Analysis and Incidence Calculation of Snowmobile Injuries Identified in a Rural Wisconsin Health Care System Over Five Years

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ABSTRACT

Introduction: Current estimates of snowmobile-related injuries are largely based on inpatient data from trauma centers. These centers care for severely injured patients and may not capture treatment information and outcomes for minor snowmobile-related injuries, therefore underestimating their volume and overestimating patient acuity.

Methods: Medically attended snowmobile injuries were identified retrospectively from inpatient and outpatient records from a health system in north-central Wisconsin using a hierarchical method of International Classification of Diseases external cause codes and text searches for key words. Manual reviews of the medical record collected information on patient characteristics, accident details, and clinical information. Descriptive analyses, comparisons between hospital admitted and nonadmitted cases, and calculations of seasonal incidence rates were conducted.

Results: From November 1, 2013, through April 30, 2018, there were 1013 snowmobile-related injuries, with 264 (26%) cases hospitalized and 749 (74%) treated as outpatients. Text search alone identified 61% of all incidents and about a quarter (26%) of hospitalized incidents. Inpatients were older and a higher percentage wore helmets, sustained multisystem trauma, sustained more fractures, more organ injuries, and had higher need for surgery and intensive care. Mortality was 1%. The average annual injury incidence rate was 313 per 100,000 snowmobiles registered.

Conclusions: Currently available studies of snowmobile-related injuries have underestimated their number and burden. Studies combining datasets from health systems in the state and statewide mortality records for cases who died prior to care could elucidate the full statewide impact of snowmobile-related injuries in Wisconsin, leading to better assessment of prevention efforts and staffing in rural trauma systems.

INTRODUCTION

With an estimated 14.5 million snowmobile trips and over 1.5 million snowmobiles registered annually,[1] driving snowmobiles is a popular winter activity in the northern United States. However, snowmobiles are fast and heavy machines, able to operate at speeds greater than 90 miles per hour and weighing 600 pounds or more.[2,3] They are frequently operated off-road, on trails, or over frozen bodies of water and are used in low visibility conditions, including snow squalls and low-light conditions. These factors—alone or in combination with others, such as alcohol use and excessive speed—[2,4-12] contributed to an average of 106 reported snowmobile incidents involving injuries (range: 58–171) per year in Wisconsin during 2014-2018,[11] though this number is likely an underestimate.

Accurate calculation of the incidence of snowmobile-related injuries (SRI) is challenging due to the rural location of SRI events and the procedure for injury reporting. Current estimates are based on trauma registry data from level I and level II trauma centers, many of which are located in urban centers distant from where recreational snowmobiling occurs.[3,10,13,14] Further complicating case identification is the method of injury reporting. Since 1971, in the state of Wisconsin, individuals involved in SRI events that result in medical care are required to self-report the incident to law enforcement officials and the Wisconsin Department of Natural Resources (DNR).[12] However, individuals may not be willing to report an SRI incident, especially if alcohol or other drugs were used at the time.[15]

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Previous investigations of the epidemiology of snowmobile injuries also have generally focused on the most serious injuries and deaths, which are reported in trauma registries, death records, and electronic medical records from trauma centers.[5,7-10,13,14,16,17] Injuries severe enough for hospitalization and transfer may have a different pattern of injuries and outcomes than SRIs treated in the outpatient setting. It is also likely that hospitalized patients represent only a small portion of the number of SRIs treated (and reported) in the United States. Identifying SRI incidents from inpatient and outpatient medical records could provide a more comprehensive description of SRIs to serve as a baseline from which to judge the impact of injury prevention strategies and to inform trauma system staffing in popular snowmobiling destinations.

To address the limitations of case identification for SRI incidence calculations and describe the patterns of SRI in the inpatient and outpatient settings, we abstracted data from the electronic health records (EHR) of an integrated rural health care organization that includes a level II trauma center during 5 consecutive winters (2013-2014 through 2017-2018). SRI cases for review were identified from the EHR data repository using a combination of text searching and disease codes. We calculated the seasonal incidence rate of snowmobile injuries in north-central Wisconsin by leveraging a defined cohort of patients from a geographically defined area who obtain nearly all care within our health system and a denominator of snowmobile registrations from the same geographic catchment area.

