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Standing electric scooter injuries: Impact on a community

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ABSTRACT

Background: This study investigates the impact of standing electric scooter-related injuries within an entire integrated hospital system.**Methods:** We performed a retrospective review of patients involved in standing electric scooter incidents presenting throughout an urban hospital network over a 10 month period. Rates of Google searches of scooter-related terms performed locally were used as a surrogate for ride frequency. Injury, mechanism, and cost data were analyzed.**Results:** Data on 248 patients were reviewed. Twenty-three (9%) were under 18 years old. Loss of balance was the most common cause of injury accounting for nearly half, while tripping over a scooter 14 (6%) affected the elderly disproportionately. Eight (3%) riders wore helmets. All TBI and closed head injuries occurred in unhelmeted patients. Most incidents occurred in the street, only one in a bicycle lane. Facilities costs were greater for patients under the influence of alcohol and marijuana.**Conclusion:** Policies related to the use of mandated safety equipment, dedicated bicycle lanes, and the proper storage of empty vehicles should be further investigated.

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Introduction

Since their introduction in 2017, standing electric scooters have become a significant means of transportation for urban residents and have assumed a substantial portion of the micro-mobility market in cities worldwide.¹ Their ready availability, ease of use, cost-effective pricing, and lack of parking requirements contribute to their popularity and offer an immediate solution to the problems of urban transportation.

Our network serves one of the first regions in the United States in which electric scooter services became available before their national expansion. Accordingly, we have observed increasing numbers of injuries presenting to our network which parallel expanding electric scooter popularity.^{2–4} The goal of the present

study was to explore factors associated with injuries related to the use of electric scooters among patients who presented throughout the various arms of our integrated academic and community-based health care system. Understanding of these factors may better inform public decisions, impact individual safety, and guide future policy. We hypothesized that a significant number of patients were being treated in the community and clinics, and that evaluating patients seen at the trauma center alone would not afford an accurate representation of their injuries.

Methods

An Institutional Review Board approved retrospective review of all patients treated for electric scooter related injuries throughout our integrated medical system between February 1 and December 1, 2018 was conducted. This method captured patients at our urban Level I trauma center, affiliated community hospital, urgent care clinics, and outpatient clinics. Our health care system uses the Epic® (Verona, WI) electronic health records platform. The Deep6 Artificial Intelligence® (Pasadena, CA), a compatible secondary machine learning system which uses artificial intelligence and

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natural language processing to analyze structured data such as ICD-10 codes and unstructured clinical data including data in free-text form was used to query the electronic health record. We used the keywords “bird”, “lime,” “electric scooters”, with variations in spelling and abbreviations of each, for the Deep6 AI® to identify all patients with medical encounters in our hospital system which involved contact with an electric scooter. Patients of all ages were included. Additional negation rules were implemented to exclude non-ride-sharing scooters such as medical mobility scooters, mopeds, e-bikes, Vespa scooters, Segways, hoverboards, and motorcycles from the search query. After a cohort was generated by the software, the list of patients was then manually screened by the physician investigators to ensure that an accurate population was identified. The cohort was also compared to our trauma registry database to verify completeness. Initial and follow-up encounters by the same patient were counted as a single encounter with respect to incidence and cost data.

Incident specific data including location of injury occurrence, mechanism of injury, and use of protective equipment was collected. Patient intoxication status and marijuana use information were also collected. Use of alcohol or marijuana was largely self-reported, as testing is not routine for these or other drugs of abuse. Patients were assessed for their injuries, procedural interventions, and length of hospital and ICU stay. Traumatic brain injury was defined as an acute injury demonstrated on imaging. Limited facilities cost data related to these specific encounters was provided by our institution.

As a proxy for monthly electric scooter ride frequency, we performed Google Trends™ queries using key words such as “bird” and “scooter” for the frequency of web-based searches which originated from our catchment area over the study period. Google Trends™ searches can be performed over a specified time frame and yield the frequency of internet searches for specified items. These quantitative searches can be further specified to reflect the number of queries which originated from a particular geographic area. These search results provided a surrogate for the relative frequency of rides in our catchment area corresponding to the time period of our investigation.⁵ The general term “bird” was specifically used for two reasons: First, Bird Rides Inc, occupied the largest market presence in the immediate vicinity of our healthcare institution during the timeframe of this retrospective analysis and second, when a company name was specifically identified by Deep6 AI®, greater than 95% of the time it was a Bird scooter.

