RESEARCH ARTICLE

Bicycle-Related Injuries of the Upper Extremity

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Abstract

Background: In recent years, the increasing popularity of cycling for commuting and leisure has led to a corresponding increase in bicycle-related injuries. However, there is a lack of extensive analysis of bicycle-related injuries to the upper limb in the literature.

Methods: A retrospective review of all patients with conventional bicycle-related injuries of the upper limb was performed. Data on demographics, mechanisms of injury, region of injury, fracture type, management type, and length of hospital stay were extracted and analyzed.

Results: A total of 177 of 733(24%) patients with bicycle-related upper limb injuries were identified. The most common mechanism of injury was a collision with another vehicle (60%). Frequently affected regions were the shoulder (48%), hand (19%), and wrist (19%). Eighty-eight (50%) patients sustained bony injuries, while the remainder (50%) had isolated soft tissue injuries. Fifty-three (30%) patients required a mean of 3.9 days of hospitalization, whereas 13 (25%) patients required high dependency or intensive care unit treatment. Surgical interventions were required in 47 (27%) patients.

Conclusion: Bicycle-related injuries to the upper limb are common and result in significant morbidity. The most common regions affected are the shoulder, wrist, and hand. Most of the injuries were caused by collisions with other vehicles. A third of affected patients required hospitalization, and a quarter required surgical intervention.

Level of evidence: III

Keywords: Accident, Bicycle, Injury, Upper limb

Introduction

Cycling is recognized as a cheap and environmentally friendly mode of transportation, with the number of cyclists growing each year substantially.[1,2] Compounded by the rise of bicycle-sharing schemes, cycling is rapidly becoming a favored mode of transportation globally.[1-4] Furthermore, cycling has provided dose-dependent health benefits, decreasing obesity, cardiovascular disease, and mortality.[5,6]

However, this increasing trend of bicycle use has not come without a cost to society. Cycling can be dangerous to both riders as well as pedestrians. Cyclists often share the same roads with motorized vehicles, which places them at risk of collision injuries. Moreover, bicycles offer little physical protection to users in a collision. Consequently, bicycle-related traumatic injuries are common and increasing in prevalence in developed countries.[7,8] The most common injuries are musculoskeletal injuries of the upper and lower limbs and head injuries.[9-11]

Traumatic shoulder injuries are the most common upper limb injuries described in the literature.[12] These include clavicle fractures, acromioclavicular joint dislocations, and rotator cuff tears.[13] Injuries to this region can limit patients' function and cause significant long-term morbidity significantly. Furthermore, Lloyd et

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al. reported that while bicycle-related lower limb injuries have remained static in the last two decades, upper limb injuries have increased.[9] Very few studies have extensively analyzed bicycle-related injuries to the upper limb in the current literature.

This study aims to assess the epidemiology of bicycle-related upper limb injuries and describe the mechanism and patterns of injuries with their associated morbidities. This may allow clinicians to manage the patients better and address their concerns and expectations. Furthermore, the presented data may help raise awareness of common injuries and guide the development of recommendations to reduce injuries sustained by cyclists.

Materials and Methods

This was a retrospective cohort study performed at a single university hospital. Local institutional review board approval was obtained before the commencement of the study. All patients treated for conventional bicycle-related injuries in our institution's emergency department (ED) from July 2012 to December 2015 were included in this study. All patients were identified using the hospital's diagnosis and operative code system. Those aged 21 years and older with bicycle-related upper limb injuries were included. Only riders and pillions on the bicycle were included, while pedestrians were excluded.

Data on demographics, mechanisms of injury, region of injury, fracture type, management type (surgical/nonsurgical), and hospital length of stay (LOS) were extracted and analyzed.