METHODS

Design and Setting

This is a retrospective study examining 5 snowmobiling seasons (2013-2014 through 2017-2018) in north-central Wisconsin. Each season—November through April—was considered an independent cross-sectional sample. All injury data were extracted from the EHR contained in the research data warehouse (RDW) of the Marshfield Clinic Health System (MCHS). MCHS is a large, privately owned, multispecialty group medical practice with a level II adult and pediatric trauma center in north-central Wisconsin. The data in the warehouse include administrative and medical information documented during routine clinical encounters and entered into CattailsMD EHR in the ambulatory environment and a combination of Centricity EHR or Cerner EHR in the inpatient environment due to a change during the years under study. As a retrospective study of existing health care data, the Marshfield Clinic Research Institute Institutional Review Board deemed this study exempt.

Sample

Records from both inpatient and outpatient (emergency department, urgent care, and outpatient clinic) encounters were included for analysis if the injury was medically attended and incurred while riding, being pulled, or being struck by a moving snowmobile. SRIs that occurred 6 months or more prior to the health care sys-

Table 1. ICD Codes and Words and Phrases Used to Identify Patient Records for Potential Inclusion in the Cohort of Snowmobile Injuries for Analysis

ICD Version 9, Billable for Dates of Service On or Before Sept 30, 2015

Dx Code	Dx Code Description
E820.0	Nontraffic accident involving motor-driven snow vehicle injuring driver of motor vehicle other than motorcycle
E820.1	Nontraffic accident involving motor-driven snow vehicle injuring passenger in motor vehicle other than motorcycle
E820.2	Noontraffic accident involving motor-driven snow vehicle injuring motorcyclist
E820.3	Nontraffic accident involving motor-driven snow vehicle injuring passenger on motorcycle
E820.4	Nontraffic accident involving motor-driven snow vehicle injuring occupant of streetcar
E820.5	Nontraffic accident involving motor-driven snow vehicle injuring rider of animal; occupant of animal-drawn vehicle
E820.6	Nontraffic accident involving motor-driven snow vehicle injuring pedal cyclist
E820.7	Nontraffic accident involving motor-driven snow vehicle injuring pedestrian
E820.8	Nontraffic accident involving motor-driven snow vehicle injuring other specified person
E820.9	Nontraffic accident involving motor-driven snow vehicle injuring unspecified person

ICD Version 10, Billable for Dates of Service On or After Oct 1, 2015

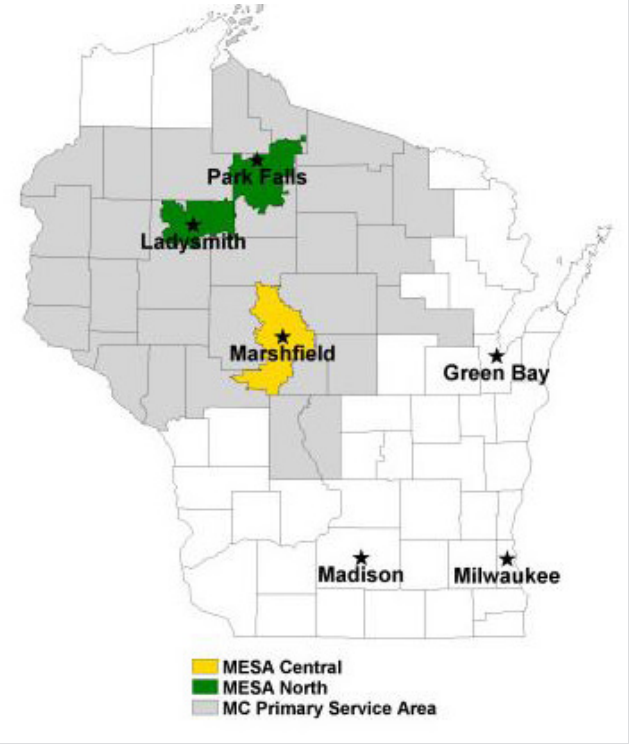
Dx Code	Dx Code Description
V86.02	Driver of snowmobile injured in traffic accident
V86.02XA	Driver of snowmobile injured in traffic accident, initial encounter
V86.12	Passenger of snowmobile injured in traffic accident
V86.12XA	Passenger of snowmobile injured in traffic accident, initial encounter
V86.2	Person on outside of special all-terrain or other off-road motor vehicle injured in traffic accident
V86.22	Person on outside of snowmobile injured in traffic accident
V86.22XA	Person on outside of snowmobile injured in traffic accident, initial encounter
V86.32	Unspecified occupant of snowmobile injured in traffic accident
V86.32XA	Unspecified occupant of snowmobile injured in traffic accident, initial encounter
V86.42	Person injured while boarding or alighting from snowmobile
V86.42XA	Person injured while boarding or alighting from snowmobile, initial encounter
V86.52	Driver of snowmobile injured in nontraffic accident
V86.52XA	Driver of snowmobile injured in nontraffic accident, initial encounter
V86.62	Passenger of snowmobile injured in nontraffic accident
V86.62XA	Passenger of snowmobile injured in nontraffic accident, initial encounter
V86.72	Person on outside of snowmobile injured in nontraffic accident
V86.72XA	Person on outside of snowmobile injured in nontraffic accident, initial encounter
V86.92	Unspecified occupant of snowmobile injured in nontraffic accident
V86.92XA	Unspecified occupant of snowmobile injured in nontraffic accident, initial encounter

