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ORIGINAL ARTICLE • EMERGENCY - TRAUMA

Orthopaedic injuries from snowmobile accidents: a multi-centre analysis of demographics, injury patterns, and outcomes

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Abstract

Purpose More than 2 million people in North America use snowmobiles, resulting in an estimated 200 fatalities and 14,000 injuries annually. The purpose of this study is to document the demographics, orthopaedic injury patterns, and short-term outcomes of patients with snowmobile-related injuries.

Materials and methods A retrospective review was performed at two regional trauma centres in a region where snowmobile use is prevalent. Patients who sustained snowmobile-related injuries over a 12-year period were identified from the hospitals' trauma registries using E-codes (E820-E820.9). Patient demographics were recorded, as were injury characteristics including rates of substance use, open fractures, Injury Severity Score (ISS), Abbreviated Injury Score (AIS) for the extremities, and mortality. Rates of inpatient surgery, as well as hospital and ICU length of stay (LOS), were also recorded.

Results We identified 528 patients with snowmobile-related injuries. Average age was 37 years, and 418 patients (79%) were male. Eighty-eight per cent of all patients with snowmobile injuries were admitted to the hospital with an average LOS of 5.7 days. Among those admitted to the hospital, average ISS was 12.3, and 28% of these patients had ISS > 15. A total of 261 patients (56%) suffered extremity injuries (including 163 upper and 173 lower extremity fractures) with an average extremity AIS of 2.4. There were 700 total fractures (1.5 per patient), and 9% of all fractures were open. A total of 208 patients (45%) suffered head injuries, and 132 patients (28%) sustained vertebral column fractures. A total of 201 patients (43%) required inpatient surgery, and eight patients (1.7%) sustained fatal injuries.

Conclusions We present a detailed multi-centre analysis of orthopaedic injury patterns and outcomes resulting from snowmobile-related injuries. Patients injured while snowmobiling share similar injury patterns with patients injured in motorcycle and other high-energy motor vehicle accidents.

Keywords Snowmobile · Orthopaedic trauma · Extremity injury · Fracture

Introduction

There are more than 1.2 million registered snowmobiles in the USA, and the average snowmobile driver rides over 1200 miles per year [1]. Snowmobiles are registered in just over half of the USA, and the majority of these vehicles are used in the upper Midwest [1]. During the 2014–2015 snowmobile season, Wisconsin boasted the highest number of registered snowmobiles (223,606), and these vehicles accounted for 96 reported injury incidents and 12 fatalities [2]. Modern snowmobiles are able to reach speeds similar to those attained by motorcycles and motor vehicles on highways, placing snowmobile users at risk of sustaining serious traumatic injury. Among survivors of snowmobile accidents, the average working adult missed 9.6 weeks of work while accumulating an average of $16,227 in medical expenses, as reported in the 1990s [3].

The majority of the current literature related to snowmobile injuries is focused on demographics, risk factors for injury, and mortality rates. Several studies have corroborated the fact that snowmobile collisions most commonly involve young male drivers and impact with fixed objects

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[4–10]. Snowmobile-related accidents in children and adolescents have also been well explored [10–13]. Additionally, the prior literature has identified alcohol consumption and driver inexperience as the two major independent risk factors for snowmobile accidents, particularly those resulting in fatalities [4–7]. Reported mortality rates following snowmobile-related injuries are as high as 3.6% [14]. In addition, compared to the more current literature investigating injuries sustained while using all-terrain vehicles (ATVs) [11, 15–17], the bulk of the literature related to snowmobile injuries was published more than 15 years ago [3–10, 12, 14, 18–20].

