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Original Article

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Retrospective Analysis of Bicycle Accidents at a Referral Pediatric Emergency Department: Mechanisms, Outcomes and Perspectives

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Abstract

Aim: We investigated the characteristics of patients involved in bicycle accidents, along with the mechanisms of accidents and clinical outcomes in children. Our secondary aim was to assess the characteristics of patients with serious clinical consequences, such as traumatic brain injury (TBI) and permanent neurological sequelae.

Materials and Methods: Children admitted to the pediatric emergency department of a tertiary referral hospital during a four-year period due to bicycle accidents were included. The mechanism of the accident was classified into two groups; high-energy trauma and low-energy trauma. Statistical analyses were performed to recognize injury patterns and clinical outcomes associated with the mechanism of the accident.

Results: Three hundred-sixty children were included. Two of the injured patients were using a bicycle helmet. Twenty-nine patients (8.1%) required surgery. Fourteen patients had clinically important TBI. Eighteen patients had handlebar trauma to the abdomen. Eight patients had permanent neurological sequelae (vision loss in three, hearing loss in three, spasticity and hemiparesis in two patients) and two patients had finger amputations. Abrasions/soft tissue injuries, scalp fractures, maxillofacial fractures and TBI were also significantly more common types of injury in high-energy trauma.

Conclusion: Although the recommendation of using helmets while riding was made two decades ago, the rate of helmet use is still very low in our country. In this retrospective cohort with low rate and no obligatory regulation of helmet use, high-energy bicycle accidents have caused significant clinical outcomes, including maxillofacial-scalp fractures, TBI, permanent sensory (visual and hearing) or motor (spasticity and hemiparesis) disability.

Keywords: Bicycle, children, traumatic brain injury, helmet, accident, disability

Introduction

Cycling is a popular activity among children for purposes of transportation, recreation and exercise. Bicycle accidents may result in mild injury, permanent disability, or even mortality. Children have a low awareness of traffic rules and a high tendency toward risky behavior. In the United States (US), bicycle injuries are among the leading causes of non-fatal injuries in children aged 5-17 years. Although bicycle-related deaths have decreased in children since 2001, children are still more prone to bicycle-related deaths than adults (1). In Turkey, 7,518 bicycle accidents occurred in 2017 (2.6% of all traffic accidents), resulting in 126 deaths (3.9% of deaths due to all traffic accidents) (2).

In children with trauma, while assessing trauma severity and making clinical decisions regarding the extent of diagnostic evaluation and patient disposition; the mechanism of accident, anamnesis and physical examination findings should be evaluated carefully (3). Because of their anatomical and physiological characteristics, children may suffer from serious injuries even when the mechanism of the accident seems to be low-risk. Bicycle accidents can occur with the mechanisms of falling off the bicycle, collision with stationary or moving objects, or vehicles (4).

Patients should be carefully evaluated because severe injuries may occur after bicycle accidents, such as blunt abdominal trauma involving bicycle handlebars or head trauma (5). The impact

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of the handlebar may cause injury to the abdominal organs, including the pancreas, duodenum, spleen or liver and to the scrotum (6). Head trauma may be complicated by craniofacial fractures, subdural, epidural, or cerebral hemorrhage and even clinically important traumatic brain injury (ciTBI) and mortality. Traumatic brain injury (TBI) is the leading cause of acquired disability in children. Wearing a helmet reduces the risk and severity of head injury (7). Colliding with a non-stationary motor vehicle while cycling has been associated with severe injuries among children (8). The patient's age, severity of injury, and the degree of structural injury are other factors associated with the neurological and cognitive sequelae of the accident (3,4). Orthopedic injuries mainly involve the clavicle, humerus and the forearm, whereas lower extremity fractures are rare. The most common indication of surgical intervention after bicycle accidents are orthopedic injuries (9).

Our clinical experience has made us concerned about the incidence and severity of bicycle injuries in our practice, especially because of the apparently low rate of helmet use, and the severe clinical consequences even in the absence of a collision with a motor vehicle. Documenting and analyzing the data on bicycle accidents, including the mechanism of the accident, can provide new perspectives into the evaluation and management of affected patients. In this study, we investigated the demographic and clinical characteristics of the patients, and the effect of the mechanism of bicycle accidents on the process of patient assessment and clinical outcomes. Our secondary aim was to assess the characteristics of patients with serious clinical consequences, such as TBI and permanent neurological sequelae.