Text Key Words

Group 1	"Accident" or "crash" or "collided" or "collision" or "ejected" or "fall" or "fell" or "hit" or "impact" or "roll" or "struck" OR "thrown"
Group 2	"Snow" and "mobile" OR "snowmobile"

Abbreviations: ICD, International Classification of Diseases.

Figure 1. Map of Marshfield Epidemiologic Study Area (MESA) and the Marshfield Clinic Health System (MCHS) Service Area



tem visit, occurred outside the snowmobiling season of November though April, or occurred from other aspects of snowmobiling that did not involve the vehicle in motion (eg, injuries during repair) were excluded. SRIs that were not the primary reason for the medical encounter and were not addressed/treated during the visit also were excluded from analysis.

Case Identification and Data Collection

Potential cases were identified in a hierarchical manner using a combination of disease/condition codes and text searching using a similar method to VanWormer et al[18] and Whiting et al.[8] First, records associated with SRIs were identified from the RDW using International Classification of Diseases (ICD) external cause codes from versions 9 and 10 (Table 1). We required key text words "snow" plus "mobile" or "snowmobile" to occur in free text chart notes (available in the RDW) within 3 days of the recorded ICD 9 or 10 code. This combined approach was enacted to reduce the risk of selecting patient records with miscodes. The first occurrence of an ICD code date in a given season was used to identify a unique record of injury. These cases were deemed ICD code identified. Second, additional potential cases for analysis without the ICD external cause codes were identified using electronic text searches requiring at least 1 word from Group 1 (Table 1) and either the combination of words or conjoined word from Group 2 to occur within the same encounter note. These cases were deemed text identified. To address oversensitivities of the electronic algorithm, a sample of sentences around these key words was extracted from the record and prereviewed. The encounter was excluded if it obviously did not meet inclusion criteria (eg, reference to snowmobile accident of a family member, snowmobiling was listed in activity limitations of discharge instructions). The resulting lists of ICD code-identified and text-identified cases were combined and deduplicated. Patients involved in 2 or more separate SRI incidents could be counted multiple times in each season or in the study period.

Trained research coordinators performed manual chart reviews on the final list of potential cases to verify case status and collect information on patient characteristics, accident details, treatment course, and clinical features of the injuries. Information was collected and stored in a research electronic data capture (REDCap) database.[19,20]

Analyses

We tabulated and described the demographic characteristics and contributing factors to injury—specifically age, sex, helmet use, blood alcohol level, and position of the injured (driver or passenger)—as well as the clinical characteristics of the injury associated with acuity, such as injury type, location of injury, hospitalization status, and clinical disposition at discharge. We classified cases as hospitalized if the patient was admitted to an inpatient care unit beyond the emergency department for care of their injuries.

Measures of central tendency were used to describe continuous variables, while frequencies and percentages were used to describe discrete variables. Data were tabulated for each season and overall. Statistical comparisons of differences between hospital admitted and nonadmitted cases (ie, cases treated in the outpatient setting) were performed using Student *t* test for continuous variables and Pearson chi-square analysis for discrete variables with SAS (version 9.4, Cary, NC, statistical software package). The threshold for statistical significance was set at a 2-tailed *P* value of 0.05.

To calculate the seasonal incidence rate of snowmobile injuries in north-central Wisconsin, we identified cases who were members of the Marshfield Epidemiologic Study Area (MESA). MESA is a defined geographic region of 24 ZIP codes surrounding primary MCHS service areas in central and northern Wisconsin (Figure 1).[21,22] Within MESA ZIP codes, the population is relatively stable and nearly all residents receive all their medical care at MCHS medical centers. From the Wisconsin DNR, we obtained counts of snowmobile registrations assigned to owners with residences in the MESA ZIP code catchment areas as of June 1 in the years 2014 through 2018. Snowmobile registrations expire June 30 each year with no penalty for registration at any point during the year. The number of MESA residents with a snowmobile injury in each of the study seasons (November-April) was divided by the total number of snowmobile registrations assigned to owners in MESA as of June 1 after the season.

