the time of injury.
Results: Altogether 253 patients with facial fracture and associated TBI were assessed. In 7.1 % of the cases, the diagnosis of TBI was missed in primary evaluation and thus delayed. When the different age groups were compared, the elderly had a 2.8-fold risk of missed TBI diagnosis (95 % CI 1.1–7.2, p=.0349).
Conclusions: Facial fracture patients are at significant risk of the diagnosis of associated TBI being missed at primary evaluation. Especially elderly patients with other than high-energy trauma mechanism, such as falling on ground level, are at risk of missed TBI diagnosis. Thus, patients with facial fracture should be carefully evaluated to exclude potential TBI. Assessment should occur in trauma centres where multiprofessional evaluation of these patients is routine.

1. Introduction

Traumatic brain injury (TBI), defined as an alteration in brain function or other evidence of brain pathology caused by an external force [1], is globally considered the leading cause of death and disability, with an estimated 69 million new cases occurring each year [2]. TBI impacts quality of life, causing potential long-term functional, cognitive, and emotional disabilities. Thus, the primary diagnosis and treatment of TBI warrant attention. Prompt evaluation and initiation of treatment, such as reversing anti-coagulation, is crucial to prevent substantial sequelae of these injuries. In low- and middle-income countries, road traffic incidents remain the leading cause of TBIs, whereas in high-income countries the number of TBIs affecting elderly people, mainly due to falls, is on the rise [3].

We have previously observed that associated injuries (AIs), with TBI being the most common, are often encountered in the facial fracture population. Around 15 % of facial fracture patients sustain a concomitant TBI, and elderly patients have an increased risk for AIs and particularly TBIs relative to adult facial fracture patients. [4] Despite the obvious risk for concomitant TBI, diagnosis and evaluation of facial fractures may distract attention from possible AIs, delaying prompt diagnosis and treatment of potentially disabling and in worst case life-threatening TBIs [5]. In addition, the literature shows a substantial risk of undertriage for elderly trauma patients [6–8]. Hence, a significant risk of delay seems to occur in primary professional diagnosis of concomitant TBI, especially regarding elderly facial fracture patients.

We aimed to investigate the occurrence of and potential clinical predictors for missed TBI diagnosis at primary evaluation (mTBId) in facial fracture patients. The specific aim was to compare the risk for

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mTBId between adults and elderly patients. We hypothesized that patients in different age groups would vary in risk for mTBId and that different predisposing factors for mTBId would emerge in facial fracture patients.

2. Materials and methods

2.1. Study design and sample

The retrospective cohort study was based on adult facial fracture patients presenting to the Töölö Trauma Centre, Helsinki University Hospital, Finland, between 2013 and 2018. Included in the study population were facial fracture patients aged at least 18 years with associated TBI and a primary Glasgow Coma Scale (GCS) score of 13 or more. Patients intubated at the scene of injury were excluded.

2.2. Study variables

The primary predictor variable was age, i.e. adults versus the elderly. The elderly group comprised patients aged at least 65 years at the time of injury.

The primary outcome variable was the presence or absence of mTBId. TBI was defined as imaging-confirmed TBI with findings in computed tomography (CT)/ magnetic resonance imaging (MRI), including intracerebral haemorraghe (ICH), subarachnoid haemorraghe (SAH), subdural haematoma (SDH), epidural haematoma (EDH), and diffuse axonal injury (DAI). mTBId was defined as present when the possibility of a TBI was not considered at the primary evaluation but was later diagnosed.