Materials and Methods

Children (<18 years of age) who presented to the pediatric emergency department of our hospital during a four-year period (June 1, 2014 to May 31, 2018) due to a bicycle accident were included in the study. Patient-related information, including date, age, sex, trauma mechanisms, physical findings, injury localization and patterns, laboratory results, complications, consultations, treatment modalities, surgical interventions, intensive care unit admissions, duration of stay in the hospital and clinical outcomes, was recorded retrospectively using a data acquisition form.

The mechanism of bicycle accidents was classified into two groups, high-energy and low-energy injury mechanisms. Patients in these groups were compared in terms of injured anatomical region, injury type, interventions, disposition and length of stay characteristics.

Our pediatric emergency department cares for approximately 75,000 patients per year, and is part of a tertiary referral academic hospital. Patients are referred from all around the country, and all surgical specialties, and intensive care and operation room facilities are available.

Multiple trauma was defined as clear injury to two or more body areas of any severity (3). Being run over or struck by a motor vehicle, falling from a height with a bicycle, rolling down a cliff, hitting the wall while cycling fast, impingement of an extremity were included in the high-energy injury mechanism group (10). Other accidents were classified as low-energy injury mechanisms. ciTBI was defined as those which result in death, neurosurgical intervention, intubation for more than 24 h, or hospitalization for more than 48 h (11,12) The diagnosis of handlebar trauma was diagnosed according to the trauma mechanism, and the signs and symptoms of the patients.

The study was conducted in accordance with the principles of the Declaration of Helsinki and it was approved by the certified ethics board of the Hacettepe University, which waived the need for informed consent from the participants (approval date: 12.06.2018, approval number: GO 18/540).

Statistical Analysis

Statistical analyses were performed to recognize injury patterns and clinical outcomes associated with the mechanism of bicycle accident. Numerical measurements were presented with mean ± standard deviation, median and range, and qualitative data with numbers and percentages. Cross tables were used in the evaluation of associations between qualitative data. In comparing patients with high- vs. low-energy injury mechanisms, numerical values were analyzed with Student's t-test for parametric data, Mann-Whitney U test for non-parametric data and chi-square or Fisher's Exact tests for qualitative data, as appropriate. The Kolmogorov-Smirnov test was used for the normality distribution. Statistical significance was set as $p<0.05$. Statistical analyses were performed using IBM Statistical Package for the Social Sciences Statistics 21 data editor software (IBM, Armonk, NY, USA).

Results

22,981 trauma patients were admitted to our pediatric emergency department during the four-year study period, 1,249 of whom were due to traffic accidents. Three-hundred-sixty children presenting with bicycle accidents were included. Their median age at presentation was 9.0 years (range: 1-17 years); 44.2% of whom were between 5 and 9 years of age. 29.4% of patients were classified as high-energy trauma mechanism. Two of the injured patients were using a bicycle helmet at the time of accident, one of whom was a 13-year-old male patient who sustained a medial malleolar fracture and required surgery after a collision with a

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motor vehicle, while the other was an 8-year-old boy with minor soft tissue injuries in the extremities. General characteristics of the patients are summarized in Table 1.

At the time of presentation, 337/360 (93.6%) patients had at least one physical finding on physical examination. Eighty-nine (26.4 %) patients had injuries more than two anatomical sites. Injuries were most commonly in the extremities, followed by the head and neck. The most common types of injuries were abrasions and soft tissue swelling (202; 56.1%); 14 (3.8%) patients developed ciTBI. As for disposition and hospital stay, it was found that most patients were discharged from the emergency department and stayed in the hospital for less than 24 h (307 and 309 patients, respectively). Injury localization, patterns and clinical course of patients are provided in Table 2.

