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### Authors

Osterberg, E Charles  
Awad, Mohannad A  
Gaither, Thomas W  
et al.

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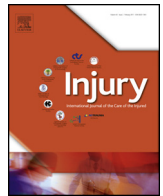
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## Major genitourinary-related bicycle trauma: Results from 20 years at a level-1 trauma center

E. Charles Osterberg<sup>a,\*</sup>, Mohannad A. Awad<sup>a</sup>, Thomas W. Gaither<sup>a</sup>, Thomas Sanford<sup>a</sup>,  
Amjad Alwaal<sup>b</sup>, Lindsay A. Hampson<sup>c</sup>, Jennie Yoo<sup>a</sup>, Jack W. McAninch<sup>a</sup>,  
Benjamin N. Breyer<sup>a</sup>

<sup>a</sup> Department of Urology, University of California – San Francisco, San Francisco, CA, United States

<sup>b</sup> Department of Urology, King Abdulaziz University, Jeddah, Saudi Arabia

<sup>c</sup> Department of Urology, University of Washington, Seattle, WA, United states

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### ABSTRACT

**Background:** Epidemiological studies have shown that bicycle trauma is associated with genitourinary (GU) injuries. Our objective is to characterize GU-related bicycle trauma admitted to a level I trauma center.

**Materials and methods:** We queried a prospective trauma registry for bicycle injuries over a 20-year period. Patient demographics, triage data, operative interventions and hospital details were collected. **Results:** In total, 1659 patients were admitted with major bicycle trauma. Of these, 48 cases involved a GU organ, specifically the bladder (n = 7), testis (n = 6), urethra (n = 3), adrenal (n = 4) and/or kidneys (n = 36). The median age of cyclists with GU injuries was 29 (range 5–70). More men were injured versus women (35 versus 13). GU-related bicycle trauma involved a motor vehicle in 52% (25/48) of injuries. The median injury severity score for GU-related bicycle trauma was 17 (range 1–50). The median number of concomitant organ injuries was 2 (range 0–6), the most common of which was the lungs (13/48, 27%) and ribs (13/48, 27%). The majority of GU injured cyclists were admitted to an ICU (15/48, 31%) or hospital floor (12/48, 25%). Operative intervention for a GU-related trauma was low (12/48, 25%). The most common GU organ injured was the kidney (36/48, 75%) however most were managed nonoperatively (33/36, 92%). Bladder injuries most often required operative intervention (6/7, 86%). Mortality following GU-related bicycle trauma was low (2/48, 4%).

**Conclusions:** In a large series of bicycle trauma, GU organs were injured in 3% of cases. The majority of cases were managed non-operatively and mortality was low.

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### Introduction

Bicycle riding is associated with numerous health benefits including improvement in cardiovascular health, diabetic glucose control and depression [1,2]. Recreational cycling, bike-sharing programs, and commuter-cycling have all recently increased [3].

Nationally, 1% of the country utilizes a bicycle to commute to work [4]. Within San Francisco, over 3% of inhabitants cycle daily [5]. This is in part due to improvements in cycling infrastructure and community support. Many cyclists, however, are inhibited from daily riding due to heavy automobile traffic and a lack of bike lanes [6].

As society works to improve sustainability for cycling nationwide, a better understanding of the health and safety of cyclists is warranted. In 2013, there were 743 cyclists killed in the United States (U.S.), which is a 19% increase in fatality since 2010 [7]. In the same year, it was estimated that 48,000 cycling injuries were associated with a motor vehicle [8]. As a result, hospital admissions for bicycle injuries have increased by 120% from 1998 to 2013 [9] and cycling is 12 times more fatal compared to automotive riding [10]. An estimated \$4 billion dollars per year is spent on healthcare associated with bicycle injuries [11]. Consequences of bicycle

Abbreviations: ZSFG, Zuckerberg San Francisco General; GU, genitourinary.

\* Corresponding author at: 1001 Potrero Ave, Suite 3a20, San Francisco, CA 94110, United States.

