Associated Injuries Are Common Among Patients With Bicycle-Related Craniofacial Fractures

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Abstract

Purpose: Ample evidence exists on the relationship between bicycle injuries and craniofacial fractures. However, as the mechanism behind these injuries is often multifactorial, the presence of associated injuries (AI) in this study population requires further examination. We hypothesized that craniofacial fracture patients injured in bicycle accidents are at high risk of sustaining severe AIs, especially those of the head and neck region.

Patients and Methods: The investigators performed a retrospective study on all bicycle-related craniofacial fracture patients admitted to a tertiary trauma centre during 2013 to 2018. The predictor variable was defined as any type of craniofacial fracture. The outcome variable was defined as any kind of AI. Other study variables included demographic and injury-related parameters. Variables were analysed using bivariate and Firth's logistic regression analyses.

Results: A total of 407 patients were included in the analysis. Our results revealed that AI were present in 150 (36.9% patients); there were multiple AI in 47 cases. Traumatic brain injuries (TBI) followed by upper limb injuries were the most frequent AI. Severe head and neck injuries were present in 20.1% of all craniofacial fracture patients. AI were observed in 57.4% of patients with combined midfacial fractures ($p<0.001$). Helmet use had a protective effect against TBI ($p<0.001$).

Conclusion: Our results suggest that AIs are relatively common in this specific patient population. Close co-operation in multidisciplinary trauma centres allowing comprehensive evaluation and treatment can be recommended for bicycle-related craniofacial fracture patients.

Keywords: Bicycle, facial fracture, associated injury, helmet use

Introduction

Bicycling is a popular, health-promoting and environmentally friendly means of transport. Despite having many positive impacts, bicycling also exposes individuals to the risk of personal injury. This is partly due to the relatively high speeds compared with a somewhat low level of protection, often resulting in potentially severe injuries induced by high-energy transmission to both soft and hard tissues. (1) In general, bicyclists are predisposed to injuries in all regions of the body. However, trauma to the head and neck region in particular may lead to long-term functional and neurological impairment. (2-4)

A correlation between bicycle accidents and facial fractures has been documented, as facial injuries occur at a rate nearly identical to that of head injuries in patients sustaining bicycle-related trauma. (5) In particular, the bones of the lower and middle third of the facial skeleton, areas not protected by standard protective helmets, are highly susceptible targets of energy transmission. Additionally, a significant portion of this patient population sustains associated injuries (AI). (6) Of particular concern are the rates of concomitant severe head and neck injuries, such as traumatic brain, cervical spine and blunt cerebrovascular injuries, in bicycle-related craniofacial fracture patients.

The relationship between bicycle accidents and head injuries has been previously established and the use of safety helmets and other protective gear is widely promoted. The protective role of helmets in injured cyclists has been well documented, as previous studies have suggested that helmet use during bicycle accidents significantly reduces the odds of head injury. (3, 7, 8) In addition to the design and shape of the protective helmet, compliance regarding helmet use, which strongly seems to be age- and gender-dependent, is an essential factor when assessing cycling-related head injuries. (1, 7, 8) However, it is unclear whether helmet use has a protective effect on AIs other traumatic brain injuries in the facial fracture population.

The aim of the present study was to clarify the occurrence and severity of AI in patients with craniofacial fractures related to bicycle accidents. In particular, we sought to determine the risk of sustaining severe head and neck injuries in this patient population. We hypothesized that craniofacial fracture patients injured in bicycle accidents are at high risk of sustaining severe AIs, especially those of the head and neck region.

Methods

Study design: This retrospective study was based on all patients admitted to a tertiary trauma centre (Helsinki University Hospital, Helsinki, Finland) with any type of craniofacial fracture during 2013 to 2018. All patients with comprehensive patient files and any radiologically confirmed craniofacial fracture induced by a bicycle accident were included in the study.