Explanatory variables were sex, mechanism of trauma, energy of injury, alcohol intoxication at time of injury, type of facial fracture, medication predisposing to bleeding, AI outside the head and face, and number of affected organ systems outside the head and face. Mechanism of trauma was categorized as assault, fall from height or stairs, fall on ground level, traffic, and other/unknown. Energy of injury was categorized as high when caused by MVAs, falls from over three metres, or industrial injuries. Alcohol intoxication at time of injury was verified by the use of a breathalyser, from blood samples, or by the history given by the patient or paramedics. Alcohol intoxication at time of injury was classified as 'no' if the influence of alcohol could not be confirmed from patient charts. Type of facial fracture was classified according to facial thirds as exclusively mandibular, exclusively midfacial, exclusively upper third (orbital roof and/or frontal sinus), or combined fracture, i.e. combination of fractures of different facial thirds. AI outside the face and head included any major injuries, i.e. fractures and injuries to internal organs, respiratory organs, and major vessels. Wounds and superficial soft-tissue injuries were excluded. Affected organ systems outside the head and face were categorized as neck (including cervical spine, cerebral vessels, and larynx), upper extremities, chest, lower extremities (including the pelvis), spine (excluding the cervical spine), and abdomen.

2.3. Data analysis

Descriptive statistics were used to conduct an initial examination of the study sample. The Chi-square test and Fisher's exact test, if any cell had five or fewer observations, were used to estimate the associations between primary predictor and explanatory variables as well as between primary outcome and explanatory variables.

Univariate logistic regression analysis was conducted to determine the association of the main predictor and other explanatory variables with outcome. Variables contributing significantly both with the exposure and the outcome were used in adjusted analyses. Unadjusted and adjusted odds ratios (ORs) were reported with confidence intervals (CIs) at 95 % and statistical significance level set at 0.05. The data analysis was conducted using JMP Software (JMP Pro v17, Cary, NC, USA).

2.4. Ethical considerations

The study was approved by the Internal Review Board of the Head and Neck Centre, Helsinki University Hospital, Helsinki, Finland (HUS/356/2017). The Declaration of Helsinki guidelines were followed.

3. Results

In total, 253 facial fracture patients with associated TBI were included in the study. The elderly group comprised 106 patients (49.1 %), and altogether 147 patients (58.1 %) were adults. Of all cases, 7.1 % were considered mTBId.

Table 1 presents the descriptive statistics of the 253 patients. Most of the patients (68.0 %) were male. The median age of patients was 61.4 years. The most common mechanism of trauma was fall on ground level; this was the injury mechanism in over one-third of patients (35.6 %). Every fifth patient (20.2 %) suffered a high-energy injury. Alcohol intoxication was involved in 37.9 % of injuries. Exclusively mandibular fracture was by far the most common type of facial fracture (62.5 %). Medication predisposing to bleeding was used by 24.9 % of patients prior to injury. One-third of patients (30.8 %) sustained AIs outside the head and face, and most commonly affected were one (19.0 %) or two (10.3 %) organ systems outside the head and face. Regarding the type of TBIs, SDH was the most common injury in both adult and elderly patients (Fig. 1).

Table 1
Descriptive statistics of 253 patients with traumatic brain injuries.

Sex		
Male	172	68.0
Female	81	32.0
Age (years)		
Range	18.6–98.1	
Mean	58.6	
Median	61.4	
Age group (years)		
Adults (< 65)	147	58.1
Elderly (≥ 65)	106	41.9
Mechanism of trauma		
Fall on ground level	90	35.6
Traffic	61	24.1
Fall from height or stairs	43	17.0
Assault	40	15.8
Other/Unknown	19	7.5
High-energy trauma mechanism		
Yes	51	20.2
Alcohol intoxication		
Yes	96	37.9
Type of facial fracture		
Exclusively mandibular	158	62.5
Combined	52	20.5
Exclusively midfacial	23	9.1
Exclusively upper third	20	7.9
Medication predisposing to bleeding		
Yes	63	24.9
Associated injury outside the head and face		
Yes	78	30.8
Number of affected organ systems outside the head and face		
1	48	19.0
2	26	10.3
3	4	1.6
≥ 4	0	0.0
Missed TBI diagnosis at primary evaluation		
Yes	18	7.1
Delay in TBI diagnosis (days)		
Range	0–13	
mean	1.9	
median	1	

TBI=traumatic brain injury.