Handlebar trauma was diagnosed in 18 patients. All these patients were evaluated with pediatric surgical consultation and abdominal ultrasonography. Notable clinical characteristics and outcomes of these patients were as follows: spleen, kidney, liver laceration (one patient each), deep inguinal laceration sutured in the operating room (two patients), superficial inguinal hematoma (one patient), penile hematoma (one patient), large pubic ecchymosis (two patients), labial, penile and scrotal laceration (one patient each), open wound on abdominal wall (one patient), right periorbital hematoma (one patient), and optic nerve avulsion (one patient). Others reporting handlebar trauma had minor injuries.

The most common medical intervention was wound care and suture (199/360, 55.3%). Twenty nine patients required surgery. Orthopedic operations were the most common (15 patients). Other departments performing surgery were plastic and reconstructive surgery (eight patients), neurosurgery (three patients), pediatric surgery (two patients), otorhinolaryngology (one patient) and ophthalmology (one patient). Two patients had permanent sequela after finger amputation.

Fourteen patients were diagnosed with ciTBI, the details of whom are provided in Table 3. Twelve of 14 ciTBI had high-energy injury mechanism. Six of them were discharged with permanent neurological damage: Two patients had vision loss due to optic trauma, two had hearing loss due to temporal

Table 1. General characteristics of the patients (n=360)

Age* (years)	9.0 (1-17)
	n (%)
Age groups (years)	
0-1	5 (1.4)
1-4	41 (11.4)
5-9	159 (44.2)
10-14	117 (32.5)
15-17	38 (10.6)
Sex	
Female	70 (19.4)
Male	290 (80.6)
Mechanism of accident	
Motor vehicle accident	69 (19.1)
Falling off bicycle	242 (67.2)
Rolling downhill with bicycle	21 (5.8)
Falling down from a height with bicycle	16 (4.4)
Other	12 (3.3)
Mechanism of injury	
High-energy	106 (29.4)
Low-energy	254 (70.6)

*Median (range)

Table 2. Injury location, pattern and clinical course of patients (n=360)

Injured body region	n (%)
Multiple	89 (26.4)
Extremity	197 (58.5)
Head-neck	185 (54.9)
Trunk	48 (14.2)
Injury type	
Abrasion/soft tissue swelling	202 (56.1)
Laceration	117 (32.5)
Fractures	83 (23.1)
Extremity fracture	54 (15)
Scalp fracture	17 (4.7)
Maxillofacial fracture	12 (3.3)
ciTBI	14 (3.8)
Internal	9 (2.5)
Interventions	
Wound care and suture	199 (55.3)
Splint-cast	66 (18.3)
Surgery	29 (0.8)
Disposition	
Discharged from the emergency department	307 (85.3)
Hospitalization	40 (11.1)
PICU	11 (3.1)
Length of stay	
<24 hr	309 (85.8)
24-48 hr	12 (3.3)
>48 hr	39 (10.8)

ciTBI: Clinically important traumatic brain injury, PICU: Pediatric intensive care unit

Table 3. Clinical characteristics of the patients with clinically important traumatic brain injury