We performed descriptive statistics to report much of the data. Continuous variables were evaluated by Welch’s ANOVA. Statistical analysis was performed in JMP Pro 13.1 (SAS Institute Inc., Cary, NC). This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Results

Patient demographics

During the study period, 248 patients met inclusion criteria, of which 142 (57%) were male. The mean age of subjects was 35.8 years (range 2–92). Fifteen (6%) were under the legal scooter riding age of 16 years old, and 23 (9%) were under the companies’ usage agreement age of 18 (Fig. 1). The greatest number of patients were brought to the Level I trauma center 109 (44%), but only 15 (6%) were trauma team activations, and 14 (6%) others were trauma team consults, the remainder being evaluated by the Emergency Department staff. Seventy-five (30%) patients presented to the affiliated community hospital, 47 (19%) at the outpatient orthopedic clinic, and 17 (7%) at an urgent care facility.

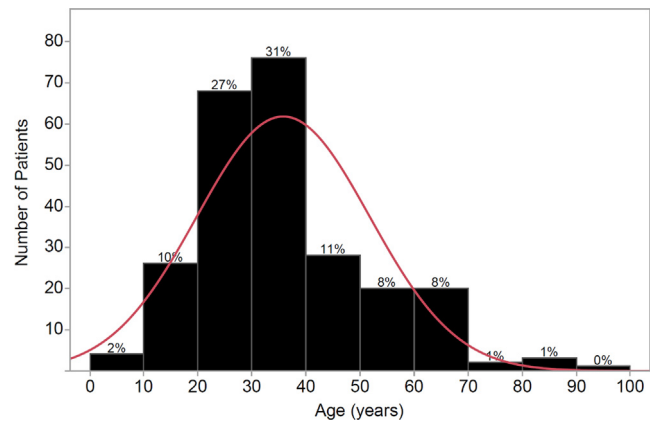


Fig. 1. Incidence of presentation by decade of life is normally distributed.

Rates of presentation

The results of Google Trends™ queries for the frequency of Google searches for scooter-related terms by internet users from within our catchment area were calculated monthly and was employed as an inferred relative rate of monthly electric scooter use. This was compared to the monthly incidence of health care encounters to our network (Fig. 2).

Cause of injury and safety equipment

Rider loss of balance was the most common cause of electric scooter events, followed by scooter vs automobile collisions (Table 1). Almost 6% of all incidents were the result of pedestrians tripping over stationary discarded scooters. This mechanism afflicted the elderly disproportionately, median age[IRQ] 67 [55–83] vs 32 [25–51], $p < .001$. Only eight (3%) riders were documented using helmets, and none used wrist guards or other protective gear, although data was incomplete on one-third of subjects.

Location of event

Most, 90 (36%), injuries occurred in the street, but 42 (17%) occurred on the sidewalk, where it was illegal to operate this type of vehicle in our jurisdiction. A single incident occurred in a bicycle lane.

Injury patterns

The distribution of injuries is presented in Table 2 with the vast majority involving the lower extremity, upper extremity, and head. Overall, 105, (42%) required a procedure: 33 (13%) required an operation, 32 (13%) required orthopedic reductions in the ED, and 40 (16%) required ED suturing. The most common injuries were orthopedic fractures, of which radius 27 (11%), ankle 9 (4%), and tibial plateau 7 (3%) comprised the majority. Three patients developed compartment syndromes of their extremities which required decompressive fasciotomies. Traumatic brain injuries (hemorrhage) were observed in five patients (2%), skull fracture 4 (2%) and closed head injuries in an additional 19 (8%), all of whom were documented as not using helmets. One patient required a craniotomy for evacuation of an epidural hematoma. Facial fractures and dental injuries were also identified.