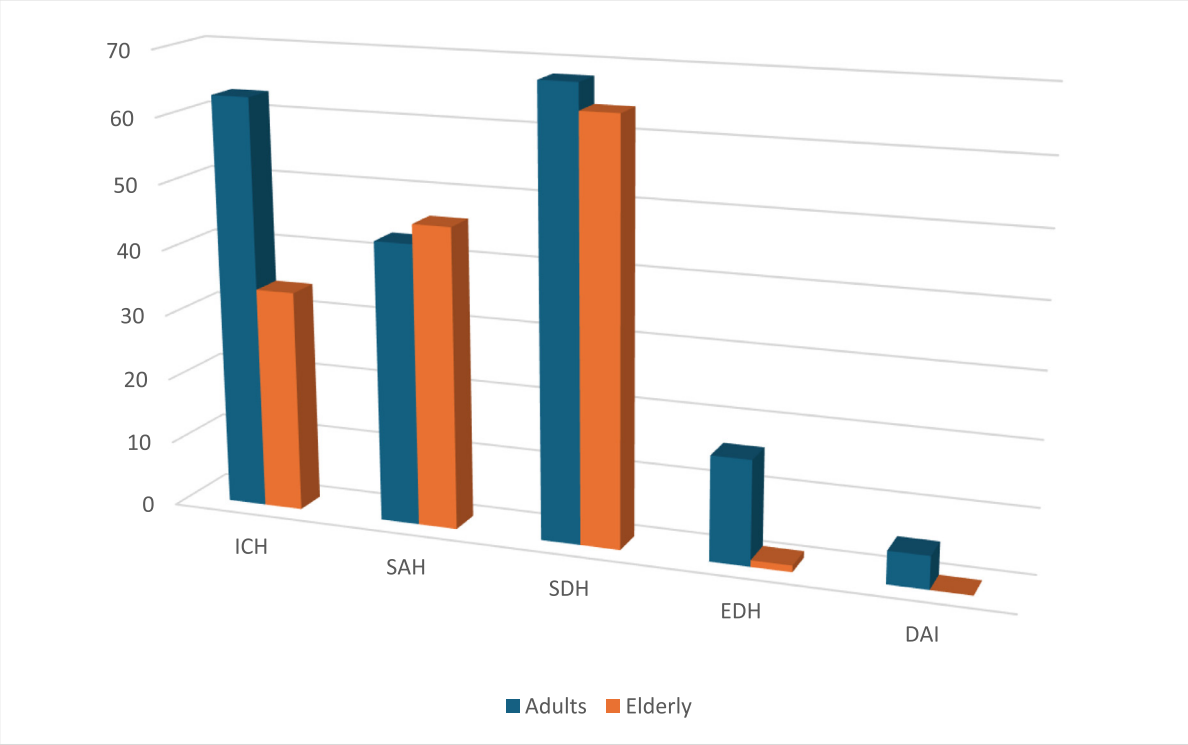

Fig. 1. Descriptive data for 340 radiological findings in 253 patients with traumatic brain injuries.

Table 2
Controlled variables by age group.

	Adults (< 65) (*n* = 147)		Elderly (≥ 65) (*n* = 106)		
	No. of patients	%	No. of patients	%	
Sex					<0.0001*
Male	118	80.3	54	50.9	
Female	29	19.7	52	49.1	
Mechanism of trauma					<0.0001**
Fall on ground level	24	16.3	66	62.3	
Traffic	43	29.3	18	17.0	
Fall from height or stairs	28	19.1	15	14.2	
Assault	38	25.8	2	1.8	
Other/Unknown	14	9.5	5	4.7	
High-energy trauma mechanism					.0193*
Yes	37	25.2	14	13.2	
No	110	74.8	92	86.8	
Alcohol intoxication					<0.0001*
Yes	74	50.3	22	20.8	
No/Unknown	73	49.7	84	79.2	
Type of facial fracture					.0310*
Exclusively mandibular	81	55.1	77	72.6	
Combined	34	23.1	18	17.0	
Exclusively midfacial	17	11.6	6	5.7	
Exclusively upper third	15	10.2	5	4.7	
Medication predisposing to bleeding					<0.0001*
Yes	10	6.8	53	50.0	
No	137	93.2	53	50.0	
Associated injury outside the head and face					.0359*
Yes	42	28.6	36	34.0	
No	105	71.4	70	66.0	
Number of affected organ systems outside the head and face					.0188**
0	105	71.4	70	66.0	
1	20	13.6	28	26.4	
2	18	12.2	8	7.6	
3	4	2.7	0	0.0	
≥ 4	0	0.0	0	0.0	

* Chi-square test.
** Fisher's exact test.