Age/sex	Accident mechanism	GCS on arrival	PTS	Vital signs	Cranial Imaging	Other notable findings	Interventions, disposition and clinical course	Clinical outcome
13, M	Rolling down a cliff with a bicycle	12	10	Unstable	Cranium base, sphenoid, temporal fracture; subarachnoid and extra axial hemorrhage	Femur fracture	Intubated in PED; PICU; operation by neurosurgery and orthopedic	Permanent vision loss
12, M	MVA	6	9	Unstable	Cranium base fracture; subarachnoid hemorrhage; diffuse axonal injury	-	Intubated in PED; PICU; operation by neurosurgery	Right hemiparesis
11, M	Falling off a bicycle	13	9	Stable	Epidural hematoma, mid-line shift	Diffuse abrasions	Ward; non-operative observation	No sequela
5, M	Falling down with a bicycle from a height	9	6	Unstable	Temporal, occipital, sphenoid fractures	Otorrhea and bleeding from the ear, pulmonary contusion and pneumothorax	Intubated in PED; PICU; non-operative observation	Hearing loss
13, F	MVA	8	6	Unstable	Temporal fracture; subarachnoid, extra axial hemorrhage; epidural hematoma; cerebral edema, diffuse axonal injury	Spleen laceration; rib fractures; pneumothorax; pulmonary contusion; humerus fracture	Intubated in PED; PICU; non-operative observation	Spastic motor deficiency
14, M	Falling off a bicycle	15	10	Stable	Parietal, temporal fracture; extra axial hemorrhage	Ear bleeding, clavicula fracture	Ward; non-operative observation	Hearing loss
16, M	Falling down with a bicycle from a height	15	10	Stable	Maxillary, orbital fracture; ethmoid and frontal sinus hemorrhage; retrobulbar air	Eye ecchymosis, loss of light reflex, traumatic ICA dissection; traumatic optic neuropathy	Ward; non-operative observation; medical treatment	Permanent vision loss
13, M	MVA	15	9	Unstable	Occipital fracture; intraparenchymal, subarachnoid hemorrhage	Arm fracture; pulmonary contusion; pneumothorax; spleen laceration; rib fracture	PICU; non-operative observation	No sequela
4, F	Falling down with a bicycle from a height	15	10	Stable	Frontal, orbital fractures	Diffuse abrasions; racoon eyes	Ward; non-operative observation	No sequela
6, M	Rolling down a cliff with a bicycle	15	10	Stable	Cranium base fracture; extra axial hemorrhage; pneumocephaly	Diffuse abrasions and lacerations	Ward; non-operative observation	No sequela
7, M	Falling down with a bicycle from a height	13	10	Unstable	Orbital, ethmoid fracture; intraparenchymal hemorrhage; extra axial hematoma; infraorbital emphysema	Racoon eyes	PICU; non-operative observation	No sequela

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Table 3. Continued

Age/sex	Accident mechanism	GCS on arrival	PTS	Vital signs	Cranial Imaging	Other notable findings	Interventions, disposition and clinical course	Clinical outcome
9, F	Rolling down a cliff with a bicycle	13	9	Unstable	Temporal fracture; subarachnoid hemorrhage; pneumocephaly; cerebral edema	Bleeding from ear	PICU; non-operative observation	No sequela
11, M	Rolling down a cliff with a bicycle	14	9	Stable	Parietal, temporal fracture; epidural hematoma	Clavicula fracture	PICU; non-operative observation	No sequela
14, M	Falling off a bicycle	15	11	Stable	Temporal, orbital fracture; subarachnoid, extra axial hemorrhage; infraorbital air and bleeding	Retrograde amnesia	Ward; non-operative observation	No sequela

ciTBI: Clinically important traumatic brain injury, GCS: Glasgow coma scale, ICA: Internal carotid artery, F: Female, M: Male, MVA: Motorized vehicle accident, PED: Pediatric emergency department, PICU: Pediatric intensive care unite, PTS: Pediatric trauma score

bone damage, and two had hemiparesis and spasticity due to diffuse axonal injury. Clinical characteristics of the patients with ciTBI are provided in Table 3. Two patients sustained significant injuries to the sensory organs without ciTBI: one developed optic nerve avulsion and subsequent complete vision loss in the left eye following handlebar impact on the eye; and the other developed hearing loss due to mastoid fracture. There were no deaths during the study period.

The age of the patients in the high-energy trauma group was significantly higher than that in the low-energy trauma group, and there was no difference between the two groups in terms of gender distribution. In high-energy trauma, significantly more commonly affected anatomical areas compared to low-energy trauma were the extremities, head and neck, and multiple injuries. Abrasions/soft tissue swelling, scalp fractures, maxillofacial fractures and ciTBI were also significantly more common types of injuries in high-energy trauma ($p<0.05$). High-energy injuries required significantly more wound care and suture, but there were no significant differences in splint-cast or surgical operations in relation to the mechanism of accident. Patients with low-energy injuries were more frequently discharged from the emergency department, and within 24 h, whereas patients with high-energy injuries were more commonly admitted to the hospital or the pediatric intensive care unit. Clinical characteristics and outcomes with regard to the mechanism of the accident are shown in Table 4.