The mechanisms of injury were classified into five categories: (1) Fall from a bicycle onto the ground, (2) Bicycle collision with a car, (3) Bicycle collision with a heavy vehicle, (4) Bicycle collision with other vehicles, and (5) Bicycle collision with a stationary structure. The region of injury was first classified into isolated or multiple areas. Following that, it was divided into (1) scapulothoracic, (2) shoulder (clavicle, glenohumeral joint, and acromioclavicular joint), (3) arm, (4) forearm (radius, ulna, and elbow joints), (5) wrist, (6) hand (carpals, metacarpals, phalanges, and interphalangeal joints). Within these regions of injury, we subclassified them into bony and soft tissue injuries for further assessment. Skeletal injuries were described as fractures and/or dislocations, while fracture types were classified into open or closed fractures. Open fractures were categorized using the Gustillo open fracture classification.[14] Soft tissue injuries were described as muscular and ligamentous injuries.

Hospital LOS was defined as the time from admission to the hospital until the patient was discharged. Surgical management of injuries was classified into: (1) single surgery conducted during a hospital stay, (2) multiple surgeries conducted during a hospital stay, and (3) interval surgery conducted after the initial hospitalization.

Frequency tables and descriptive statistics were used for all variables. Categorical variables are presented as proportions, while continuous variables are presented as mean (standard deviation). The chi-square test was used to compare categorical variables, while the student's t-test was used for continuous variables. Statistical significance was set at $P < 0.05$, and data analysis was performed using the SPSS software (version 16; IBM, Chicago, IL).

Results

Over the study period of 3.5 years, 733 patients were treated at our institution for bicycle-related injuries. Of these, 177 (24.1%) patients sustained upper limb injuries [Table 1]. The mean age was 41.8 (±13.3) years, and 156 (88.1%) participants were male. Singapore

Table 1. Patient demographics and other accident details (n=177)

Age (years), mean (SD)	41.8 (13.3)
Gender, *n (%)*	
Male	156 (88.1)
Female	21 (11.9)
Race, *n (%)*	
Chinese	96 (54.2)
Malay	40 (22.6)
Caucasian	18 (10.2)
Indian	13 (7.3)
Others	10 (5.6)
Nationality, *n (%)*	
Singaporean	108 (61.0)
Non-Singaporean	69 (39.0)
Alcohol intake prior to injury, *n (%)*	
Yes	5 (2.8)
No	172 (97.2)
Head injury during accident, *n (%)*	
Yes	52 (29.4)
No	125 (70.6)
Loss of consciousness during accident, *n (%)*	
Yes	11 (6.2)
No	166 (93.8)
Amnesia after accident, *n (%)*	
Yes	12 (6.8)
No	165 (93.2)
Mechanism of injury, *n (%)*	
Fall from bicycle onto the ground	67 (37.9)
Collided with car	59 (33.3)
Collided with heavy vehicle	25 (14.1)
Collided with other vehicles	22 (12.4)
Collided with stationary structure	4 (2.3)
Type of management, *n (%)*	
Surgical	47 (26.6)
Non-surgical	130 (73.4)
Surgical intervention, *n (%)*	
Single operation	18 (38.3)
Multiple operations	11 (23.4)
Interval operation	18 (38.3)
Length of stay (days), mean (SD)	3.9 (8.7)

SD, standard deviation

citizens constituted 108 (61.0%) of patients.

Mechanisms of Injury

Common mechanisms of injury were direct fall from the bicycle onto the ground (37.9%) and collision with a car (33.3%). Less common were collisions with heavy vehicles (14.1%) and other vehicles (12.4%).

Injuries Sustained

A total of 160 (90.4%) patients had isolated injuries to the upper limb, while 17 (9.6%) participants had concomitant multi-regional injuries. There were 85 (48.0%) shoulder injuries, 34 (19.2%) hand injuries, 33 (18.6%) wrist injuries, 25 (14.1%) forearm injuries, and 12 (6.8%) scapulothoracic injuries, and 4 (2.3%) arm injuries [Table 2]. No significant associations were found between the mechanisms of injury and the regions of injury (*P = 0.781*).

