

Unique Epidemiology of Spinal Cord Injury in Hawai'i: Wave-related Incidents

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Abstract

Spinal cord injury remains one of the most devastating forms of traumatic injury. The purpose of this study was to characterize the clinical characteristics of spinal cord injury patients and the geographic location where the injury occurred in the state of Hawai'i. Spinal cord injury cases from 2009-2017 were identified using the State Trauma Registry, which included demographics, mechanism of injury, and outcomes. In 1170 spinal cord injury cases, the second most frequent etiology was an ocean-wave related incident. Over half of wave related spinal cord injury occurred on ten beaches on four islands. Compared to other mechanisms, patients with wave related spinal cord injury were significantly less likely to be Hawai'i residents (15%), screen positive for alcohol (4%), or have an injury in the lower thoracic or lumbar region (4%). These patients were also less likely to die (1%) and more likely to be discharged to home (66%). Wave related incidents are a major cause of spinal cord injury in Hawai'i, disproportionately affecting visitors. Education focused toward middle-aged male visitors at beaches with moderate to severe shorebreak may reduce the incidence of injury.

Keywords

spinal cord injury, trauma, wave-related accidents, wave-related incidents

Abbreviations

SCI = Spinal cord injury
WRI = Wave related incidents

Introduction

Spinal cord injury (SCI) is a devastating form of nonlethal traumatic injury. Approximately 17,500 new cases occur annually in the United States. Tetraplegic survivors have more than a 50% reduction in life expectancy, and each injury incurs millions of dollars in added direct health care and living costs.¹ It is postulated that a majority of SCI in the United States could be prevented by adherence to existing public safety statutes.² This is based upon the epidemiology of SCI nationwide, with 38% resulting from motor vehicle crashes (MVC) and 14% caused by acts of violence.¹ However, the heterogeneous epidemiology of SCI mandates a data-driven approach and targeted prevention programs.³

In 2002, Chang, et al, described the occurrence and risk factors for water-sports related to cervical SCI in Hawai'i. Their five-year, retrospective study of 100 inpatients disclosed demographic differences between those injured by wave related accidents versus shallow water dives.⁴ In comparing the epidemiology of SCI from wave related incidents (WRI) and SCI

from non-WRI, the authors hypothesize that the demographic and geographic patterns of SCI from WRI are different from those of SCI from non-WRI.

Methods

Data from the State of Hawai'i Trauma Registry were reviewed for the period from 2009-2017. The State Trauma Registry, maintained by the Department of Health Injury Prevention Systems Branch, is a central repository to track patterns, treatment and outcomes of injured patients. All 9 state-designated trauma centers submit data which captures trauma team activations and admissions at each center. Patients with SCI seen at any other facility are transferred to a trauma center for admission.

SCI were identified by ICD9-CM diagnosis codes in the 806.0-806.9 and 952.0-952.9 for presentations from January 2009 through September 2015, and ICD10-CM diagnosis codes in the S14.0-S14.159, S24.0-S24.159, and S34-S34.139 from October 2015 through December 2017. Diagnostic codes were reviewed by 2 senior trauma surgeons and a state epidemiologist who concurred that they should capture all traumatic spinal cord injury diagnoses. Codes were assigned at either the initial or definitive care facility. Demographic and clinical data included age, sex, residency status, mechanism and location of injury, level and completeness of SCI, and discharge disposition. Causes of SCI were categorized by both the mechanism (eg, fall, motor vehicle crash) and intent of the incident, using ICD9-CM external cause of injury codes and ICD10-CM diagnostic codes. Injuries that were unintentional were grouped by mechanism, while those that were self-inflicted or caused by assaults were grouped by intent. Information from an open text narrative field was used to further identify injuries related to ocean activities. Wave related incidents (WRI) were defined as any mechanism of injury in which the surf played a factor, including board surfing, body surfing, body boarding, or incidents described as "tossed by a wave." SCI from dives were separated from WRI, since they were usually caused by diver impacts with hard surfaces and not related to surf (analogous to diving into a pool). WRI were compared to the four other most common causes of unintentional SCI, with data analyzed by chi-square for categorical and t-test for continuous data. All statistical analyses were conducted with JMP software, version 5 (SAS: Cary, NC), and significance determined at $P < .05$. This study was approved as exempt by the University of Hawai'i Institutional Review Board.