Significant injury to internal organs of the trunk and torso were uncommon. One patient sustained a grade III liver injury, and

Regional Google Search Frequency and Rates of Patient Presentation

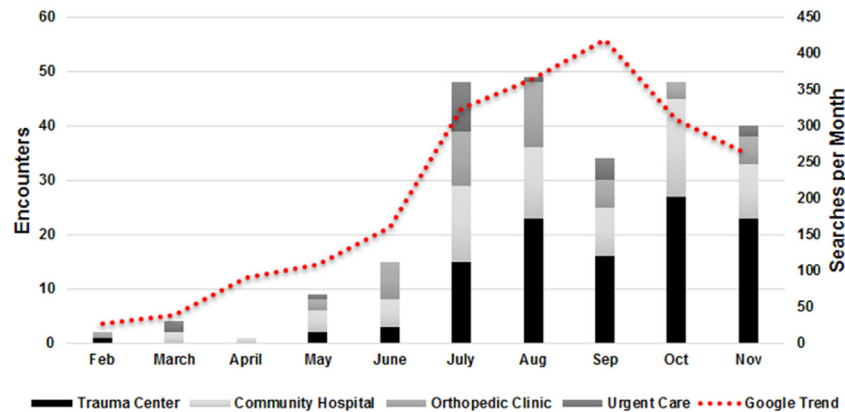


Fig. 2. Google Trends™ search results for the frequency of web searches of terms synonymous with electric scooters which originated from the same geographic area as our study population were used as surrogate for relative monthly scooter use.

another a grade III splenic laceration with multiple left rib fractures and a hemothorax. Three others had rib fractures. No abdominal operations were required in any of the patients.

Due to significant injuries, 37 (15%) patients required a hospitalization. Among these patients, 30 (81%) patients had at least a 1–4 night hospital stay, 4 (11%) patients required a 5–10 night stay, and 3 (8%) patients required greater than 10 nights in the hospital. In our population, 6 (2%) patients required ICU admission. There were no deaths in this study cohort.

Substance use and cost data

Cost data was available for 176 subjects. Of the 72 encounters missing cost data, 57 (79%) were clinic visits. The median[IQR] total facilities cost for these encounters (direct + indirect costs) was \$1213[\$499–\$3312]. Rates of alcohol and marijuana use were

largely self-reported and low, 15/161 (9%) alcohol and 3/173(2%) marijuana. Despite this, the trend of facilities costs were greater for patients under the influence of alcohol with a median[IQR] \$2674 [\$1033–\$15727] vs \$1028[\$494–\$3114], $p = .07$, and marijuana \$42132[\$9695–\$110095] vs \$1211[\$495–\$3157], $p < 0.01$, but due to low rates of occurrence, statistical significance is not reliable.

Discussion

What began in late 2017 as a means of providing a simple solution to first-and-last mile public transit has quickly grown in popularity in cities throughout the world and has evolved into a multibillion-dollar industry. Along with the rapid adoption of this accessible means of transportation, hospitals have witnessed new waves of injuries related to these devices.⁶

For a nominal fee, instant access is provided with a credit card,

Table 1
Incident demographics (n = 248).

| Description of Event | | Overall Incidence (%) |
|---------------------------|---|-----------------------|
| Mechanism | Loss of balance | 121 (49%) |
| | Scooter vs automobile | 35 (14%) |
| | Uneven pavement | 25 (10%) |
| | Scooter pollution (trip over discarded scooter) | 14 (6%) |
| | Equipment malfunction | 7 (3%) |
| | Scooter vs pedestrian | 3 (1%) |
| | Other and unknown | 43 (17%) |
| Approximate Speed | 0 - 5 miles per hour | 8 (3%) |
| | 6 - 10 miles per hour | 8 (3%) |
| | 11 - 15 miles per hour | 19 (8%) |
| | Unknown | 213 (86%) |
| Location of Event | Street | 90 (36%) |
| | Sidewalk | 42 (17%) |
| | Bicycle lane | 1 (0.4%) |
| | Unknown | 115 (46%) |
| Protective Equipment Used | Helmet | 8 (3%) |
| | Wrist guards | 0 (0%) |
| | None | 155 (63%) |
| | Unknown | 85 (34%) |

Table 2

Distribution and nature of injuries associated with electric scooter use presenting to a healthcare system (n = 248).