Type of Injuries

Eighty-eight (49.7%) patients sustained bony injuries (fractures or dislocations), while 89 (50.3%) cases had isolated soft tissue injuries (muscle tears, strains, sprains, and contusions). In patients who sustained bony injuries, 78 (88.6%) had injuries to a single region, while 10 (11.4%) had injuries to multiple areas [Figure 1]. The most common bony injuries were in the shoulder (39/88, 44.3%), hand (25/88, 28.4%), and forearm (16/88, 18.2%) regions. Patients with multiple bony injuries sustained trauma, most commonly to the shoulder and scapulothoracic area (6/10, 60.0%). Most of these skeletal injuries were closed injuries, but 8 (9.1%) patients sustained open fractures (Gustilo 1: 6, Gustilo 2: 1, Gustilo 3B: 1).

The most common soft tissue injury was shoulder contusion (35/89, 39.3%), with soft tissue contusion and sprain to the wrist being the next most common (14/89, 15.7%). All soft tissue injuries were treated conservatively.

Table 2. Distribution of injuries (both bony and soft tissue injuries) in the upper limb regions in a descending rank

Region of injury	n (%)
Shoulder	85 (48.0)
Isolated	75 (88.2)
Multiple	10 (11.8)
Hand	34 (19.2)
Isolated	30 (88.2)
Multiple	4 (11.8)
Wrist	33 (18.6)
Isolated	31 (93.9)
Multiple	2 (6.1)
Forearm	25 (14.1)
Isolated	21 (84.0)
Multiple	4 (16.0)
Scapulothoracic	12 (6.8)
Isolated	6 (50.0)
Multiple	6 (50.0)
Arm	4 (2.3)
Isolated	2 (50.0)
Multiple	2 (50.0)

Management of Injuries

Fifty-three (29.9%) patients required hospitalization. The mean LOS was 3.9 days; 10 (18.9%) patients required high dependency care, and 3 (5.7%) patients were managed in the intensive care unit. There was no significant association between the region of injury and length of hospitalization stay (*P =0.37*).

Surgical interventions were performed on 47 (26.6%) patients. Out of these patients,18 (38.3%) cases had a single surgery performed during the hospital stay, 11 (23.4%) participants had multiple surgeries performed during the hospitalization, and 18 (38.3%) had surgery performed at a later interval. Thirty-one (66.0%) patients had fixation of bony injuries. These included 11 clavicle fractures (35.5%), 6 acromioclavicular joint dislocations (19.4%), 5 finger fractures (16.1%), 5 radius/ ulna fractures (16.1%), and 2 humerus fractures (6.5%). A total of 6 (12.8%) patients had debridement performed for open wounds, 6 (12.8%) patients had debridement and fixation of open fractures (one olecranon fracture, three clavicle fracture, two radius/ ulna fractures), and 2 (4.3%) patients had initial debridement and temporary stabilization of an open fracture, followed by an interval fixation of the bony injuries (both finger fractures). Two (4.3%) patients required neurosurgical intervention for intracranial hemorrhage. All patients survived.

Discussion

In recent years, cycling has become increasingly popular as a mode of transportation and exercise, with a corresponding rise in cycling-related injuries presenting to the ED.[4,15] In Singapore, the popularity of cycling has surged during the COVID-19 pandemic, with increased sales of personal bicycles and usage of bicycle-sharing platforms.[3] Furthermore, with the increased uptake of food delivery services due to social distancing measures, electric bicycle usage is also on the rise.[16-18] Every year, there are over 400 road injuries involving cyclists locally, and this figure is expected to rise with the increased number of cyclists on the roads.[19] In this study, we found that a quarter of patients who had bicycle-related injuries sustained injuries to the upper limb. The majority of these patients were young (mean 41 years) and male (88.1%). The most common mechanism of injury was that of collision with a moving vehicle (59.8%). More than 90% of patients sustained at least an isolated injury to the upper limb, while 9.6% had multiple injuries.