Table 3
Controlled variables by missed traumatic brain injury diagnosis at primary evaluation.

	Missed TBI diagnosis at primary evaluation present,n(%)	% of n	Missed TBI diagnosis at primary evaluation absent, n(%)	% of n	p-value
All (*n* = 253)	18 (7.1)	7.1	235 (92.9)	92.9	
Sex					.1934*
Male (*n* = 172)	15 (83.3)	8.7	157 (66.8)	91.3	
Female (*n* = 81)	3 (16.7)	3.7	78 (33.2)	96.3	
Mechanism of trauma					.0100*
Fall on ground level (*n* = 90)	12 (66.7)	13.3	78 (33.2)	86.7	
Traffic (*n* = 61)	1 (5.6)	1.6	60 (25.5)	98.4	
Fall from height or stairs (*n* = 43)	0 (0.0)	0.0	43 (18.3)	100.0	
Assault (*n* = 40)	3 (16.7)	7.5	37 (15.7)	92.5	
Other/Unknown (19)	2 (11.1)	10.5	17 (7.2)	89.5	
High-energy trauma mechanism					.0284*
Yes (*n* = 51)	0 (0.0)	0.0	51 (21.7)	100.0	
No (*n* = 202)	18 (100.0)	8.9	184 (78.3)	91.1	
Alcohol intoxication					.6757**
Yes (*n* = 96)	6 (33.3)	6.2	90 (38.3)	93.8	
No/Unknown (*n* = 157)	12 (66.7)	7.6	145 (61.7)	92.4	
Type of facial fracture					.6120*
Exclusively mandibular (*n* = 158)	10 (55.6)	6.3	148 (63.0)	93.7	
Combined (*n* = 52)	4 (22.2)	7.7	48 (20.4)	92.3	
Exclusively midfacial (*n* = 23)	3 (16.7)	13.0	20 (8.5)	87.0	
Exclusively upper third (*n* = 20)	1 (5.6)	5.0	19 (8.1)	95.0	
Medication predisposing to bleeding					.0467**
Yes (*n* = 63)	8 (44.4)	12.7	55 (23.4)	87.3	
No (*n* = 190)	10 (55.6)	5.3	180 (76.6)	94.7	
Associated injury outside the head and face					.2882**
Yes (*n* = 78)	3 (16.7)	3.9	75 (31.9)	96.1	
No (*n* = 175)	15 (83.3)	8.6	160 (68.1)	91.4	
Number of affected organ systems outside the head and face					.7563*
0	15 (83.3)	8.6	160 (68.1)	91.4	
1	2 (11.1)	4.2	46 (19.6)	95.8	
2	1 (5.6)	3.9	25 (10.6)	96.1	
3	0 (0.0)	0.0	4 (1.7)	100.0	
≥ 4	0 (0.0)	0.0	0 (0.0)	0.0	

* Fisher's exact test.
** Chi Square test
TBI: Traumatic brain injury.

Tables 2 and 3 show the associations between primary predictor and explanatory variables as well as between primary outcome and explanatory variables. The variables mechanism of trauma, energy of injury, and medication predisposing to bleeding were significantly associated with primary predictor and primary outcome alike.

The risk analysis between mTBId and age groups is shown in Table 4. Elderly patients had a 2.8-fold higher risk of mTBId than adults (95 % CI 1.1–7.2, *p*=.0349).