E-mail addresses: [charles.osterberg@ucsf.edu](mailto:charles.osterberg@ucsf.edu) (E. C. Osterberg), [Mohannad.awad@ucsf.edu](mailto:Mohannad.awad@ucsf.edu) (M.A. Awad), [Tom.gaither@ucsf.edu](mailto:Tom.gaither@ucsf.edu) (T.W. Gaither), [Thomas.sanford@ucsf.edu](mailto:Thomas.sanford@ucsf.edu) (T. Sanford), [amjadwal@yahoo.com](mailto:amjadwal@yahoo.com) (A. Alwaal), [Lindsay.hampson@gmail.com](mailto:Lindsay.hampson@gmail.com) (L.A. Hampson), [jennie.yoo@ucsf.edu](mailto:jennie.yoo@ucsf.edu) (J. Yoo), [Jack.McAninch@ucsf.edu](mailto:Jack.McAninch@ucsf.edu) (J.W. McAninch), [Benjamin.Breyer@ucsf.edu](mailto:Benjamin.Breyer@ucsf.edu) (B.N. Breyer).

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injuries include persistent disability, cognitive and behavioral changes, and prolonged leaves of absence from work [12]. Cycling injuries do not spare single organs and are associated with multiple traumatic orthopedic and intra-abdominal injuries, including gastrointestinal, reproductive, and genitourinary injuries [13]. Bicycle-related trauma is the most common cause of genitourinary (GU) injury presenting to U.S. Emergency Departments (ED) [14].

Given the increasing popularity of cycling and the associated increased risks of injury, we aim to characterize GU cycling injuries presenting to a single-center, inner-city, Level 1 trauma center. To date, only national data sets have explored GU-related cycling injuries and fail to report on specific, patient-centric details such as operative interventions and outcomes. Our objective is to characterize the management of GU-related bicycle trauma admitted to Zuckerberg San Francisco General (ZSFG) over a 20-year period.

## Materials and methods

### Population and study design

ZSFG is San Francisco's only Level I trauma center for the city of San Francisco and Northern San Mateo county. All trauma patients who are admitted to ZSFG are entered into a prospective, longitudinal trauma disease registry [5]. We performed a retrospective chart review of cases that involved a bicycle injury. These cases were identified using International Classification of Diseases–9th Revision (ICD-9) external cause of injury codes which included: (810.6, 811.6, 812.6, 813.6, 814.6, 815.6, 816.6, 817.6, 818.6, 819.6, 826.1) to select for bicycle injuries. GU cases were identified using ICD-9 codes for the kidney (866), ureter (867.2, 867.3), bladder and urethra (867.0, 867.1), penis (878.0, 878.1), and testes and scrotum (878.2, 878.3). From January 1995 to March 2015, 32,250 trauma patients were admitted to ZSFG and 1659 had major bicycle trauma. Of these, 48 (3%) cases involved a GU organ. (Fig. 1) The Institutional Review Board at the University of California San Francisco approved this study.

### Definitions of variables

Variables collected included demographic, triage data, operative interventions and hospital course details. Specifically, we recorded patient age, date of accident, location of accident (street versus sports-related/recreational), helmet usage (yes versus no) and pre-hospital transportation mode (ambulance versus walk-in). Helmet usage was consistently recorded during the primary trauma survey and in patient transfer from ambulance to trauma bay. External cause of injury codes were utilized to classify how

cyclists were injured: (813.6—motor vehicle versus pedal cyclist or 826.1—road versus pedal cyclist).

On arrival to the ED, initial vital signs, Injury Severity Scores (ISS), Glasgow Coma Scales, and transfusion requirement(s). Hospital admission was defined as greater than 23-h length of stay.

Renal injuries were graded according the American Association of the Surgery of Trauma (AAST) staging system [15]. We collected intraoperative details for all surgical cases including the type of surgery performed (e.g. primary repair versus removal of affected organ). Bladder injuries were categorized as intraperitoneal or extraperitoneal and testicular injuries were categorized if violation of the tunica albuginea occurred. The associated concomitant injuries were also recorded (e.g. lung, ribs, liver, pelvis, spine, spleen, brain, and bowel).

Patient outcomes including postoperative disposition (e.g. intensive care unit, step down unit, or floor), date of discharge, and length of hospital stay were tabulated. The location(s) of hospital discharge (home, hospital transfer, skilled nursing facility, or rehabilitation facility) were also captured. We recorded if patients died secondary to their trauma within 30 days of injury. Comparisons were made between patients who had a GU injury and underwent operative intervention versus those that were managed conservatively.

### Statistical analysis

We used descriptive statistics to report frequencies and prevalence of GU-related bicycle injuries. All analysis was performed using STATA v11 (College Station, TX, USA).