The main outcome variable was any AI. These were categorized into traumatic brain injury (TBI), upper limb injury (including fractures and joint dislocations), thoracic and abdominal injury, cervical spine injury (CSI), blunt cerebrovascular injury (BCVI), ocular injury (injuries to the bulbus and optic nerve), pelvic ring injuries, and lower limb injury (including fractures and joint dislocations). Occurrence of AI types and patient mortality were reported.

The primary predictor variable was the type of craniofacial fracture (categorized as exclusively facial fracture, exclusively cranial fracture, and combination of both facial and cranial fracture). Additional predictor variables were the need for surgical intervention for craniofacial fractures and need for intubation upon primary evaluation.

Additional analyses for specific cranial and facial fracture subtypes and AI were performed. Isolated, unilateral zygomatic-maxillary and/or orbital fractures were grouped as zygomatic-maxillary-orbital (ZMO) fractures. Le Fort fractures and other different combinations of midfacial fractures were classified as combined midfacial fractures.

Explanatory variables included age, gender, specific injury mechanism, helmet use and the influence of alcohol at the time of injury. Alcohol influence was verified from blood samples, by use of a breathalyzer, or history provided by the patient or paramedics. If alcohol influence could not be confirmed, these patients were classified as “No alcohol”.

In addition, associations between study variables and helmet use were analysed separately, where patients with unknown helmet use status during the time of accident were excluded.

Statistical analyses

Pearson Chi Square tests or Fisher's Exact test were used as appropriate for categorical variables. The continuous variables were reported as means and standard deviations, as these were normally distributed. Firth's method of logistic regression was used for the univariate and multivariable analysis due to the low number of cases with five or less for craniofacial fracture injuries, which was the primary predictor variable. The variables retained in the multivariable model were based on a p-value <0.2 due to the small sample size. Estimates were reported as odds ratios (OR), with the statistical significance at 0.05 and 95% confidence intervals (CI). The final model was found to have a good fit based on the Firthfit test. The Variance Inflation Factor (VIF) was used to test for multicollinearity. The variables in the final model each had a VIF <5 indicating minimal multicollinearity. Data analysis was performed using Stata version 16 (StataCorp, TX, USA).

Ethical considerations:

The study was approved by the Internal Review Board of the Head and Neck Center, Helsinki University Hospital, Helsinki, Finland (HUS/356/2017 and HUS/54/2019).

Results

Out of 3256 craniofacial fracture patients, 407 patients (12.5%) were included in the analysis (Table 1). Patient age ranged from 4 to 89 years. Males were overrepresented (n=274; 67.3%). The most frequent injury mechanism was falling over, which occurred in 319 (78.4%) patients. Approximately a quarter (n=111; 27.3%) of the patients used helmets at the time of the injury. Almost one third (n=124; 30.5%) were found to been under the influence of alcohol prior to injury. Surgical intervention for craniofacial fractures was required for 153 (37.6%) of all patients.

In general, AIs were common in the study population as altogether 150 patients (36.9%) sustained AIs. Patients with cranial fractures were at high risk of AI, as these occurred in 94.1% of patients with exclusively cranial fractures and 80.5% of patients with combined cranial and facial fractures. AI occurrence was 28.9% in patients with exclusively facial fractures. Primary intubation was required in 26 (6.4%) patients and injures in 7 (1.7%) patients lead to death.

Of the 150 patients with AIs, 47 (31.3%) sustained multiple AIs (Table 2). The most common AI was traumatic brain injury, which occurred in 68 (16.7%). A high rate of upper limb injuries (n=58; 38.7% of patients with AI) was also observed. In total, 85 patients (56.7% of patients with AI and 20.9% of all patients) sustained severe head and neck injuries.

Unilateral ZMO (n=134; 32.9%) and mandibular (n=117, 28.8%) fractures were the most common facial fractures in this study population (Table 3). Only 14.5% of patients with mandible fractures presented with AI, whereas 57.4% of patients with mid-facial fractures sustained AI.