RESULTS

Over 5 consecutive snowmobiling seasons, there were 1013 medically attended snowmobile injury cases, with a range

of 142 to 278 cases per year. Of these cases, 39% were identified via ICD code method and 61% were identified via text method (Figure 2). Descriptive characteristics of the SRI cases are presented in Table 2. Cases were predominantly male, the driver of the snowmobile, about half were aged 40 years and over, and three quarters only required outpatient medical care. Among cases for which helmet use information was available (530 of 1013), 89% (n = 471) were reported as wearing a helmet at the time of the accident. Children less than 16 years of age represented 8% (n = 70) of drivers injured (data not shown).

Statistically significant differences in case age, sex, and method of case identification were noted between hospitalized and nonhospitalized cases (Table 3). Individuals aged 40 years and over represented about 70% of the hospitalizations and less than 50% of the nonhospitalized cases. A higher percentage of hospitalized cases were male. About one quarter of hospitalized cases were identified via text method without an ICD code for snowmobile injury compared to 72% of nonhospitalized cases. Hospitalized cases had helmet use evaluated significantly more frequently than nonhospitalized cases (84% of cases vs 42%) and were found to have worn helmets more frequently than nonhospitalized cases (94% vs 85%).

As expected, we observed differences in injury patterns between hospitalized and nonhospitalized cases. About 84% of those hospitalized sustained fractures; the most common were thoracic, lower extremity, and upper extremity (Table 3). Over half (54%) of hospitalized cases required at least 1 surgical repair during hospitalization. Approximately 33% of nonhospitalized cases sustained a fracture, and the most common were upper extremity and lower extremity fractures. Only 7% of nonhospitalized cases required surgical repairs. Spine fractures were relatively uncommon in both groups, although there were 18 cases among the nonhospitalized. Inpatient mortality was 1% (3 cases).

Figure 2. Flowchart of Medical Encounters Screened and Included in Analyses of Snowmobile Injuries, 2013-2014 to 2017-2018

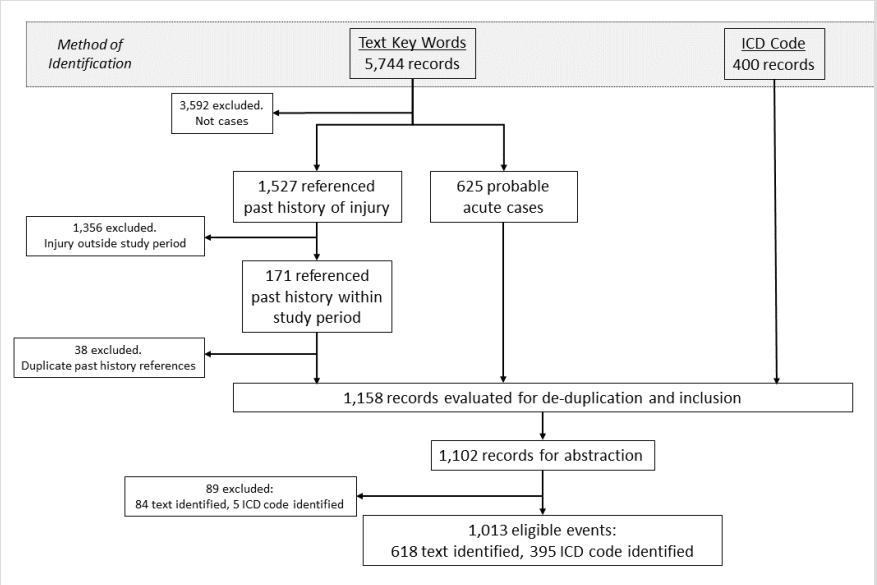


Table 2. Characteristics of Snowmobile Injuries Occurring From November 2013 to April 2018 and Treated in the Marshfield Clinic Health System or Affiliated Hospitals/Clinics by Season