Another major limitation of the existing snowmobile literature is the lack of specificity in documenting injury patterns. Numerous studies report the average Injury Severity Score (ISS) [11–14], including a 1996 study that calculated a mean ISS of 9.3 among patients injured in snowmobile-related accidents [3]. Another study three years later reported a mean ISS of 15 and an average Glasgow Coma Scale (GCS) of 14.1 [14]. However, the specific injury patterns sustained after snowmobile accidents and patient outcomes are not as well documented. Furthermore, while extremity injuries are known to occur following snowmobile accidents, there are no studies in the published literature documenting the nature of orthopaedic injuries commonly sustained as a result of this mechanism. The aims of this multi-centre study are to document the demographics, orthopaedic injury patterns, and short-term outcomes of patients with snowmobile-related injuries.

Methods

Following institutional review board (IRB) approval, we identified all patients treated for snowmobile-related injuries between 1 April 2005 and 31 March 2017 at two regional trauma centres in a geographic region where snowmobile use is prevalent. One institution is a rural level 2 trauma centre that serves as a referral centre for numerous smaller hospitals in the region. The other institution is an academic level 1 trauma centre that serves as a referral centre for the majority of the state. Using each institution's trauma registry, all patients who sustained snowmobile-related injuries were identified by E-codes, which catalogue mechanisms of injury. Specifically, the E-code E820, "Non-traffic accident involving motor-driven snow vehicle", and its subgroups were utilized to identify all patients injured in snowmobile-related accidents. Patients injured while driving or riding on snowmobiles, those being pulled by a snowmobile, pedestrians struck by snowmobiles, and individuals injured when a snowmobile collided with a motor vehicle were all included.

To identify patients with snowmobile-related injuries who were not entered into the trauma registries, we also employed a "natural language processing" algorithm to search the electronic medical record for predetermined key words (specifically "snowmobile", "snowmobiles", and "snowmobiling"). Patients identified by this method were then cross-referenced with patients previously identified in the trauma registries to eliminate duplicate records.

For the final cohort of patients, basic demographics were recorded, as were injury characteristics including rates of substance use and the patient's first documented body temperature. Details of all orthopaedic injuries, including rates of open fracture, were recorded, and the Abbreviated Injury Score (AIS) for the extremities was calculated. Injuries to other body regions including the head, chest, abdomen, pelvis, spine, and face were documented, and the Injury Severity Score (ISS) was determined. Emergency Department (ED) disposition, rates of inpatient surgery, hospital and ICU length of stay (LOS), and in-hospital mortality were also recorded.

Results

Over the 12-year study period, we identified 528 patients injured in snowmobile-related accidents. A total of 196 patients (37.1%) were treated at the level 1 trauma centre, and the remaining 332 (62.9%) were treated at the level 2 centre. As shown in Table 1, average age was 37 years and 79.2% were male. The majority of injured patients were adults (86.6%), and blood alcohol content (BAC) was above the legal limit in 60% of patients (90 of 158) in whom it was tested. In total, 470 patients (89%) were identified using the trauma registries, and the remaining 58 patients (11%) were identified by the natural language processing algorithm. Of all patients, 61 (11.6%) were discharged directly from the ED. The majority of this cohort sustained minimal injuries that necessitated limited observation and treatment in the ED. Twenty of these ambulatory patients (32.9%) sustained an isolated extremity injury with an average extremity AIS of 1.89 (SD = 0.32). None of these patients had open fractures. Three patients (4.9%) in this population eventually underwent an inpatient surgical procedure, and five patients (8.2%) required an outpatient operation at a later date.

Table 1 Demographics of the entire population ($n = 528$)

Demographics	
Age (years)	37.0 ± 16.0
< 18 years	71 (13.4%)
Male	418 (79.2%)
BAC tested	158 (29.9%)
BAC (above 0.08)	90 (60%)

BAC blood alcohol content

Table 2 Hospital course for admitted patients ($n=467$)

Hospital course	
Temperature in ED	98.1 ± 1.5
Hospital LOS (days)	5.7 ± 6.6
ICU admissions	148 (31.7%)
ICU LOS	4.9 ± 5.4
Patients intubated	57 (12.2%)
Intubation period (days)	6.1 ± 6.5
Inpatient surgery	201 (43%)
Mortality	8 (1.7%)

LOS length of stay, *ICU* intensive care unit

Table 3 Patients with an ICU stay ($n=148$)