Results

A total of 1170 SCI cases from 2009-2017 were identified. Of these, 942 were categorized as “unintentional” and are the focus of this study. The most frequent causes of injury were falls (n=365, 31%), followed by WRI (n=323, 28%), car/truck crashes (n=153, 13%), motorcycle/moped crashes (n=62, 5%), being struck by objects or persons (n=44, 4%), and dives into the ocean (n=39, 3%) (Figure 1: Mechanisms of SCI). Specific activities included in WRI were board surfing (n=30, 9%), body boarding (n=82, 25%), body surfing (n=68, 21%), skim boarding (n=1, 1%), or being “tossed by a wave” (n=142, 44%) (Figure 2: Mechanisms of WRI).

The WRI were widely distributed across the islands, in contrast to SCI from falls, ocean dives, and motor vehicle crashes which mostly occurred on the most populated island of O‘ahu. The 323 wave related SCI occurred on at least 69 separate beaches in the state. (Beach location was not known for 33 (10%) of these SCI.) The 5 beaches with the highest number of wave related SCI were on 4 islands. Despite this overall geographic dispersion, 10 beaches accounted for 59% of all wave related SCI (Figure 3). Forty-six percent of the wave related incidents occurred on the island of Maui, including 94 (29% of the total) along the coast from Kihei south to Makena.

Patient demographics differed markedly across the 5 main mechanisms of SCI (Table 1). Males comprised a high majority of patients injured from wave related incidents (81%) and diving into the ocean (92%). With the exception of those injured in motor vehicle crashes, each group was significantly different in mean age, with the youngest distribution for SCI from ocean dives and the oldest for falls. Forty-three percent of those injured by falls were 65 years or older, compared to only 14% of the 577 patients injured by the other 4 most common mechanisms (data not shown). Only 15% of those injured by waves were Hawai‘i residents, a significantly lower proportion than any of the other categories. Seventy-four percent of the non-residents injured by waves were from other US states.

Patients suffering wave related SCI were the least likely to have a positive blood alcohol level, and were least likely to be tested (Table 2). Twenty-nine percent of those injured in car/truck crashes, and 23% of those injured in ocean dives tested positive for alcohol, versus 4% of those with wave related SCI. Patients injured in motor vehicle crashes were also most likely to screen positive for cannabis (18%), while those injured by waves were least likely. These observations were consistent whether patients who were not tested were included or excluded.

Characteristic	Wave Related Incidents (WRI) (n=323)	Dives into the ocean (39)	Falls (365)	Car/Truck Occupants (153)	Motorcycle/Moped Riders (62)	P-value, WRI vs Other Main Causes
Year						
2009 (total n=104)	26	1	20	15	12	
2010 (n=104)	35	9	21	15	4	
2011 (n=116)	30	3	28	18	6	
2012 (n=147)	43	10	39	19	4	
2013 (n=159)	44	9	52	22	6	
2014 (n=143)	42	0	59	22	3	
2015 (n=128)	39	2	37	11	13	
2016 (n=167)	45	5	58	21	8	
2017 (n=102)	19	0	51	10	6	
County of Injury						
Hawai‘i	82 (25%)	5 (13%)	69 (19%)	49 (32%)	20 (32%)	.61
Honolulu (island of O‘ahu)	60 (19%)	23 (59%)	226 (62%)	75 (49%)	28 (45%)	<.001
Kaua‘i	33 (10%)	3 (8%)	19 (5%)	9 (6%)	3 (5%)	.011
Maui	148 (46%)	8 (21%)	51 (14%)	20 (13%)	11 (18%)	<.001
Demographics						
Males	261 (81%)	36 (92%)	265 (73%)	87 (57%)	54 (87%)	.002
Age, Years (mean + SD)	52 (+13)	30 (+12)	58 (+22)	43 (+21)	41 (+17)	>.05
Residence						
State of Hawai‘i	49 (15%)	20 (51%)	320 (88%)	143 (93%)	58 (94%)	<.001
Other US State	202 (63%)	14 (36%)	38 (10%)	6 (4%)	4 (6%)	<.001
Foreign Country	72 (22%)	5 (13%)	7 (2%)	4 (3%)	0 (0%)	<.001