Characteristic N (%)	All Events Season n = 1013	2013–2014 Season n = 278	2014–2015 Season n = 230	2015–2016 Season n = 161	2016–2017 Season n = 142	2017–2018 n = 202
Age years, median (IQR)	41 (23–53)	41 (25–52)	42 (23–53)	38 (22–51)	38.5 (19–53)	42.5 (23–56)
Age category						
<12 years	42 (4)	13 (5)	6 (3)	5 (3)	7 (5)	11 (5)
12–19 years	145 (14)	30 (11)	33 (14)	26 (16)	29 (20)	27 (13)
20-29 years	159 (16)	46 (17)	38 (17)	25 (16)	25 (18)	25 (12)
30-39 years	137 (14)	40 (14)	29 (13)	28 (17)	11 (8)	29 (14)
40-49 years	194 (19)	63 (23)	49 (21)	30 (19)	23 (16)	29 (14)
50-59 years	208 (21)	55 (20)	48 (21)	28 (17)	29 (20)	48 (24)
≥60 years	128 (13)	31 (11)	27 (12)	19 (12)	18 (13)	33 (16)
Male	703 (69)	189 (68)	171 (74)	116 (72)	98 (69)	129 (64)
Role of patient						
Driver/operator	876 (86)	231 (83)	209 (91)	143 (89)	115 (81)	178 (88)
Passenger	48 (5)	13 (5)	10 (4)	5 (3)	12 (8)	8 (4)
Rider, specific position unknown	60 (6)	28 (10)	5 (2)	8 (5)	11 (8)	8 (4)
Pulled behind snowmobile	20 (2)	4 (1)	5 (2)	3 (2)	2 (1)	6 (3)
Other	9 (1)	2 (1)	1 (0.4)	2 (1)	2 (1)	2 (1)
Helmet use[a]						
No	59 (6)	12 (4)	19 (8)	13 (8)	5 (4)	10 (5)
Yes	471 (47)	122 (45)	110 (48)	71 (44)	64 (45)	104 (51)
Unknown	474 (47)	140 (51)	100 (44)	76 (48)	71 (51)	87 (43)
Admitted to hospital						
No	749 (74)	212 (76)	164 (71)	117 (73)	98 (69)	158 (78)
Yes	243 (24)	63 (23)	60 (26)	36 (22)	43 (30)	41 (20)
Unknown	21 (2)	3 (1)	6 (3)	8 (5)	1 (1)	3 (1)
Case ID method						
ICD code	395 (39)	87 (31)	89 (39)	60 (37)	70 (49)	89 (44)
Text	618 (61)	191 (69)	141 (61)	101 (63)	72 (51)	113 (56)

Abbreviations: IQR: interquartile range; ID, identification; ICD, International Classification of Diseases.

[a]Injured bystanders (not riding on vehicle) are not shown in helmet use data (n = 9). 2013-2014 season (n = 4), 2014-2015 season (n = 1), 2015-2016 season (n = 1), 2016-2017 season (n = 2), 2017-2018 season (n = 1).

Table 3. Characteristics of Snowmobile Injuries Occurring From November 2013 to April 2018 and Treated in the Marshfield Clinic Health System or Affiliated Hospitals/Clinics Stratified by Hospitalization Status

Characteristic	Non-Hospitalized, n = 749 N (%)	Hospitalized, n = 243 N (%)[a]	*P* value
Age years, median (interquartile range [IQR])	37 (21–52)	49 (37–56)	<0.0001
Age category			0.0001
<12 years	40 (5)	2 (1)	
12–19 years	115 (15)	29 (12)	
20–29 years	137 (15)	19 (8)	
30–39 years	110 (15)	22 (9)	
40–49 years	133 (18)	55 (23)	
50–59 years	126 (17)	78 (32)	
≥60 years	88 (12)	38 (16)	
Male	501 (67)	187 (77)	0.003
Helmet use[b]			<0.0001
No	47 (6)	12 (5)	
Yes	269 (36)	193 (79)	
Unknown	424 (57)	38 (16)	
First facility of care			<0.0001
Emergency department	343 (46)	237 (98)	
Urgent care	172 (23)	2 (1)	
Clinic	196 (26)	2 (1)	
Telephone	30 (4)	2 (1)	
Other	8 (1)	0 (0)	
Number of injured areas per event (among head, face, spine, neck, thorax, abdomen, lower extremity, upper extremity)			
0	10 (1)	1 (0.4)	
1	529 (71)	89 (37)	
>1	210 (28)	153 (63)	
Number of body areas with fractures per event (among face, spine, thorax, lower extremity, upper extremity areas)			<0.0001
0	501 (67)	41 (17)	
1	235 (31)	133 (55)	
2	11 (1)	53 (22)	
3	2 (0.3)	11 (5)	
4	0 (0)	5 (2)	
Fracture type(s)			
Facial	7 (1)	12 (5)	
Spinal	18 (2)	38 (16)	
Thoracic (ribs, sternum)	52 (7)	89 (37)	
Lower extremity	59 (8)	85 (35)	
Upper extremity	127 (17)	68 (28)	
Organ injuries			
Brain	1 (0.1)	20 (8)	
Lung/heart	24 (3)	70 (29)	
Abdominal organ	0 (0)	25 (10)	
Number of surgically repaired areas per event (among head, face, spine, neck, thorax, abdomen, lower extremity, upper extremity)			
0	701 (94)	112 (46)	
1	47 (6)	109 (45)	
>1	1 (0.1)	22 (9)	
Surgical repairs			
Lower extremity	11 (1)	74 (30)	
Upper extremity	35 (5)	39 (16)	
Other surgery (head, face, spine/neck, thoracic, abdominal)	3 (0.4)	43 (18)	
Hospital length of stay, median (IQR)	Not applicable	3 (1–6)	
Discharge location	Not applicable		
Home		217 (89)	
Transferred to another hospital		1 (0.4)	
Skilled nursing facility		9 (4)	
Inpatient rehab/designated unit		12 (5)	
Deceased		3 (1)	
Other		1 (0.4)	
Admitted to intensive care unit	Not applicable		
No		174 (72)	
Yes		62 (26)	
Unknown		7 (3)	
Case identification method			<0.0001
International Classification of Diseases code	211 (28)	180 (74)	
Text	538 (72)	63 (26)	