Compared with the patients with exclusively facial fractures, in the unadjusted models (Table 4) the odds of AI were significantly higher among patients with only cranial fractures (OR 26.93, 95% CI 4.98-145.56; $p<0.001$), and with combined facial and cranial fractures (OR 9.65, 95% CI 4.39-21.20; $p<0.001$). Patients who had collided with a motorized vehicle had an over three-fold increased risk of presenting with AI (OR 3.54, 95% CI 1.82-6.90; $p<0.001$). On the other hand, patients who had fallen over as the mechanism of injury were less likely to have AI (OR 0.39, 95% CI 0.24-0.63; $p<0.001$).

In the multivariable analysis (Table 5) by fracture type, AI were associated with an increased risk for exclusively cranial fractures (OR 22.16, 95% CI 3.69-133.15; $p=0.001$) and combined craniofacial fractures (OR 6.22, 95% CI 2.67-14.48; $p<0.001$) compared with only facial fractures. With each increase in age, there was a 2% increase in the risk for AI (OR 1.02, 95% CI 1.01-1.03; $p=0.003$). There was also an increased risk for AI in patients needing primary intubation (OR 45.66, 95% CI 2.64-788.34; $p=0.009$)

To further analyse the protective role of helmet use in this population, patients with “unknown” helmet use were omitted (Table 6). There were no significant differences in injury mechanisms between the groups, whereas over 80% of patients not wearing a helmet were under the influence of alcohol ($p<0.001$). A total of 67.2% of patients who sustained some type of craniofacial fracture requiring surgical intervention were not wearing a helmet at time of injury. Patients not wearing helmets had a five-fold increased occurrence rate for TBI compared with patients wearing helmets ($p=0.001$).

Discussion

Our hypothesis was confirmed as our results suggest that AIs are common in the bicycle-related craniofacial fracture population. Four out of five patients with cranial fractures had AI regardless of the presence of a concomitant facial fracture. AI also occurred in nearly one third of exclusively facial fracture patients as well. Traumatic brain injuries, thoracic and abdominal injuries, and upper limb injuries were the most frequent AI. Even though alcohol use was strongly associated with fracture occurrence in this patient population, cycling under the influence of alcohol seemed to decrease the risk of AI. As expected, helmet use had a protective effect on intracranial injuries.

The current literature concerning the AI of patients sustaining bicycle-related cranio-facial fractures is relatively limited. A dual-centre study by Boffano et al. reported a total of 38 AI in 208 facial fracture patients, with the most common injuries being classified as orthopedic or encephalic by anatomical location. (9) This is consistent with the present study. Additionally, thoracic and abdominal injuries were relatively common. A pivotal observation was that in 31.3% of patients with AI, these injuries were multiple. Amongst all craniofacial fracture patients, the mortality rate was 1.7%. Due to the high occurrence rate of AI in patients with craniofacial fractures, it is imperative that patients sustaining bicycle-related cranio-facial fractures should be evaluated and treated at a low threshold in multidisciplinary trauma centres where different specialties are well represented.

Our institution published a similar report almost four decades ago, where 93 patients sustained bicycle-related maxillofacial fractures over a period of 3 years. (10) Even though this study cohort did not include patients with isolated cranial fractures, it is plausible that the incidence rate of craniofacial fractures related to bicycling has more than doubled during the past 40 years. Similar to our results, the authors also noted that 38% of facial fracture patients had AI, although there is a distinct difference in the definition of AI used between these two studies. Therefore, our study convincingly suggests that even though the clinical presentation of these injuries might have remained unchanged, their rates are significantly increasing, which is in agreement with a recently published extensive registry-based study. (11)

Several reports have convincingly suggested that patients with bicycle related injuries are at a high risk of sustaining TBIs. (5, 12) Indeed, Joseph and colleagues reported that over 52% of patients in bicycle-related accidents had severe TBIs. (8) Additionally, due to the increased recognition and updated screening protocols, the occurrence rates for CSI and BCVI in patients with facial fractures are presumably higher than previously reported. (13-15) In our study, over 20% of the patients sustained either individual or multiple severe head and neck injuries, reflecting that patients of this population are at a particularly high risk of sustaining long-term neurological impairments. Our results are supported by a recent report that showed that over 10% of patients with bicycle-related injuries sustained CSI. (16) Thus, it is imperative that these injuries must be disclosed in all bicycle-related craniofacial fracture patients. (17)