Discussion

In this study, most of the patients were male, the most common accident mechanism was falling off the bicycle and the most common surgical interventions were orthopedic; all in line with the previously published work on children (9). However, the most common age group involved in bicycle accidents was a different cohort, indicating a younger demographic compared to other studies (5-9 vs. 10-14 years) (8,9). The main finding of this study, performed in a cohort of patients usually not using helmets during cycling, was the demonstrate that in high-energy mechanisms such as motor vehicle accidents, hitting a wall, or rolling down a cliff, children may suffer from ciTBI and permanent neurological disability.

The most common injuries related to bicycle accidents are soft tissue injuries; however, fractures, abdominal injuries and TBI cause emergency admissions and hospitalization (13). TBI and maxillofacial injuries are common in children who do not use helmets; emergency management is important as these can lead to death and permanent disability. Both individual and environmental precautions should be taken together in the prevention of bicycle accidents (13). In a large recent study on 2,219 patients aged five and 17 years old who were treated in emergency departments in the US for injuries after bicycle accidents between 2006 and 2015, it was reported that collisions with a motor vehicle was a factor associated with TBI and injury-related hospitalization (9). The same study also demonstrated that using a helmet decreased hospital admissions and craniocervical injuries (9). In our study, severe clinical outcomes were also observed with mechanisms other than a collision with a motor vehicle. In our country, using a helmet while cycling is not widespread, and not required by law. Consequently, the vast majority of the patients included in our study were not using a helmet, except for two. Since there were too few patients using

Table 4. Clinical characteristics and outcomes with regard to the mechanism of the accident

	High-energy n=106 (%)	Low-energy n=254 (%)	p
Age*	10.0 (1-17)	9.0 (1-17)	0.001
Sex (male)	200 (78.7)	90 (35.4)	0.178
Injured anatomic region			
Multiple	53 (52.4)	36 (15.2)	<0.001
Extremity	73 (72.2)	124 (52.5)	0.001
Head-neck	69 (68.3)	116 (49.1)	0.001
Trunk	15 (14.8)	33 (13.9)	0.834
Injury type			
Abrasion/soft tissue swelling	69 (68.3)	133 (56.3)	0.027
Laceration	35 (34.6)	82 (34.7)	0.892
Extremity fracture	15 (14.8)	39 (16.5)	0.771
Scalp fracture	14 (13.8)	6 (2.5)	<0.001
Maxillofacial fracture	14 (13.8)	4 (0.1)	<0.001
ciTBI	12 (11.8)	2 (0.1)	<0.001
Internal	5 (4.9)	4 (0.1)	0.082
Interventions			
Wound care and sutures	70 (69.3)	129 (54.6)	0.008
Splint-cast	23 (22.7)	43 (18.2)	0.286
Surgery	8 (7.9)	21 (0.8)	0.819
Disposition			
Discharged from the emergency department	83 (82.1)	226 (95.7)	0.008
Hospitalization	12 (11.3)	28 (11.8)	0.008
PICU	11 (10.8)	0	<0.001
Length of stay			
<24 h	83 (82.1)	226 (95.7)	0.008
24-48 hr	3 (2.9)	9 (0.3)	0.731
>48 h	20 (19.8)	19 (0.8)	0.002

*Median (range).
ciTBI: Clinically important traumatic brain injury, PICU: Pediatric intensive care unit

helmets, the association of ciTBI or permanent neurologic sequela with helmet use could not be analyzed. However, the need to wear protective gear to prevent/attenuate head injuries is not new. Previous studies with large numbers of participants have clearly demonstrated that wearing a helmet can reduce cranial injuries, as per the recommendations of the American Academy of Pediatrics (AAP) (14,15). Studies have shown that helmets decrease head, brain and serious brain injuries by 63-88% and prevent upper- and mid-facial trauma by 65% (16). Regardless of the age of the patient or the type of crash, helmets can reduce craniofacial injuries in bicycle accidents (17). In countries such as Australia, New Zealand and Finland, the law requires the use of a helmet while riding a bicycle. In a population-based study conducted in a state where there is no helmet law in the US, it was stated that the use of helmet is rare and causes severe consequences (18). In our study, there were patients with severe clinical consequences, such as TBI, permanent visual loss, permanent hearing loss, spasticity and hemiparesis. In patients with motor deficit diffuse axonal damage; in patients who developed vision and hearing loss, fractures in the skull bones (especially temporal fracture in hearing loss) were detected. There are publications in the literature reporting hearing loss due to temporal bone fracture in bicycle accidents in children (19,20). None of these patients were wearing a helmet at the time of the accident. Considering that helmet use reduces the risk and severity of head trauma, it can be argued that clinical outcomes would have been better if these patients had used helmets.