[a] Events were classified as hospitalized if they were admitted to an inpatient care unit beyond the emergency department for care of their injuries.
[b] Injured bystanders (not riding on vehicle) are not shown in helmet use data (n=9); 7 were non-hospitalized; 2 unknown hospitalization status.

On average, about 25 of the total injury cases each year occurred to MESA residents, with a range of 14 in 2016–2017 to 35 in 2013–2014 (Table 4). The average injury incidence rate was 313 per 100,000 snowmobiles registered in the MESA area over the study period, with a range from 248 per 100,000 in 2015–2016 to 374 per 100,000 in 2017–2018.

Table 4. Incidence of Snowmobile Injuries

Season	Injuries Among MESA Residents	Snowmobile Registrations Among MESA Residents	Injury Rate per 100,000 Registrants
2013–2014	35	10,486	334
2014–2015	32	10,065	318
2015–2016	23	9,262	248
2016–2017	14	4,802	292
2017–2018	20	5,341	374

Abbreviation: MESA: Marshfield Epidemiological Study Area.
Seventeen of the 42 total ZIP codes were excluded from MESA beginning in Oct 2016.

DISCUSSION

In previous studies, SRI data were collected from trauma registries,[13] EHR data,[23] death registries,[7,9] state databases (hospital discharge, injury surveillance),[16,24] voluntary reports of recreational activity injuries provided by health providers or victims to state agencies,[6,15] or a combination of these sources.[3-5,8,10,14,17] However, these data sources are limited due to the exclusion of less severe injuries, the method of case ascertainment, and reliance on passive reporting of SRIs.[6,12,17] Evaluation of mortality or severe injuries alone underestimate the full impact of the injuries on patients, their families, and health systems that provide care. In this study, since MCHS is an integrated health care system, we were able to abstract data from both inpatient and outpatient departments using a strategy combining ICD coding and text screening tailored to our EHR to provide a comprehensive summary of medically attended injuries.

We calculated an average annual injury rate of 313 per 100,000 registered snowmobiles among a geographically defined population-based cohort included in the study. This is likely a conservative estimate, as some with injuries may have sought care outside our health system and some registered snowmobiles may not have been used in a season, reducing the denominator at risk. The average number of snowmobiles registered annually in Wisconsin during 2013-2018 was 214,109. Assuming our injury rate to be representative of injury occurrence in the state, we would expect approximately 670 injuries statewide each season. The Wisconsin DNR recorded between 58 and 171 incidents involving injuries annually over a similar time period (2014-2018) or only between 10% and 20% of the total number of injuries we would expect given our data.[11] These discrepancies in injury reporting between health care organizations and state agencies represent an opportunity for future improvements in injury reporting and surveillance associated with recreational vehicle use.

Compared to other studies, our study showed fewer of the highest acuity injuries, such as spinal fractures and traumatic brain injuries (TBI), but showed similar presence of extremity and thoracic fractures. In our study, 16% sustained spine fractures, similar to the 21% found by Plog et al[14] but lower than 29% for Beilman et al[10] and 28% for Whiting et al.[8] TBIs, which are common in all-terrain vehicle and motorcycle crashes and previously noted in over a third of snowmobile injuries, [8,14] were also relatively rare in our study, with only about 8% of cases suffering this injury.We speculate that helmet use is at least partially related to mitigating the cold and wind experienced while snowmobiling; and where helmet use was assessed in our study, it was quite high, which may have reduced the number of both facial fractures and brain injury we observed. Despite having a robust neurosurgical service, we also speculate that our level II trauma status at our main referral hospital may have decreased the number of cases observed compared to level I trauma centers featured in other studies. In contrast to spinal fracture and TBI, thoracic injuries and lower extremity injuries in our hospitalized population were in line with observations from prior studies, while upper extremity injuries appeared to be slightly more common and were the most frequently fractured area among the outpatients.