In a retrospective review, Chen et al. reported that motor vehicle collisions accounted for 58% of all bicycle-

involved injuries from 2001 to 2008 in the United States of America.[15] In another study illustrating bicycle-related injuries affecting the pediatric population in Singapore, the majority of the patients were involved in collisions with vehicles (87.5%).[11] Our study reported similar results, with the most common mechanism of injury being a collision with a vehicle (59.8%), followed by falling off the bicycle (37.9%). The similarity in the epidemiology of the mechanism of injury may be accounted for by the fact that there are no dedicated bicycle lanes on roads in Singapore and a lack of bicycle lanes on pedestrian footpaths. As such, cyclists often have little choice but to cycle on and share the road with vehicles, putting themselves at a higher risk of collision. For cyclists who choose to cycle on pedestrian footpaths, the risk of falling from the bicycle is high due to the unevenness of the trails, which are not paved for cycling. To reduce cycling injuries in Singapore, an ideal solution would be to have bicycle-specific lanes on the roads. Multiple studies have shown that bicycle-specific facilities such as bicycle paths, lanes, and routes decrease the risk of collisions between bicycles and motor vehicles.[20,21] These facilities offer an even path to prevent falls from bicycles and avoid unnecessary collisions between bicycles and other vehicles. In Hong Kong, which has 160km of cycle tracks, only 8.2% of bicycle crashes occurred on cycle tracks.[22] Hence, it is evident that when cycling-specific infrastructure is present, the incidence of cycling injuries can be greatly reduced.

We found that the most common region of injury was the shoulder, followed by the hand, wrist, and forearm. While the high prevalence of shoulder injuries has been documented in the literature, there was also a high