ICU patients	
Hospital LOS (days)	9.6 ± 7.9
Patients intubated	55 (37%)
Intubation period (days)	6.3 ± 6.5
Inpatient surgery	71 (48%)
Mortality	5 (3.4%)
ISS	19.3 ± 10.9
Extremity injuries	76 (51%)
Extremity AIS	2.4 ± 0.5

ISS Injury Severity Score, *AIS* Abbreviated Injury Score

Among patients admitted to the hospital ($n=467$), average hospital LOS was 5.7 days (range 1–69, see Table 2). A total of 148 patients (31.7%) were admitted to the ICU with an average ICU LOS of 4.9 days (range 0.5–26). Fifty-seven patients (12.2%) required intubation for an average of 6.3 days (range 1–25), and inpatient surgery was required during the index hospitalization for 43% of patients. Average ISS among the patients admitted to the hospital was 12.3, and 28% of these patients had an ISS > 15. Not surprisingly, patients requiring ICU admission ($N=148$) sustained more severe injuries, with an average ISS of 19.3 (range 1–75). Average hospital length of stay in this cohort was 9.6 days (range 1–38), and 55 patients (37.2%) required intubation (see Table 3). Eight patients died during their index hospitalization, representing an in-hospital mortality rate of 1.7%.

A total of 261 patients (56%) suffered extremity injuries (including 163 upper and 173 lower extremity fractures). The average extremity AIS for these patients was 2.4. There were 700 total fractures (1.5 per patient), and 9% of all fractures were open. The most common orthopaedic injury was a fracture of the vertebral column, affecting 28% of patients, followed by fractures of the pelvis (11%) and femur (11%). Additional details of the orthopaedic injury patterns sustained are shown in Table 4. Non-orthopaedic injuries were also quite common, with 47% of patients sustaining abdominal injuries, 45% suffering head injuries, and 30% sustaining rib fractures.

Discussion

Snowmobiling remains a popular wintertime activity, particularly in the Midwest. Our study examined the injury patterns seen following snowmobile-related accidents at two regional trauma centres in a region where snowmobile use is prevalent. Our results indicate that snowmobile accidents cause substantial morbidity, resulting in an average ISS of 12.2. Beilman et al. investigated outcomes following snowmobile injuries in the general population and reported an average ISS of 15, which is marginally higher than our observed average ISS of 12.2 [14]. Three studies have investigated injury severity following paediatric snowmobile accidents, with reported mean ISS ranging from 10.0 to 12.1, scores that often exceed average ISS associated with ATV or dirt bike accidents [11–13]. Our average hospital LOS (5.7 days) and overall mortality rate (1.7%) are consistent with the previously published literature [11, 12, 14], and nearly a third of our patients required an ICU stay. Although there is variability in average ISS reported in the literature, our results are consistent with prior studies indicating that snowmobile accidents result in high-energy injury patterns and significant morbidity.

Our study is the first in the published literature to present a detailed, multi-centre analysis of the orthopaedic injury patterns sustained from snowmobile injuries. More than half of our patients (56%) sustained extremity injuries, with an average AIS of 2.4. Reported rates of extremity injuries in the literature range from 18 to 74% [18, 20, 21]. This wide variation in the rate of extremity fracture is primarily attributable to variable inclusion and exclusion criteria in these previous studies; some include minor musculoskeletal sprains and strains, whereas other studies calculate the prevalence of extremity fracture after excluding patients with isolated craniofacial or rib injuries. Our reported rate of 56% is a more accurate representation, as it excludes minor sprains and strains and uses the entire cohort of snowmobile-injured patients as the denominator. The 700 fractures sustained by our entire cohort represent an average of 1.5 fractures per patient.