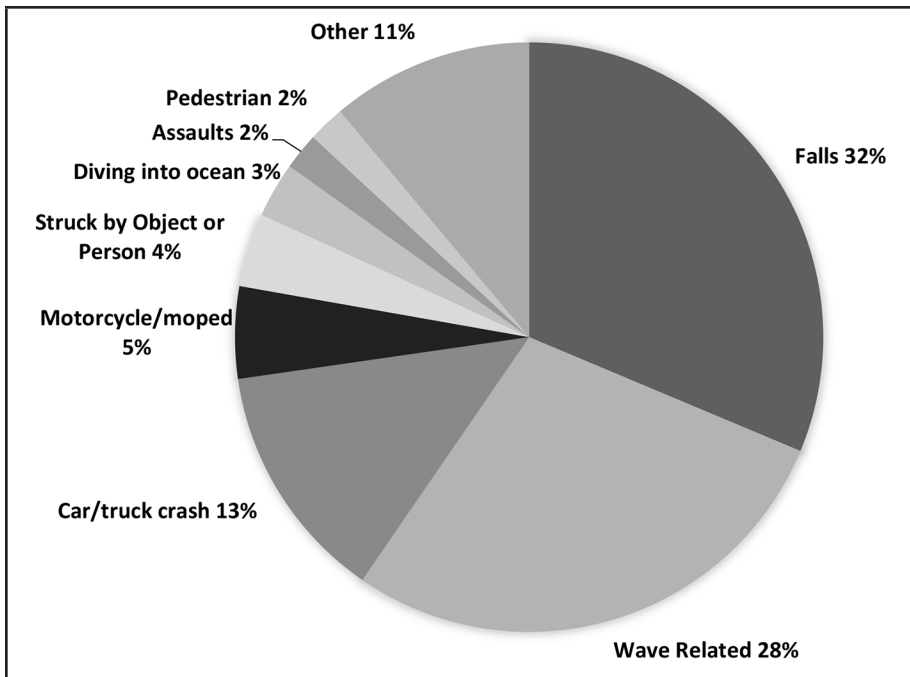


Figure 1. Mechanisms of Spinal Cord Injury in Hawai'i