## Results

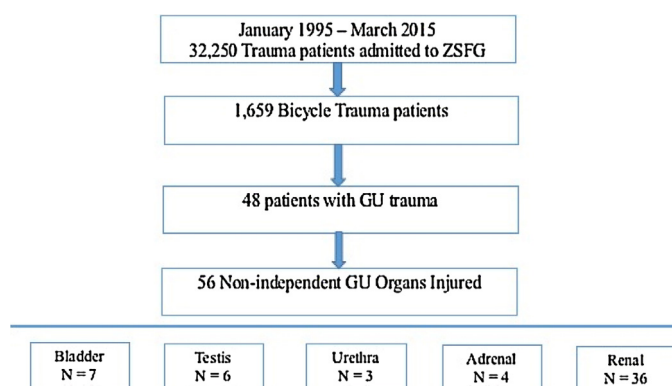
### Baseline demographics of GU-related bicycle trauma

Of the 48 GU-related bicycle traumas admitted to the hospital, the kidneys (n = 36), bladder (n = 7), testis (n = 6), urethra (n = 3), and/or adrenal (n = 4) were involved. The demographic data of patients with GU-related bicycle trauma is shown in Table 1. The median age of cyclists with GU injuries was 29 (range 5–70). There were 4 pediatric patients under 18 years.

More men were injured versus women (35 versus 13). All GU-related bicycle trauma occurred on a street meanwhile only 29% (14/48) of riders reported wearing a helmet. GU-related bicycle trauma involved a motor vehicle in 52% (25/48) of injuries. The median ISS for our cohort was 17 (range 1–50). The median ISS for pediatric patients was 29.5 (range 14–45). The median number

**Table 1**  
Baseline Demographic Features of GU Injuries Associated with Cycling Admitted to ZSFG; January 1995–March 2015.

	GU Injuries
	N = 48 (%) or (median (range))
Age	29 (5–70)
Gender	
Male	35 (73)
Female	13 (27)
Type of Accident	
Cyclist vs. Car	25 (52)
Isolated cyclist	23 (48)
Accident site	
Street	46 (100)
Recreation/Sport	0
Helmet worn	
Yes	14 (29)
Injury Severity Score (median, range)	17 (1–50)



**Fig. 1.** GU-related bicycle trauma presenting to ZSFG.

of concomitant organ injuries was 2 (range 0–6) which included the: lung (13/48, 27%), ribs (13/48, 27%), liver (12/48, 25%), pelvis (11/48, 23%), spine (11/48, 23%), spleen (6/48, 13%), brain (4/48, 8%), and bowel (4/48, 8%).

#### GU-Related bicycle injury outcomes

Table 2 demonstrates the differences in organs injured and operative management. 12/48 (25%) of GU-related bicycle traumas required operative intervention specific to their GU injury. The most common GU organ injured was the kidney (36/48, 75%) however the majority were managed non-operatively. AAST grades for renal trauma included Grade 1 (6/36, 17%), Grade 2 (11/36, 31%), Grade 3 (8/36, 22%), Grade 4 (8/38, 22%), and Grade 5 (3/36, 8%). The 3 patients with renal trauma (all grade 5) underwent operative interventions with a nephrectomy (n=2) or renorrhaphy (n=1). The patient with a grade 5 renal injury whose kidney was spared had a laceration to the renal hilum and underwent an upper pole renorrhaphy. The 4 pediatric patients all suffered a renal injury—grades 1, 2, 4, and 5 respectively. Only the grade 5 renal injury in a 15-year-old boy required operative intervention with a nephrectomy.

Seven patients with GU-related bicycle trauma had a bladder injury, of which 6 required operative intervention. The majority (n=5) had intraperitoneal bladder perforations and one had an extraperitoneal bladder injury however underwent cystorrhaphy due to a pelvic fracture with concern for bone displacement into the bladder wall. Of the 6 men with testicular injuries, 3 underwent scrotal exploration. The intraoperative findings in all 3 cases revealed a ruptured tunica albuginea (bilateral in 1 case) that were all repaired primarily and salvaged. The remaining 3 cases had testicular contusions on ultrasound and were managed non-operatively. There were 3 cases of urethral injury, all of which involved a urethral disruption confirmed on retrograde urethrogram. One case was managed with a single-pass catheter placement and was asymptomatic at 6 months post-injury; he was subsequently lost to follow-up. The remaining 2 men had a suprapubic tube placed intraoperatively. One patient underwent primary realignment and the other was managed with a suprapubic tube alone. Both men required a subsequent urethroplasty approximately 6 months after injury.