| Region of Body | | Overall Incidence (%) |
|-------------------------------------|-----------------------------------|-----------------------|
| Head | Intracranial hemorrhage/contusion | 5 (2%) |
| | Closed head injury | 19 (8%) |
| | Skull Fracture | 4 (2%) |
| | Facial Fracture | 10 (4%) |
| | Dental Injury | 9 (4%) |
| | Laceration | 41 (17%) |
| | Contusion | 33 (13%) |
| | Abrasion | 28 (11%) |
| Neck | Cervical Fracture | 2 (1%) |
| | Ligamentous Injury | 2 (1%) |
| | Disk Injury | 0 (0%) |
| | Contusion | 0 (0%) |
| Chest & Abdominal Injuries | Solid organ injury | 2 (1%) |
| | Body wall contusion | 15 (6%) |
| | Body wall abrasion | 6 (2%) |
| | Rib fractures | 4 (2%) |
| | Hemothorax | 1 (0.4%) |
| | Laceration | 0 (0%) |
| Thoracolumbar Spine Injuries | Fracture | 2 (1%) |
| | Ligamentous Injury | 0 (0%) |
| | Disc Injury | 4 (2%) |
| | Contusion | 2 (1%) |
| Shoulder & Upper Extremity Injuries | Fracture | 53 (21%) |
| | Sprain | 14 (6%) |
| | Laceration | 6 (2%) |
| | Contusion | 48 (19%) |
| | Abrasion | 61 (25%) |
| Hip & Lower Extremity Injuries | Fracture | 38 (15%) |
| | Sprain | 16 (6%) |
| | Laceration | 8 (3%) |
| | Contusion | 43 (17%) |
| | Abrasion | 51 (21%) |

driver's license, and a smartphone. These ecologically friendly scooters have established a global presence and in many cities are a well-received solution to minimize city congestion and supplement local transit.⁷ Recent transportation data has demonstrated that 45% of vehicular trips made in the United States last 3 miles or less, and 78% of these are made with a personal vehicle.⁸ Additionally some scooter companies offer subsidized rates for lower income riders in an effort to provide an affordable means of transportation to underserved populations.⁹ This freedom to come and go as one pleases (and not need to look for a parking space), has great appeal in urban environments.

This is one of the first analyses of these injuries which captures patients who presented throughout a hospital system with multiple levels of care. Our network services metropolitan Los Angeles extending to neighborhoods along the Pacific coast. *In contrast to other studies based on trauma registry data¹⁰ or emergency department-based registries¹¹, our study captures less-severe, but frequent encounters at outpatient and urgent care clinics and at community hospitals. Our system-wide data collection demonstrates that within at a level I trauma center, the majority of encounters do not involve the trauma service, and that trauma registry-based studies greatly underestimate the true incidence of injuries from these devices. Similar to an earlier paper based in an adjacent catchment area¹²,*

we demonstrate a broad spectrum of injury patterns and patients of all ages.

In all studies, the use of safety equipment is essentially non-existent. During the timeframe of this study, helmet use was required under law, and yet rates of their use were shockingly low despite free giveaways of helmets by the ridesharing companies. As of January 1, 2019, however, helmet usage is no longer required in the state of California except for riders under the age of 18, where the legal riding age is 16. While most electric scooter companies prohibit the use of these devices in their usage agreements by riders under 18 years of age, our encounter data shows that this practice is common. Further, under this new helmet law, riders are allowed to ride upon roadways with concurrent automobile traffic speed limits of 35 miles per hour, up from 25 previously.¹³ The combined impact of these two changes has yet to be fully realized.

The very design of electric scooters present inherent dangers. These vehicles weigh approximately thirty pounds, and reach top speeds of 15 mph or faster when traveling downhill.¹⁴ The rider's upright stance upon a narrow deck, lack of ability to shift their weight side-to-side, their relatively locked knees, and a tall fixed steering column sum to produce an unstable platform compared to a that of bicycle or motorcycle on which a rider can both lean into a turn and countersteer to keep their center of mass optimally

positioned. Additionally, small hard wheels with the absence of shock absorbers make it difficult to accommodate for sudden changes in riding surfaces such as curbs, potholes, and foreign objects. Of the reported mechanisms of injury, roughly half the patients from our cohort reported loss of balance as the reason for their falls, and an additional 10% reported uneven pavement.