The 1% fatality rate found in our study is also lower than previous studies[10,17] and we, along with other studies utilizing medical record data, may be limited by the inability to count those who were deceased prior to making it to care. We expect the Wisconsin DNR would receive more complete reporting of fatalities compared to underreporting expected for less severe medically attended snowmobile-related injuries. Fatality reports or death records would be an important addition to understanding the full scope of snowmobile injuries in the state.

While our study has many strengths, including a large number of cases included over the 5-year period and use of text searching to identify SRIs in the EHR, it has some limitations. Due to its retrospective nature, we relied on chart abstraction to provide details of medical care. Exact details of the crashes were difficult to obtain, as was data on helmet use—especially in the nonhospitalized population. We believe that patients seen in the outpatient setting are more likely to have a more focused assessment of their injuries versus the more comprehensive assessment of a trauma evaluation. This may have led to discrepancies in data collection between inpatient and outpatients, particularly with regard to helmet and alcohol use. Another limitation is exclusion of cases who sought care outside of our health system or died before arrival to a medical facility, but given the extensive network of regional facilities in our system, we likely captured most of the SRI injury cases that sought care in the service region. Though the denominator of our incidence calculation has the strength of including snowmobile registrations from a 24 ZIP code area where the majority of residents receive nearly all their care from our health system, the calculation is still quite

limited. We did not have access to direct identifiers for registrations to link our patients to registrations and develop a defined cohort at risk.

Since MCHS is an integrated health care system, we were able to abstract data from both inpatient and outpatient departments using a strategy combining ICD coding and text screening in our EHR. We propose that a similar approach could be enacted in other health care organizations to enhance injury reporting and surveillance of SRIs to better inform prevention efforts and staffing of rural trauma systems. While the acuity of injuries treated in the outpatient setting are not as high as those hospitalized, many still involved broken bones and were plaguing enough that patients sought care. The total number of injuries we found were significantly more than recognized through reports made to the Wisconsin DNR. All medically attended injuries, whether requiring a hospital stay or not, represent a potentially significant burden to the patient in terms of missed work and decreased quality of life due to pain or morbidity and burden to rural health care systems.

CONCLUSIONS

Using a combination search strategy of ICD codes and text searching to identify patient records from an integrated health care system, we were able to abstract SRI data from both outpatient and inpatient departments. We found the majority of patients suffering from SRIs (74%) sought treatment as outpatients and never sought treatment in the hospital. Currently available studies of SRIs focused on inpatients appear to have underestimated the number and burden of SRIs. Outpatients with SRIs differ significantly with regard to the types and severity of injuries compared with inpatients with SRIs. Our methods allowed us to examine a larger number of SRIs and identify the true number of SRIs in our health system. Further studies combining datasets from the other health systems in the state and statewide mortality records for patients who died before arrival to the hospital could elucidate the full statewide impact of SRIs in Wisconsin. This could lead to further education for snowmobile enthusiasts regarding the significance of SRIs and their prevention, as well as improved staffing for rural trauma systems.

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REFERENCES

1. Burakowski E, Magnusson M; Protect Our Winters; Natural Resources Defense Council. Climate impacts on the winter tourism economy in the United States. December 2012. Accessed January 31, 2019. https://www.nrdc.org/sites/default/files/climate-impacts-winter-tourism-report.pdf

2. Pierz JJ. Snowmobile injuries in North America. *Clin Orthop Relat Res.* 2003;(409):29-36. doi:10.1097/01.blo.0000057781.10364.c9

3. DeCou JM, Fagerman LE, Ropele D, Uitvlugt ND, Schlatter MG, Connors RH. Snowmobile injuries and fatalities in children. *J Pediatr Surg.* 2003;38(5):784-787. doi:10.1016/jpsu.2003.50167

4. Centers for Disease Control and Prevention (CDC). Injuries and deaths associated with use of snowmobiles--Maine, 1991-1996. *MMWR Morb Mortal Wkly Rep*. 1997;46(1):1-4.

5. Landen MG, Middaugh J, Dannenberg AL. Injuries associated with snowmobiles, Alaska, 1993-1994. *Public Health Rep*. 1999;114(1):48-52. doi:10.1093/phr/114.1.48

6. Centers for Disease Control and Prevention (CDC). Injuries associated with use of snowmobiles--New Hampshire, 1989-1992. *MMWR Morb Mortal Wkly Rep*. 1995;44(1):1-3.