Table 5 summarizes the logistic regression analysis for mTBId. In the univariate analysis, significant predictors for mTBId were age and mechanism of trauma. Elderly patients had 3.0 times greater odds (95 % CI 1.1–8.3, *p*=.0337) for mTBId than adults. Falling on ground level increased the odds for mTBId to 4.0 times (95 % CI 1.5–11.1, *p*=.0073) relative to other mechanisms of trauma. After adjusting for age group and medication predisposing to bleeding, patients falling on ground level had 2.9 times greater odds for mTBId than patients injured with other mechanisms of trauma, however, this result was statistically nonsignificant (95 % CI 0.9–9.3, *p*=.0723). In the adjusted analysis, elderly patients had 1.6 times greater odds for mTBId than adults, but the adjusted analysis was also statistically nonsignificant (95 % CI 0.5–5.4, *p*=.4818).

4. Discussion

The purpose of this study was to clarify the occurrence of missed TBIs in primary care in order to increase the recognition of these injuries in facial fracture patients. We hypothesized that different predisposing factors for mTBId associated with facial fractures would be found and that the elderly, in particular, are at risk of mTBId compared with adult facial fracture patients. The results revealed that the elderly had a 2.8-fold higher risk of mTBId than adults. The elderly also had greater odds for mTBId than adults, although this result in the adjusted analysis was statistically nonsignificant.

Table 4
Calculation of risk ratio (RR) by age group between patients with and without primary professional delay in traumatic brain injury diagnosis.

Age group (years)	Patients with missed TBI diagnosis at primary evaluation	Patients without missed TBI diagnosis at primary evaluation	Total	RR(95 % CI)	p-value
Elderly (≥ 65) n (%)	12 (11.3)	94 (88.7)	106 (41.9)	2.8 (1.1–7.2)	.0349
Adults (< 65) n(%)	6 (4.1)	141 (95.9)	147 (58.1)	Ref	
Total	18 (7.1)	235 (92.9)	253		

TBI=traumatic brain injury.

Table 5
Logistic regression analysis for missed traumatic brain injury diagnosis at primary evaluation.

	OR(95 % CI) Unadjusted	p-value	OR(95 % CI) Adjusted*	p-value
Age group, unadjusted (years)				
Adults (< 65)	ref		ref.	
Elderly (≥ 65)	3.0 (1.1–8.3)	.0337	1.6 (0.5–5.4)	0.4818
Sex				
Male	2.5 (0.7–8.8)	.1599		
Female	ref			
Mechanism of trauma				
Fall on ground level	4.0 (1.5–11.1)	.0073	2.9 (0.9–9.3)	0.0723
Other mechanism than fall on ground level	ref		ref	
High-energy trauma mechanism	NA			
Yes				
No				
Alcohol intoxication				
Yes	ref			
No/Unknown	1.2 (0.5–3.4)	.6762		
Type of facial fracture		0.6894		
Exclusively mandibular	1.3 (0.2–10.6)	.8165		
Combined	1.6 (0.2–15.1)	.6896		
Exclusively midfacial	2.9 (0.3–29.8)	.3821		
Exclusively upper third	ref			
Medication predisposing to bleeding				
Yes	2.6 (1.0–7.0)	.0536	1.4 (0.4–4.3)	0.5717
No	ref		ref	
Associated injury outside the head and face				
Yes	ref			
No	2.3 (0.7–8.3)	.1885		
Number of affected organ systems outside the head and face			0.4190	
0	2.7 (0.3–21.4)	.3420		
1	1.3 (0.1–14.5)	.8527		
≥2	ref			

OR=odds ratio
CI=confidence interval.
* adjusted for mechanism of trauma and medication predisposing to bleeding.

The results showed a notable occurrence of mTBId (7.1 %). The alarming rate of mTBId in these patients can be explained in several ways. The literature provides evidence that the clinical specialty of the examining physician plays a significant role in diagnosing TBI. Clinical specialty other than neurology/neurosurgery seems to increase the risk of failure to diagnose TBI [9,10]. Hence, patients with facial fractures should be evaluated in centres with access to a multiprofessional trauma team. In our study, most of the primarily missed TBIs were found in patients with no other concomitant injuries. The challenges in diagnosing TBI were typically encountered in elderly patients injured in low-energy accidents, mostly falling on ground level. As shown in this study, concomitant TBI of facial fracture patients with high-energy injury mechanisms is rarely missed in primary care. The risk of mTBId clearly lies in patients with minor injuries. Patients with high-energy injuries are typically rapidly referred to higher level trauma centres, with multiprofessional trauma teams and solid experience in evaluating these patients, whereas patients with minor injuries are evaluated through various routes and possibly lower level trauma centres. Also, imaging of high-energy trauma patients is based on trauma protocols, as opposed to patients with minor injuries, whose imaging is usually based on solely clinical examination.