As shown in Table 4, fractures of the femur and tibia/fibula were the most common extremity injuries, affecting 11% and 9% of patients, respectively. Pelvic fractures were also quite common, affecting 11% of our cohort. The most common orthopaedic injury sustained by our cohort was a fracture of the vertebral column, affecting 28% of patients. The prevalence of spine fractures in our cohort is higher than that reported by Withington and Hall [18] (11.9%) and Stewart et al. [21] (18%). Interestingly, our

Table 4 Injury characteristics for admitted patients ($n=467$)

Injury characteristics	
ISS	12.3 ± 9.0
ISS > 15	130 (27.8%)
Extremity injuries	261 (55.9%)
Extremity AIS	2.4 ± 0.5
Open fractures	40 (8.6%)
Orthopaedic injuries	254 (54.4%)
Upper extremity fracture	
Total	163 (34.9%)
Clavicle fracture	38 (8.1%)
Scapula fracture	35 (7%)
Humerus/radius/ulna fracture	68 (14.4%)
Hand or finger fracture	22 (4.7%)
Lower extremity fractures	
Total	173 (37%)
Pelvis fracture	49 (10.5%)
Femur fracture	53 (11.3%)
Patella fracture	11 (2.4%)
Tibia/fibula fracture	42 (9.0%)
Foot/ankle fracture	18 (3.9%)
Other orthopaedic injuries	
Vertebral fracture	132 (28.3%)
Spinal cord injury	10 (2.1%)
Dislocations	39 (8.4%)
Non-orthopaedic injuries	
Head injury	208 (44.5%)
Skull fracture	27 (5.8%)
Rib fracture	140 (30%)
Abdominal injury	231 (47.4%)
Pneumothorax or hemothorax	80 (17.1%)

ISS Injury Severity Score, *AIS* Abbreviated Injury Score

rate of spinal cord injuries (2.1%) was lower than the rate of 3.4% reported in a previous study by Shannon et al. [11]. Providers treating patients injured in snowmobile accidents must have a high suspicion for fractures of the vertebral column; careful physical examination and appropriate imaging of the spine are warranted. Furthermore, fractures of the long bones, pelvis, and spine represent high-energy musculoskeletal injuries that often require urgent orthopaedic surgery [22]. In addition, given the high frequency of non-orthopaedic injuries identified in our cohort (abdominal injuries in 47%, head injuries in 45%, rib fractures in 30%), coordinated care among multiple surgical teams is recommended in the initial management of patients injured in snowmobile accidents [23, 24].

Strengths of our study include the high volume of patients included, with injury details available for more than 500 patients over a 12-year study period. Furthermore, the use of a natural language processing algorithm allowed us to capture snowmobile-injured patients not already identified by the trauma registry. In addition, the inclusion of two distinct institutions—a rural level 2 trauma centre and an academic level 1 trauma centre—improves the generalizability of our study. The level 2 trauma centre represents a key referral centre for numerous smaller hospitals in the northern region of the state, where snowmobile use is more pervasive. Inclusion of the academic level 1 trauma centre enabled us to capture additional patients injured in snowmobile accidents from an even wider geographic area of the state. The detailed analysis of orthopaedic injury patterns sustained by this cohort also represents a significant strength of our study. Limitations include the retrospective nature of our study. However, this limitation is mitigated by the fact that injury data were gathered prospectively into the institutional trauma registries for the vast majority (89%) of patients in our cohort. Another limitation is the absence of functional outcome data, which was not included in the trauma registries at either centre.

Our study represents a detailed multi-centre analysis of the demographics, orthopaedic injury patterns, and short-term outcomes resulting from snowmobile injuries. Patients injured while snowmobiling share similar injury patterns with patients injured in motorcycle or other high-energy motor vehicle accidents. Providers should be aware of the most common orthopaedic injury patterns and other associated injuries. Trauma centres that regularly treat patients with snowmobile injuries must be equipped to provide the multidisciplinary care such patients require. Furthermore, institutions where snowmobile use is prevalent should lead the way in advocating for proper safety precautions among individuals engaging in this popular wintertime activity.

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Compliance with ethical standards

Conflict of interest David Goodspeed, M.D. is a paid consultant for Synthes. All other authors declare that they have no conflicts of interest.

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