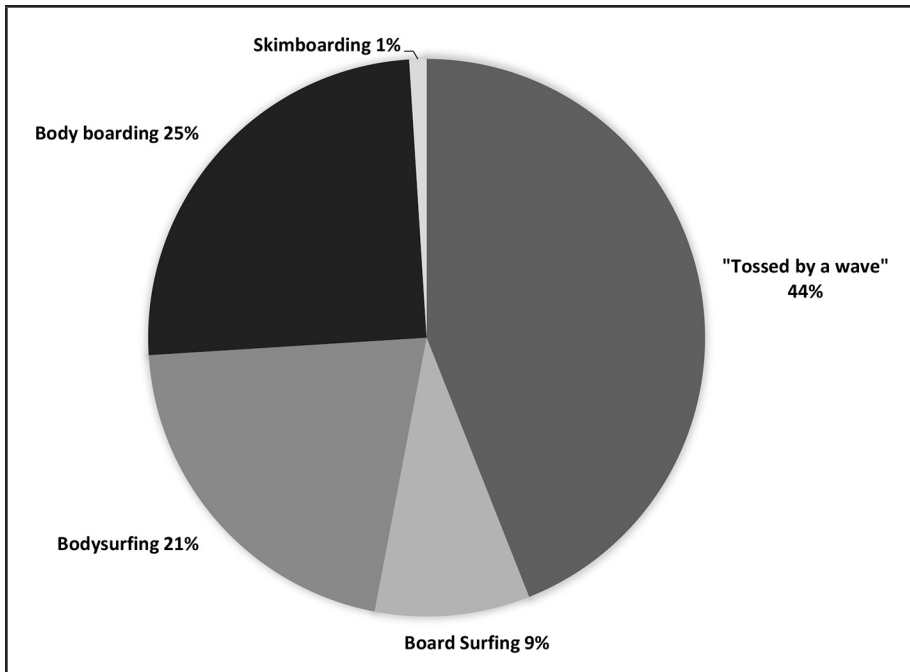
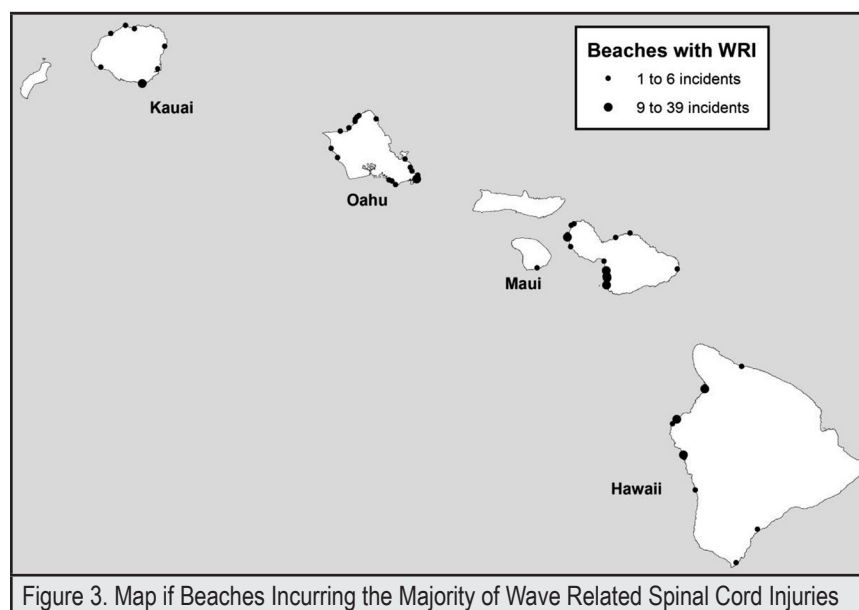