Table 3 demonstrates the outcomes of patients with GU-related bicycle trauma. All GU injured cyclists were admitted either to: an ICU (15/48, 31%), followed by a hospital floor (12/48, 25%) or step-down unit (9/48, 19%). The remainder were taken straight to the operating room (12/48, 25%). The median number of packed red blood cells given was 10 (range 0–33). The median length of hospitalization was 4 days (range 1–26). Mortality following GU-related bike injury was low (2/48, 4%). One patient had a pelvic fracture and intraperitoneal bladder perforation that was

**Table 3**  
Outcomes Following GU-related Bicycle Trauma.

	N = 48 (%) or median (range)
Disposition	
OR	12 (25)
ICU	15 (31)
Step Down Unit	9 (19)
Floor	12 (25)
Transfusion Requirement(s)	
Red blood cells	10 (0–33)
Platelets	2 (0–2)
Plasma	15 (0–15)
Length of Hospitalization (Days)	4 (1–26)
Outcome	
Died	2 (4)
Survived	46 (96)
Discharge Destination (N = 46)	
Home	34 (74)
Hospital Transfer	5 (11)
Skilled Nursing Facility	2 (4)
Rehabilitation Facility	5 (11)

closed however the patient expired due to hemodynamic instability secondary to a lower extremity degloving injury. The other mortality had a testicular rupture that was managed nonoperatively after the patient was found to have brainstem herniation and care was withdrawn. Of the 46 patients discharged, the majority were discharged to home (34/46, 74%) compared to another hospital (5/46, 11%), a rehabilitation facility (5/46, 11%), or a skilled nursing facility (2/46, 4%). The 4 pediatric patients who suffered renal trauma were all discharged to home within a median of 9 days.

#### Discussion

We demonstrate that despite a high prevalence of major bicycle trauma requiring hospital admissions to a Level I trauma center, associated GU injuries are rare. Furthermore, operative GU-related bicycle trauma is exceedingly rare. Of those 3% (48/1659) of cyclists with a GU injury, only 12 patients required operative intervention. Male cyclists at a median age of 29 most often experienced a GU injury while riding on streets. Despite California state laws requiring helmet usage [16], a small percentage of riders actually used a helmet for protection at the time of their trauma. Both automotive and isolated cycling trauma was common. Not surprisingly, concomitant injuries associated with GU-related bicycle trauma were numerous. As a result of their poly-trauma, the majority of patients received care in an ICU and the median lengths of hospital stay exceeded 4 days. Our data suggests that a GU injury following bicycle trauma is a surrogate marker for other, perhaps more severe injuries. Multidisciplinary services (e.g. Trauma Surgery, Critical Care, Orthopedics, Urology, Neurosurgery, etc.) may be necessary to care for patients with poly-trauma from bicycle injuries.

This study provides a greater understanding of the presentation, management and outcomes of major GU-related bicycle trauma. National data sets lack the granularity and outcomes reported in single-center series. Our group has previously surveyed GU injuries presenting to EDs following bicycle trauma using the National Electronic Injury Surveillance System (NEISS) [17]. With this national data, we found that bicycle collisions were the most common cause of GU morbidity (11% of total injuries) [18]. From the NEISS data, there was a greater prevalence of scrotal trauma following bicycle injury compared to our findings (25% versus 13%)

**Table 2**  
Operative GU-related Bicycle Trauma by Organ(s) Involved.

	Total (N = 48, %)	Operative (N = 12, %) <sup>a</sup>
Kidney Injury	36 (75)	
Grade		
1	6 (17)	0
2	11 (31)	0
3	8 (22)	0
4	8 (22)	0
5	3 (8)	3 (100)
Bladder	7 (15)	6 (86)
Testis	6 (13)	3 (50)
Urethra	3 (6)	2 (67)
Adrenal	4 (8)	2 (50)

<sup>a</sup> Some cases had more than one GU organ injured.

and less renal trauma (16% versus 75%). This is best explained by sampling bias as NEISS data captures less acute trauma patients that may be discharged. Other disparate findings comparing NEISS data to the present study include pediatric bicycle trauma. Children were nearly 10 times more likely to have a GU injury from a bicycle versus adults yet adults are more nearly twice as likely to get admitted [14,17]. In our cohort, only 3/48 cases were pediatric GU-related bike traumas. Beyond demographics, the NEISS dataset does not capture outcomes, causes of injury, and operative interventions [18].