Undertriage is common in emergency patients, and especially the elderly are prone to diagnostic errors [6]. Anticoagulant medication use before TBI is a well-known risk factor for mortality. To optimize the results of the treatment of the brain, anticoagulant medication should be reversed promptly [11]. With often multiple comorbidities and medications, such as anticoagulants, elderly patients have an elevated risk of severe injuries even from injury mechanisms traditionally considered to be low energy, e.g. a fall at ground level. In 2010, Spaniolas et al. [12] showed that ground-level fall in patients aged over 70 years with primary GCS lower than 15 was associated with significant mortality. Other studies have reported similar results of ground-level falls being a significant predictor of severe injuries in elderly patients [13,14]. In this study, ground-level fall, being the most common mechanism of injury, was mostly sustained by elderly patients, significantly increasing the odds for mTBId compared with other injury mechanisms. On the other hand, concomitant TBIs are also found in younger age groups (4.1 %). Thus, the professional treating patients with facial fractures is required to know when to suspect concomitant TBI and to rely on multiprofessional help with a low threshold.

In this study, the missed TBI diagnoses in primary care were mainly due to failed suspicion and lack of imaging. These patients received facial fracture diagnosis prior to TBI diagnosis. When reviewing the types of facial fractures, the concomitant TBI of patients with exclusively midfacial fracture was most commonly missed at primary evaluation. The delay of TBI diagnosis ranged from hours to 13 days.

In this study population, alcohol intoxication was encountered in almost one in four patients at the time of injury. It could be speculated that some of the neurological symptoms might be interpreted as alcohol-related behaviour and that intoxicated patients might be at risk of delayed TBI diagnosis and treatment. However, alcohol intoxication in this study was not associated with mTBId. This is in concordance with previous reports showing that the effect of alcohol intoxication on assessment of potential TBI does not result in significant clinical changes in GCS score of the patient [15,16].

Due to the retrospective nature of this study and the partly lacking information on possible clinical symptoms of mild TBI, we included only patients with imaging-confirmed TBIs. This might lead to underestimation of the rate of missed diagnoses of concomitant mild TBI. Moreover, since the clinical symptoms and radiological findings of TBI can develop with a delay, it is possible that the primary evaluation did not reveal the diagnosis.

5. Conclusion

The diagnosis of concomitant TBI in the facial fracture population is often missed at primary evaluation. Particularly elderly facial fracture patients with other than high-energy mechanism injuries, such as falls at ground level, are at significant risk of missed TBI diagnosis. Professionals treating patients with facial fractures are required to understand and manage the primary diagnostics of TBI and must be able to consult neurology/neurosurgery at a low threshold. This emphasizes the multiprofessional nature of evaluating facial fracture patients.

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Declaration of competing interest

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CRediT authorship contribution statement

L Kokko: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software,

Visualization, Writing – original draft, Writing – review & editing. **T Puolakkainen:** Conceptualization, Data curation, Investigation, Methodology, Software, Writing – original draft, Writing – review & editing. **H Thorén:** Conceptualization, Formal analysis, Methodology, Project administration, Resources, Supervision, Writing – review & editing. **A Piippo-Karjalainen:** Conceptualization, Methodology, Project administration, Supervision, Validation, Writing – review & editing. **AL Suominen:** Conceptualization, Formal analysis, Investigation, Project administration, Software, Supervision, Writing – review & editing. **J Snäll:** Conceptualization, Data curation, Methodology, Project administration, Supervision, Writing – original draft, Writing – review & editing.

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