Figure 2. Mechanisms of Wave Related Incidents in Hawai'i



Characteristic	Wave Related Incidents (WRI) (n=323)	Dives into the ocean (39)	Falls (365)	Car/Truck Occupants (153)	Motorcycle/Moped Riders (62)	P-value, WRI vs Other Main Causes
Alcohol Status						
Not Tested	155 (48%)	9 (23%)	104 (28%)	31 (20%)	13 (21%)	<.001
Tested, Negative	156 (48%)	21 (54%)	188 (52%)	77 (50%)	37 (60%)	.26
Tested, Positive	12 (4%)	9 (23%)	73 (20%)	45 (29%)	12 (19%)	<.001
Cannabis Status						
Not Tested	207 (64%)	17 (44%)	165 (45%)	59 (39%)	18 (29%)	<.001
Tested, Negative	104 (32%)	19 (49%)	172 (47%)	69 (45%)	31 (50%)	<.001
Tested, Positive	12 (4%)	3 (8%)	28 (8%)	25 (16%)	13 (21%)	<.001
Anatomic Location of SCI*						
C1-C4 Level	159 (49%)	14 (36%)	165 (45%)	62 (41%)	18 (29%)	.032
C5-C7 Level	158 (49%)	23 (59%)	112 (31%)	47 (31%)	12 (19%)	<.001
T1-T6 Level	17 (5%)	1 (3%)	41 (11%)	10 (7%)	10 (16%)	.013
T7-T12 Level	7 (2%)	2 (5%)	32 (9%)	8 (5%)	10 (16%)	<.001
Lumbar	7 (2%)	3 (8%)	49 (13%)	19 (12%)	12 (19%)	<.001
Complete Lesion of Spinal Cord	28 (9%)	10 (26%)	48 (13%)	24 (16%)	12 (19%)	.004
Fractures of Vertebral Column	135 (42%)	34 (87%)	196 (54%)	88 (58%)	40 (65%)	<.001
Final Discharge Status of Survivors						
Home	214 (66%)	18 (46%)	123 (34%)	69 (45%)	19 (31%)	<.001
Skilled Nursing	19 (6%)	4 (10%)	82 (22%)	27 (18%)	9 (15%)	<.001
Transferred to Hawai'i Hospital	36 (11%)	5 (13%)	31 (8%)	12 (8%)	7 (11%)	.27
Transferred Out of State	17 (5%)	4 (10%)	4 (1%)	1 (1%)	1 (2%)	.003
Rehabilitation	33 (10%)	8 (21%)	90 (25%)	32 (21%)	16 (26%)	<.001
Died	4 (1%)	0 (0%)	35 (10%)	12 (8%)	10 (16%)	<.001

*Some patients suffered injuries at multiple anatomic locations.

Cervical level of spinal cord injury was significantly more frequent with a wave related mechanism. Injuries at the C1-C4 level were most common among patients injured by waves (49%), while SCI in the C5-C7 level were most common among those injured by dives into the ocean (59%). Injuries in the T7-T12 region were relatively uncommon in these 2 groups of patients, and only 2% of those injured by waves had SCI in the lumbar region. Thirteen percent of the 942 patients suffered a complete lesion of the spinal cord. This proportion was highest for those injured by ocean dives or motorcycle/moped crashes.

Fractures of the vertebral column were significantly higher among those injured by dives into the ocean compared to any other group of patients ($P < .0001$). Compared to the other 4 main etiologies, patients with wave related SCI had generally favorable discharge dispositions. Two-thirds were discharged home, and the mortality rate was significantly lower than that for the other 619 patients (1% vs 9%, respectively).

Discussion

The incidence of SCI in Hawai'i in recent years has exceeded the national rate, peaking in 2016 with approximately 83 cases per combined 1 million resident and visitor population (54% higher than the national average).^{3,6} The causes of SCI in Hawai'i are significantly different from the rest of the nation where automobile crashes, falls, gunshot wounds, motorcycle crashes, and diving accidents predominate.^{3,6} Whereas Tyroch and colleagues highlighted the frequent incidence of SCI among individuals breaking the law,² that is not the case in Hawai'i. Consequently, law enforcement activity has a lesser role in SCI prevention in Hawai'i.

A large proportion of Hawaii's SCI occur in the ocean, with WRIs as the primary ocean-related cause. Hawai'i has a large number of beaches with the potential to experience moderate to severe shorebreak. The degree of shorebreak depends upon several factors including topography, wind, wave, and weather conditions. Though Hawai'i has more than 350 beaches, with 58 of them lifeguarded, injuries were clustered on 10 beaches which host a minority of beachgoers.^{7,8} This analysis is limited by the lack of detailed information regarding the number of beachgoers at the date and time of SCI, which precludes accurate calculation of the relative risk of injury at a single beach. However, the geographic clustering of injury (Figure 3: Map of Beaches Incurring WRI) supports prior research citing shorebreak as a major precipitating factor.^{4,9}

Classic wave related SCI displays a distinct pattern of injury: low incidence of unstable fracture, incomplete central cord injury, and isolation to the cervical spine.¹⁰ A large body habitus and pre-existing spinal stenosis may also predispose an individual to injury.^{4,9} Due to the rare association of low thoracic or lumbar injury with wave related accidents, in contrast to other mechanisms of SCI, imaging of the thoracolumbar spine may not be

necessary in the patient who presents with a wave related SCI without symptoms of thoracolumbar injury.