The mean age of patients sustaining bicycle-related facial fractures is approximately 40 years old (1, 9). In concordance with other facial fracture studies, our results show that the risk of AI was significantly increased in older patients. (18) In contrast to a recent publication by Toivari et al. who found that females were more prone to AI, we found no significant difference in the occurrence rates of AI between genders. (19) This discrepancy is likely to be due to the fact that our study population was not confined to a specific age group. Most studies have reported that males are overrepresented in bicycle-related accidents. (20-22) Our findings are consistent with these previously reported figures and may be due in part to the assertion that alcohol consumption is more prominent in men. (23)

Our results suggest that the mid-facial region and mandible are often the primary targets of energy transmission induced by bicycle accidents, which is in concordance with numerous other reports. (1, 6, 9) Based on our findings, patients with multiple fractures of the midfacial region in particular had high occurrence rates of AI. Almost 60% of patients with combined mid-facial fractures sustained AI. Interestingly, patients with isolated mandibular fractures were less likely to have AI than patients with other fracture types. This finding is controversial, as mandibular fractures have previously been linked to CSI and BCVI regardless of trauma mechanism (13, 24). One proposition is that in isolated mandibular fractures, the energy transmission is confined to the mandible and forces are not directly exerted to the surrounding tissues. (25)

The protective role of helmets in injured cyclists has been well documented as current literature suggests that helmet use may decrease the odds of significant head injury by 51% to 72%. (3, 7) However, it is widely accepted that standard helmets do not offer a sufficient level of protection against facial injuries. A recent wide registry-based study by Benjamin and colleagues analysed facial injury patterns in cyclists and evaluated the role of safety helmets and concluded that the level of protection depends on the proximity of the injury to the helmeted head. (26) Quite interestingly, helmet use did not have an effect on the need for surgical intervention in craniofacial fractures in our patient population. This can be postulated by the supporting notion that most of the patients that did not wear a helmet were under the influence of alcohol at the time of injury. A state of intoxication can directly influence the behaviour of bicyclists and they may intuitively ride at lower speeds, resulting in lower energy trauma upon falling down or collisions.

Alfrey et al recently reported a further corroboration of the protective effect of safety helmets, as they demonstrated that helmet use significantly protects cyclists from serious head injuries. (27) Even though helmet use was unknown in 25% of our patients, our findings may support the proposition that helmet use may protect patients from intracranial injuries but not from cervical injuries or blunt cerebrovascular injuries. This is in consistent with previous findings by Page and colleagues. (16) These results indicate that standard bicycle helmets do not protect the neck region from bicycle-related injuries. Therefore, patients in this trauma population could benefit from the use of airbag helmets. (28)

Limitations

A significant and concerning limitation was the lack of reported helmet use in the patient files. As helmet use has been demonstrated to protect against intracranial injuries, the proper reporting of helmet use is essential for descriptive communication between medical specialties and analyzing cases retrospectively. Other publications have not thoroughly described how they have taken unknown helmet use into consideration in their reports and we strongly encourage other institutions to review their in-house codes of conduct related to documentation of helmet use. Even though the retrospective study design may limit the conclusions drawn from the relationship between variables, our results do indicate high occurrence rates of AI in patients with craniofacial fractures and can generate hypotheses for future prospective studies.

Conclusion

The occurrence rate for AI in patients with craniofacial fractures related to bicycle accidents is high. Accordingly, these patients require careful examination in a primary treatment unit. Close cooperation and a low threshold assessment allowing comprehensive evaluation and treatment in multidisciplinary trauma centres can be recommended in bicycle-related craniofacial fracture patients.

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Table 1 – Characteristics of bicycle-related craniofacial fracture patients in patients with and without associated injuries.