When we compare our cohort to the National Trauma Data Bank (NTDB), Bjurlin et al. report on operative details surrounding genitourinary bicycle trauma [19]. Looking at 16,585 isolated cycling traumas, GU organ injuries were sustained in 358 (2%) similar to our single-center series (48/1659, 3%). Like the present study, Bjurlin et al. found that renal trauma occurred most frequently (75%) followed by bladder (15%), and then penis/scrotum (10%). The rate of nephrectomy performed was 0.4% meanwhile the most common operative intervention reported was testicular repair (42%) [19]. We report cystorrhaphy to be the most common operative intervention for GU-related bicycle trauma meanwhile our rate of nephrectomy was similar at 0.12% (2/1659). The mean ISS in this cohort was 12.5 which was lower than the present study (ISS 17), yet the authors' report an overall mortality rate of 6% which is higher. This is perhaps explained by the data captured by the NTDB which includes Level I–V trauma centers who may not be readily equipped for highly acute, poly-traumas secondary to bicycle injury. We found that while external genitalia (penis, testis, or labia) are often most exposed and vulnerable to injury, the organs are less commonly injured compared to renal or bladder trauma. This is consistent with data from the NTDB registry [19]. Similarly, we did not observe any ureteral injuries, which is congruent with data from national data sets whereby such an injury is extraordinarily rare [18,19].

The median LOS for our cohort was 4 days which is longer than National Inpatient Sample data for all bicycle traumas (1.8 days) admitted to US hospitals [8]. This suggests that bicycle trauma involving a GU organ is associated with a greater degree of injury. As such, our median Injury Severity Scores for GU-related bicycle trauma were higher (17 vs. 7.8) than national averages for all types of bicycle trauma [8]. The implications of this data are important. Upon injuring a GU organ, bicycle trauma patients will spend longer in the hospital, have significant numbers of concomitant injuries, and a quarter will require nursing or rehabilitation services upon discharge. Furthermore, this data reflects that non-critical patients with GU-related bicycle trauma are seldom admitted. With the popularity of cycling rising, particularly in older patients, specific attention towards bicycle safety and injury prevention is warranted in effort to curtail the estimated \$4 billion dollars spent per year on bicycle trauma [11].

There are limitations to our descriptive study. Our trauma database collected patients admitted to ZSFG therefore it underestimates the true prevalence of GU organ injuries who were discharged from the ED. As a result, the injuries reported are more severe and represents selection bias. We speculate that the addition of subacute data from EDs or outpatient facilities would increase the incidence and decrease the mortality of GU-related bicycle trauma. Lastly, we present a single-center series from the largest trauma center in San Francisco and San Mateo counties. This data may not generalize among suburban or rural areas where daily cycling is less commonplace and conditions are different from a large metropolitan city. Despite these limitations, our data was collected in a uniform and standard fashion consistent with our trauma registry and is not subject to the heterogeneity or information bias of many national data sets.

## Conclusions

In a large series of bicycle trauma admitted to a Level I trauma center, GU organs were injured in 3% of cases. The majority of cases were managed non-operatively and mortality was low. While the immediate threat of mortality is low, GU-related bicycle trauma is associated with a lengthy hospital stay secondary to increased morbidity from concomitant injuries. With the increasing popularity of cycling for sport or daily commuting, safety, infrastructure investment and injury prevention are paramount to prevent a rise in bicycle trauma nationwide.

## Conflicts of interest

None.

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## Author contributions

ECO: literature search, study design, data collection, data analysis, data interpretation, writing, critical revision.

MAA: data collection, data analysis, data interpretation, writing, critical revision.

TWG: data collection, data analysis, data interpretation, writing, critical revision.

TS: data collection, data analysis, data interpretation, writing, critical revision.

AA: data collection, data analysis, data interpretation, writing, critical revision.

LAH: critical revision.

JY: data collection, data analysis, data interpretation.

JWM: writing, critical revision.

BNB: study design, data collection, data analysis, data interpretation, writing, critical revision.

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