7. Rowe B, Milner R, Johnson C, Bota G. Snowmobile-related deaths in Ontario: a 5-year review. *CMAJ*. 1992;146(2):147-152.

8. Whiting P, Rice C, Siy A, et al. Orthopaedic injuries from snowmobile accidents: a multi-centre analysis of demographics, injury patterns, and outcomes. *Eur J Orthop Surg Traumatol.* 2019;29(8):1617-1621. doi:10.1007/s00590-019-02514-3

9. Bakke HK, Wisborg T. Rural high north: a high rate of fatal injury and prehospital death. *World J Surg.* 2011;35(7):1615-1620. doi:10.1007/s00268-011-1102-y

10. Beilman GJ, Brasel KJ, Dittrich K, Seatter S, Jacobs DM, Croston JK. Risk factors and patterns of injury in snowmobile crashes. *Wilderness Environ Med.* 1999;10(4):226-232. doi:10.1580/1080-6032(1999)010[0226:rfapoi]2.3.co;2

11. Wisconsin Department of Natural Resources. Wisconsin recreational vehicle safety education & enforcement: annual program report. 2018. Accessed December 11, 2020. https://dnr.wi.gov/files/pdf/pubs/le/LE0203_2018.pdf

12. Wisconsin Department of Natural Resources. Wisconsin snowmobile safety & enforcement: 2016-2017 annual report. 2017. Accessed December 11, 2020. https://dnr.wi.gov/files/pdf/pubs/le/LE0203_2017.pdf

13. Shannon SF, Hernandez NM, Sems SA, Larson AN, Milbrandt TA. Pediatric orthopaedic trauma and associated injuries of snowmobile, ATV, and dirtbike accidents: a 19-year experience at a level 1 pediatric trauma center. *J Pediatr Orthop.* 2018;38(8):403-409. doi:10.1097/BPO.0000000000000838

14. Plog BA, Pierre CA, Srinivasan V, Srinivasan K, Petraglia AL, Huang JH. Neurologic injury in snowmobiling. *Surg Neurol Int.* 2014;5:87. doi:10.4103/2152-7806.134074

15. Wenzel FJ, Peters RA. A ten-year survey of snowmobile accidents, injuries, and fatalities in Wisconsin. *Phys Sportsmed*. 1986;14(1):140-149. doi:10.1080/00913847.1986.11708972

16. Skokan EG, Olson LM, Cook LJ, Corneli HM. Snowmobile injuries in Utah. *Acad Emerg Med.* 2001;8(12):1173-1177. doi:10.1111/j.1553-2712.2001.tb01135.x

17. Gabert T, Stueland DT. Recreational injuries and deaths in northern Wisconsin: analysis of injuries and fatalities from snowmobiles over 3 years. *Wis Med J.* 1993;92(12):671-675.

18. VanWormer JJ, Holsman RH, Petchenik JB, Dhuey BJ, Keifer MC. Epidemiologic trends in medically-attended tree stand fall injuries among Wisconsin deer hunters. *Injury*. 2016;47(1):220-225. doi:10.1016/j.injury.2015.09.012

19. Harris PA, Taylor R, Minor BL, et al. The REDCap consortium: building an international community of software platform partners. *J Biomed Inform.* 2019;95:103208. doi:10.1016/j.jbi.2019.103208

20. Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap)--a metadata-driven methodology and workflow process for providing translational research informatics support. *J Biomed Inform.* 2009;42(2):377-381. doi:10.1016/j.jbi.2008.08.010

21. Greenlee RT. Measuring disease frequency in the Marshfield Epidemiologic Study Area (MESA). *Clin Med Res*. 2003;1(4):273-280. doi:10.3121/cmr.1.4.273

22. Kieke AL, Kieke BA Jr, Kopitzke SL, et al. Validation of health event capture in the Marshfield Epidemiologic Study Area. *Clin Med Res.* 2015;13(3-4):103-111. doi:10.3121/cmr.2014.1246

23. Soininen L, Hantula L. Snowmobile accidents in Lapland. *Arctic Med Res.* 1992;51 Suppl 7:64-70.

24. Dempsey RL, Layde PM, Laud PW, Guse CE, Hargarten SW. Incidence of sports and recreation related injuries resulting in hospitalization in Wisconsin in 2000. *Inj Prev.* 2005;11(2):91-96. doi:10.1136/ip.2004.006205

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