Variable	Patients with associated injuries			Patients without associated injuries			Chi square / Fisher's exact p-value
	N.o of patients	%	% of n	N.o of patients	%	% of n	
All	150	36.9		257	63.1		
Age							
Mean (SD)	49.3 (17.9)			40.8 (19.0)			<0.001
Gender							
Male	108	72.0	39.4	166	64.6	60.6	0.124
Female	42	28.0	31.6	91	35.4	68.4	
Mechanism of injury							
Falling over	102	68.0	32.0	217	84.4	68.0	0.001
Collision with stationary object	8	5.3	47.1	9	3.5	52.9	0.373
Collision with other cyclist	13	8.7	44.8	16	6.2	55.2	0.356
Collision with motorized vehicle	27	18.0	64.3	15	5.8	35.7	0.001
Helmet							
No	82	54.7	42.5	111	43.2	57.5	0.033
Yes	40	26.7	36.0	71	27.6	64.0	
Unknown	28	18.7	27.2	75	29.2	72.8	
Alcohol							
No	111	74.0	39.2	172	66.9	60.8	0.135
Yes	39	26.0	31.4	85	33.1	68.6	
Craniofacial fracture requiring surgical intervention							
No	105	70.0	41.3	149	58.0	58.7	0.016
Yes	44	30.0	29.4	108	42.0	70.6	
Primary intubation							
No	124	82.7	32.6	257	100.0	67.4	0.001
Yes	26	17.3	100.0	0	0.0	0.0	
Fracture type							
Exclusively facial	101	67.3	28.9	248	96.5	71.1	0.001
Exclusively cranial	16	10.7	94.1	1	0.4	5.9	
Combined	33	22.0	80.5	8	3.1	19.5	

Table 2 – Types of associated injuries present in bicycle-related craniofacial fracture patients.

Variable	No. of patients with associated injury	% of patients with associated injury	% of 407 patients
Associated injury (any)	150		36.9
One associated injury	103	68.7	25.3
Two or more associated injuries	47	31.3	11.5
Type of associated injury			
Traumatic brain injury	68	45.3	16.7
Upper limb	58	38.7	14.3
Thoracic/abdominal	42	28.0	10.3
Cervical spine injury	23	15.3	5.7
Blunt cerebrovascular injury	5	3.3	1.2
Ocular	4	2.7	1.0
Pelvic	3	2.0	0.7
Lower limb	2	1.3	0.5
Severe head and neck injury	85	56.7	20.9

Table 3 – Comparison of the presence of associated injuries based on fracture location

Variable	Patients with associated injuries			Patients without associated injuries			p-value
	No. of patients	%	% of n	No. of patients	%	% of n	
Facial fracture (any)							
No	16	10.7	94.1	1	0.4	5.9	0.001
Yes	134	89.3	34.4	256	99.6	65.6	
Mandible	17	11.3	14.5	100	38.9	85.5	0.001
Unilateral ZMO	54	36.0	40.3	80	31.1	59.7	0.313
Combined midfacial	31	20.7	57.4	23	9.0	42.6	0.001
Combination of facial thirds	22	14.7	45.8	26	10.1	54.2	0.180
Upper third	5	3.3	50.0	5	2.0	50.0	0.509
Nasal	4	2.7	18.2	18	7.0	81.8	0.071
Other	1	0.7	20.0	4	1.6	80.0	0.656
Cranial fracture (any)							
No	101	67.3	28.9	248	96.5	71.1	<0.001
Yes	49	32.7	84.5	9	3.5	15.5	
Skull base	30	20.0	83.3	6	2.3	16.7	<0.001
Other than skull base	14	9.3	82.3	3	1.2	17.7	<0.001
Combined	5	3.3	100.0	0	0.0	0.0	0.007

Table 4 Univariate logistic regression analysis of bicycle-related craniofacial fracture patients