Whether scooters were left on the sidewalk in an orderly fashion or discarded haphazardly, they presented an obstacle for elderly pedestrians who tripped over them and sustained injuries requiring medical attention in significant numbers. Interestingly, an additional 11% active riding incidents occurred on sidewalks where it is illegal to ride. This suggests that riders are choosing to ride on sidewalks, perhaps because they feel it is safer than riding in the street with automobile traffic. This is consistent with what was found in a survey of users conducted by the city of Austin, Tx.¹⁵

Importantly, only a single patient in our study had an event in a dedicated bicycle lane, where riding is legal. This was a seven-year-old boy who sustained only minor abrasions. Furthermore, emergency departments located in areas such as Washington D.C. which have substantial allocated bike lanes, have reported seeing a lower frequency of electric scooter injuries¹⁶ suggesting a value in using these protected lanes for electric scooters. As most major cities already have already prepared such lanes, further investigation into the protective effects of these lanes for electric scooter use could provide significant insight into how to safely incorporate this rapidly growing modality.

Given the scooters' simple appearance and ubiquitous presence, riders may underestimate the potential for harm, as evidenced by the infrequent use of protective equipment. The decision to ride may be spontaneous, and riders may lack experience with the controls or in maneuvering around crowded or uneven city sidewalks and streets. A portion of riders may be tourists who are unfamiliar with the terrain and distracted by sight-seeing. In the Austin-based study, one-third of injured riders experienced their injury during their first ride.¹⁷ Our limited data suggests that alcohol and marijuana use is related to injuries with increased health care costs. The safety of these devices, compared to automobiles, may be underappreciated by the public, as drunk driving campaigns do not address this new technology and may in fact unintentionally encourage the use of these ride-sharing options.

We used local Google Trends™ data as a novel surrogate for monthly ride frequency data which could not be obtained directly. These trends matched strikingly well with the overall rates of injuries which were observed. While no direct correlation of search frequency to either ride or injury incidence is claimed, we feel this finding is an interesting one, and similar applications of this technique may be useful in other population-based studies.

This study has the inherent weakness associated with retrospective reviews, especially the under-capture of significant data and selection bias. Self-reported rates of substance use are likely not representative. Other surveys have implicated alcohol use in the 12 h preceding an incident in about 30% of interviewed riders.¹⁷ Our temperate weather and year-round low precipitation rate does not allow us to investigate the effects of climate and road conditions on collision rates. But our examination does serve to document an increasingly common mechanism of injury which we have observed since the introduction of electric scooters into our area. Formal diagnosis coding has not yet caught up to these new mechanisms of injury, and a set of unique ICD External Causes codes for this mechanism would substantially improve subsequent national data collection and allow for larger, structured studies to be performed in the future. Less than 12% of our population were seen by the trauma surgery service, and trauma registries alone will not appreciate the burden of injury that these devices have introduced.

Most electric scooter injuries were orthopedic in nature or involved the head and face. There were relatively few internal injuries. This suggests that in appropriately stable and evaluable patients with a non-tender abdomen and low index of suspicion, an assessment might concentrate on musculoskeletal and head and neck injuries, and that serial observation of the abdomen may be appropriate rather than reflexively performing computed tomography. But certainly, more studies are necessary before any recommendations could be made.

Electric scooter use continues to grow, and policymakers must be aware of their impact. The ride-sharing companies have established a global presence and in some cities, are a well-received solution to minimize city congestion and supplement local transit.⁷ And yet in other major municipalities such as New York City, the debate about whether or not to allow these devices at all is still very active.¹⁸ Legislators, city planners, and business interests should focus on maximizing the safety of both riders and pedestrians while the on-demand mobility market continues to mature. Future studies evaluating the role of bicycle lanes, the proper storage of unused vehicles, and the impact of changing helmet laws should be performed.

Authorship

M.B.B., C.L., M.L., and S.S.T. contributed to the design of the study. M.B.B., A.N., C.L., M.L., and S.S.T. contributed to the acquisition of data. M.B.B., A.N., and E.Y.L. contributed to data analysis. M.B.B., A.N., D.R.M., and S.S.T. drafted the article. All authors contributed to critical review of the article and have agreed to the final version of the article.

Declaration of competing interest

All authors have no conflicts of interest to disclose.

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