Twenty-nine percent of patients were injured by a high-energy mechanism. Although helpful as an initial guide, mechanism alone is not a highly accurate predictor of the risk of sustaining significant injuries (3). Physiological parameters (pupils, blood pressure, respiratory rate, heart rate, etc.) that are quickly and easily accessible have great importance in the assessment of patient stability. The decision of immediate intervention (intravenous bolus hydration, intubation etc.) was made according to the physiological findings of our patients who were diagnosed with ciTBI among the patients in our study group. The fact that two patients with ciTBI were in the low-energy group (falling off the bicycle) underlines that the mechanism of accident alone is not an adequate indicator of the assessment and management of pediatric trauma patients. Similarly, patients with mild physical findings and normal physiological parameters were present also in the high-energy mechanism group.

Cycling accidents most commonly affect the upper extremities, followed by the lower extremities, face, head and neck (9). Extremity injuries were common in our study (58.5%), ranging from strains to open fractures. Considering that the extremities are the most commonly affected areas after bicycle accidents, soft tissue injuries amenable to simple medical interventions and fractures of long bones, which may require surgery account for most of the injuries. Both the American Association of Orthopedic Surgeons and the AAP recommend not only helmets, but also extremity-protecting gear while skateboarding (17,21). Similar protective wear may decrease extremity injuries in bicycle accidents.

The impact with bicycle handlebars is an important mechanism to consider. Eighteen patients in this study reported handlebar trauma, who had a wide array of injuries ranging from inguinal bruising to splenic rupture. Three patients had internal injuries (spleen, liver and kidney laceration), and one suffered from permanent vision loss due to optic nerve avulsion caused by handlebar trauma. This mechanism of vision loss has been reported in only a few cases (22,23). A significant characteristic of handlebar traumas is their propensity to cause a rapidly worsening clinical course (within hours) in the absence of abnormal physical examination findings at the initial evaluation (24). The accuracy of the history of the mechanism of accident taken from the child may vary, depending on the age, pain, anxiety and clinical status of the child. Therefore, the trauma caused by bicycle handlebars cannot be excluded by history alone, especially if the accident was not witnessed by an adult. To prevent abdominal trauma caused by bicycle handlebars, bicycle models with retractable handlebars and wearing protective abdominal pads should be encouraged (25).

Study Limitations

This study is limited by its retrospective nature. Data regarding the mechanisms of accident and the parameters at admission were retrieved from anamnesis and consultation forms. Although it was based in a single centre, it does reflect the experience of one of the largest pediatric trauma centres in the country. The lack of long-term assessment of outcomes is a limitation of the study since the neuropsychological evaluation was not universally performed in follow-up.

Conclusion

Although the recommendation of using helmets while riding was made two decades ago, the rate of helmet use is still very low in our country. In this retrospective cohort with low rate and no obligatory regulation of helmet use, high-energy bicycle accidents have caused significant clinical outcomes, including maxillofacial and scalp fractures, TBI, and permanent sensory (visual and hearing) or motor (spasticity and hemiparesis) disability.

Ethics

Ethics Committee Approval: The study were approved by the Hacettepe University of Local Ethics Committee (approval date: 12.06.2018, approval number: GO 18/540).

Informed Consent: Retrospective study.

Peer-review: Externally peer-reviewed.

Authorship Contributions

Concept: L.A.Y., Ö.T., Design: L.A.Y., A.T., Ö.T., Data Collection or Processing: L.A.Y., A.T., Analysis or Interpretation: L.A.Y., Literature Search: L.A.Y., A.T., Writing: L.A.Y., Ö.T.

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