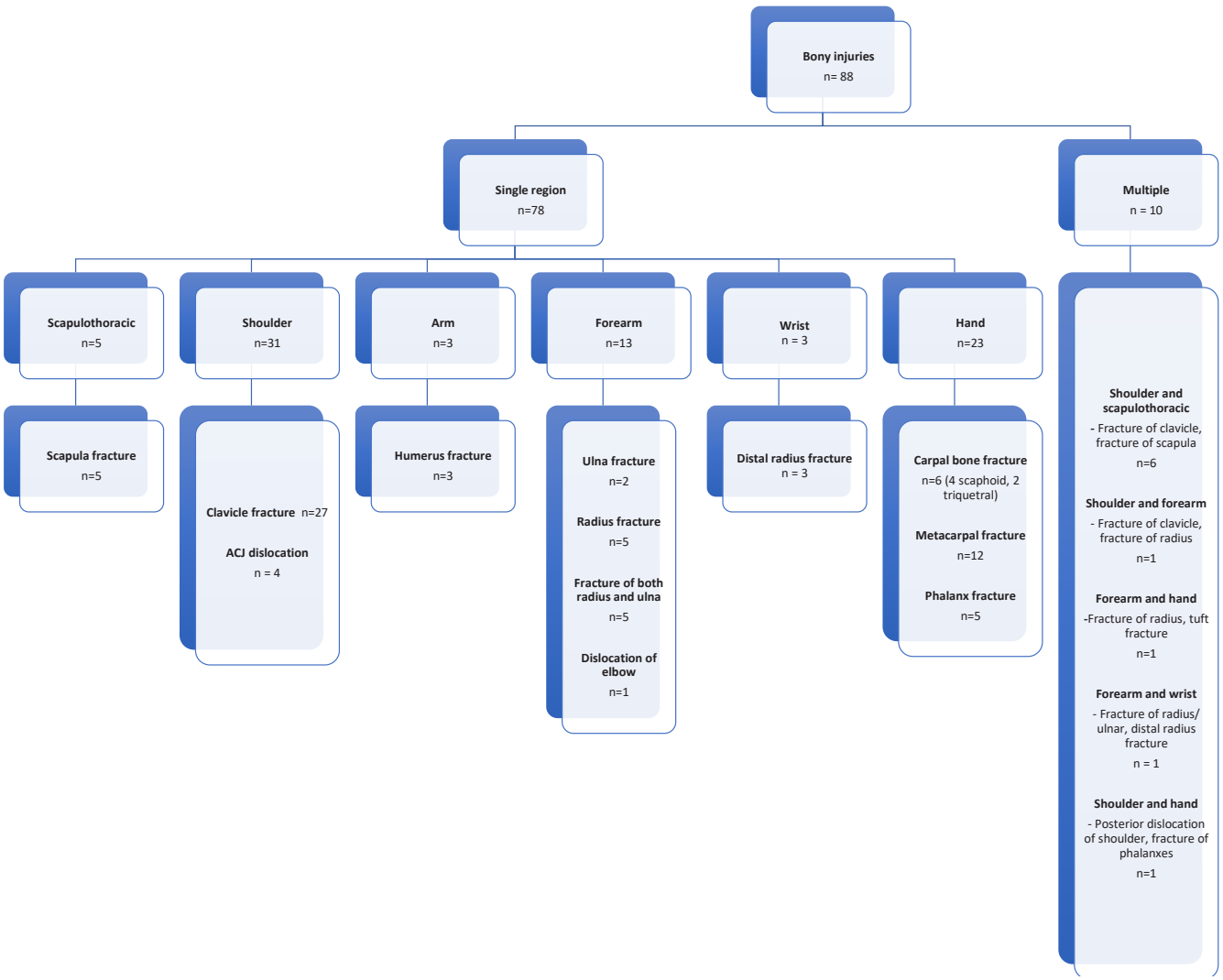

Figure 1. Figure 1 shows the distribution of types of upper limb bony injuries.

proportion of other injuries in this study.[13] Injuries to the wrist and hand constituted 38% of all injuries sustained, while injuries to the forearm constituted 14%. This could be explained by the classic mechanism of falling from the bicycle onto an outstretched arm. While our study was not designed to study protective gear for the upper limb, it is intuitive to consider such apparatus for the safety of cyclists. The use of wrist guards has been shown in experimental models to reduce wrist, and elbow accelerations resulting from simulated forward falls, reducing the likelihood of upper limb injuries.[23] Hagel et al. showed that wrist guard use among snowboarders reduced the risk of hand, wrist, or forearm injury by 85%.[24]

Similarly, shoulder pads have been shown to reduce peak linear and rotational acceleration in contact sports, such as ice hockey and rugby, reducing shoulder and head injuries. We postulate that upper limb injuries from cycling activities can be prevented and reduced with such protective gear.[25-28] However, ill-fitted equipment could limit mobility and reduce reaction time, possibly resulting in the opposite effect. Hence, more studies should be conducted to support this hypothesis.

Multiple studies have consistently shown that these upper limb injuries contribute to a significant financial burden on the healthcare system.[29-31] In addition to the healthcare costs, these injuries indirectly incur enormous socioeconomic costs due to long periods of sick leave, with reduced productivity of the workforce.[32] In a retrospective review of 22 personal mobility device-related injuries in an ED, patients had a mean hospital stay of 4 days and an average hospital bill of S$2700 to S$4300.[33] Correspondingly, our study found that bicycle-related upper limb injuries posed substantial morbidity, requiring hospitalization for almost one-third and surgical intervention in one-fourth of the patients. Of the patients who required hospitalization, up to a quarter required specialized care in high-dependency or intensive care units. This was similar to a retrospective study based on a pediatric trauma registry of bicycle injuries.[34] While there was no mortality in our patient population, mortality rates for trauma patients admitted to the intensive care unit after bicycle-related injuries are up to 36%.[35] This demonstrates the potentially devastating impact of such injuries on patients and the healthcare system.

This study is limited by its retrospective nature, lack of outcome data, and results from a single center. Despite these limitations, we presented the diverse mechanisms and patterns of injuries from bicycle-related upper limb injuries with their accompanying morbidities.

Bicycle-related injuries to the upper limb are common and give rise to significant morbidity. The most common regions affected are the shoulder, wrist, and hand, with the majority of the injuries caused by collisions with vehicles. Most patients had isolated injuries, but a sizable proportion suffered multiple injuries. Close to a third of affected patients required hospitalization and up to a quarter required surgical intervention. With this knowledge, potential improvements can be recommended to enhance cycling infrastructure on public roads and use protective gear for the upper limb, as they may help mitigate severe injuries.

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