Limitations of this study include a reliance on retrospective analysis of a statewide trauma data base, lacking patient-specific information on the classification of SCI, functional outcome and economic impact. In addition, as this study focuses solely on spinal cord injury, it does not capture the patients who may have suffered incapacitating bony or ligamentous injury without spinal cord injury. The data set does not permit a controlled, multivariate analysis of the prognosis of wave related SCI versus other mechanisms. However, based upon univariate analysis of the discharge dispositions of patients with wave related SCI (rare mortality, two-thirds return from the hospital), which postulates a more favorable prognosis in this group. This may be related, in part, to the lower incidence of fractures and complete cord injury with wave related SCI.

The data confirm prior studies by Chang, et al,⁴ and Robles, et al,⁹ that middle-aged male visitors are at highest risk for this mechanism of injury. Despite this knowledge, the incidence of wave related SCI rose at a steeper rate than tourism. Over the period from 2009-2016, visitor days increased by 37% while the number of wave related SCI increased by 73%.¹¹ Social media influence (eg, photos of President Barack Obama bodysurfing), marketing and infrastructure enhancements which increase popularity, and access to more dangerous, isolated beaches likely contributed to the rising incidence of wave related SCI.¹² The dip in wave related SCI in 2017 was an encouraging finding (Table 1). Continued data collection is necessary to determine if this is a reliable trend.

Patients with wave related SCI had a lower prevalence of testing positive for alcohol or cannabis compared to other mechanisms of injury. The fact that they were also less frequently tested may reflect the attending physician's lower degree of suspicion for intoxication, based on negative histories and absence of symptoms of intoxication. This lower prevalence of substance use suggests that those suffering wave related incidents are not prone to risky behavior. Visitors' lack of knowledge regarding ocean hazards is common, and a major predisposing factor to injury.¹³ Signs are highly visible on most beaches but may have limited impact.¹⁴ Recent injury prevention strategies have included web based applications to advise beach goers of current ocean conditions (hawaii beachesafety.com), and addition of lifeguard coverage to one unpatrolled high-risk beach. More resource intensive, targeted individual preventive actions by lifeguards may be needed to reduce wave related injuries.¹⁵ A successful intervention that is attributed with the reduction of ocean related injuries, including SCI, was the relocation of lifeguard towers to specific locations of the most serious injuries. Concurrently, lifeguards were trained to use a specific script when performing public contact/preventive actions. The script includes giving beach patrons information about alternative, nearby lifeguarded beaches that do not have

the powerful shorebreak associated with SCI incidents. This intervention has resulted in a 23% reduction in incidence rate over a 5-year period at 1 beach. (Bridget Velasco PT, MPH, email communication, March 6, 2017.)

The decline in wave related SCI in 2017 was encouraging. Focus for future research includes collection of more recent data to determine if this decline continues, and geographic analysis to explore links to prevent injuries.

Conclusions

Wave related incidents are a common cause of SCI in Hawai'i, and disproportionately affect visitors to Hawai'i. Patients who present with a wave related incident should be screened carefully for evidence of cervical SCI. Education may be an effective injury prevention tactic, aimed at those at highest risk for injury -- middle-aged male visitors who use beaches with high grade shorebreak.

The views expressed are those of the authors and do not necessarily represent the official views of the Queen's Medical Center or the Hawai'i State Department of Health.

Conflict of Interest

None of the authors identify any conflict of interest.

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