Variable	Unadjusted Odds Ratio	Confidence Interval	p-value
Age	1.02	1.01, 1.04	<0.001
Gender (ref: Male)	0.71	0.46, 1.10	0.125
Fracture type			
Exclusively facial	1		
Exclusively cranial	26.93	4.98, 145.56	<0.001
Combination	9.65	4.39, 21.20	<0.001
Craniofacial fracture requiring surgical intervention			
No (ref)	1		
Yes	0.59	0.39, 0.91	0.016
Alcohol			
No (ref)	1		
Yes (ref)	0.71	0.45, 1.11	0.136
Helmet use			
No (ref)	1		
Yes	0.76	0.47, 1.23	0.270
Unknown	0.51	0.30, 0.85	0.010
Mechanism of injury			
Falling over	0.39	0.24, 0.63	<0.001
Collision with stationary object	1.55	0.59, 4.11	0.376
Collision with another cyclist	1.43	0.67, 3.06	0.358
Collision with motorized vehicle	3.54	1.82, 6.90	<0.001
Primary intubation	109.62	6.63, 1813.49	0.001

Table 5 Multivariable logistic regression analysis of bicycle-related craniofacial fracture patients

Variable	Unadjusted Odds Ratio	Confidence Interval	p-value
Age	1.02	1.01, 1.03	0.003
Gender (ref: Male)	0.71	0.43, 1.18	0.190
Fracture type			
Exclusively facial	1		
Exclusively cranial	22.16	3.69, 133.15	0.001
Combination	6.22	2.67, 14.48	<0.001
Alcohol	0.64	0.38, 1.09	0.101
Primary intubation	45.66	2.64, 788.34	0.009
Collision with motored vehicle	1.81	0.83, 3.95	0.136

Table 6 – Differences in characteristics in bicycle-related craniofacial fracture patients between helmeted and non-helmeted patients.

Variable	Patients with helmet			Patients without helmet			Chi square / Fisher's exact p-value
	No. of patients	%	% of n	No. of patients	%	% of n	
All	111	36.5		193	63.5		
Age Mean (SD)	44.61 (19.8)			43.6 (18.7)			0.658
Gender							
Male	70	63.1	34.7	132	68.4	65.3	0.343
Female	41	36.9	40.2	61	31.6	59.8	
Mechanism of injury							
Falling over	85	76.6	37.4	142	73.6	62.6	0.562
Collision with stationary object	3	2.7	23.1	10	5.2	76.9	0.387
Collision with other cyclist	13	11.7	50.0	13	6.7	50.0	0.135
Collision with motorized vehicle	10	9.0	26.3	28	14.5	73.7	0.163
Alcohol							
No	96	86.5	43.8	123	63.7	56.2	<0.001
Yes	15	13.5	17.6	70	36.3	82.4	
Craniofacial fracture requiring surgical intervention							
No	72	64.9	38.9	113	58.5	61.1	0.277
Yes	39	35.1	32.8	80	41.5	67.2	
Fracture type							
Exclusively facial	102	91.9	40.3	151	78.2	59.7	0.007
Exclusively cranial	3	2.7	18.8	13	6.7	81.2	
Combined	6	5.4	17.1	29	15.0	82.9	
Associated injury							
No	71	64.0	39.0	111	57.5	61.0	0.269
Yes	40	36.4	32.8	82	42.5	67.2	
One	23	57.5	27.7	60	73.2	72.3	0.081
Two or more	17	42.5	43.6	22	26.8	56.4	
Type of associated injury							
Traumatic brain injury	9	8.1	15.3	50	25.9	84.7	<0.001
Upper limb	24	21.6	54.5	20	10.4	45.5	0.007
Thoracic/abdominal	14	12.6	40.0	21	10.9	60.0	0.649
Cervical spine injury	6	5.4	31.6	13	6.7	68.4	0.645
Blunt cerebrovascular injury	3	2.7	60.0	2	1.0	40.0	0.359
Ocular	0	0.0	0.0	3	1.6	100.0	0.556
Pelvic	1	0.9	33.3	2	1.0	66.7	1.000
Lower limb	0	0.0	0.0	2	1.0	100.0	0.535
Severe head and neck injury							
No	95	85.6	41.1	136	70.5	58.9	0.003
Yes	16	14.4	21.9	57	29.5	78.1	
Primary intubation							
No	104	93.7	37.0	177	91.7	63.0	0.529
Yes	7	6.3	30.4	16	8.3	69.6	