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# Traumatic Spinal Injury Associated with All-Terrain Vehicle (ATV) Accidents: A 10-Year Retrospective Analysis of the Coachella Valley

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## ABSTRACT

**Objective:** The use of all-terrain vehicles (ATVs) and associated injuries have significantly increased in the last decade. This study aimed to determine the frequency of ATV-associated spinal cord injuries (SCIs) in the Coachella Valley, California, and provide recommendations for data reproducibility in other areas with a similarly substantial level of ATV usage and injuries.
**Methods:** This retrospective analysis included data obtained through screening the trauma database of a level II trauma center for ATV-related injuries between January 1, 2010 and January 1, 2020.
**Results:** Our data suggest that more than one-third of patients admitted to the trauma center over a 10-year period suffered from spinal injury. Injuries to the spine were further categorized as including the spinal cord (radiographically or clinically) or only including the bony or ligamentous elements of the spine. Injury was more common in men and predominantly located in the thoracic spine. Injuries such as epidural hematoma, vertebral artery, and cord contusion were common, with many patients requiring neurosurgical intervention.
**Conclusion:** Highlighting the implicit dangers of ATV accidents on the spine could help identify outcomes and variables predictive of spinal injuries and spinal cord injuries necessary for patient management. Additionally, our study sets the framework by which legislating bodies could replicate the study for proper legislation and recommendations that may help prevent such injuries.

**Keywords:** All-terrain vehicles; Spinal fracture; Spinal cord injury; Off-road motor vehicles

## INTRODUCTION

An all-terrain vehicle (ATV) is defined by the United States Consumer Product Safety Commission as a motorized, off-highway vehicle with a seat designed to be straddled by the operator, handlebars for steering control, and designed to travel on 3 or 4 wheels.[10)] First introduced to the United States markets in 1970, ATVs quickly gained popularity for recreational use, climbing from an estimate of 400,000 ATVs in use in 1985 to 4.2 million by

**Conflict of Interest**
The authors have no financial conflicts of interest.

2000.[12] However, as ATV-related mortalities similarly trended upward, the associated risk was quickly recognized, leading the U.S. Consumer Product Safety Commission (CPSC) to sue ATV manufacturers in the 1980s.[12] This resulted in the "1988 Consent Decrees," which temporarily decreased the mortality rate, however expired in 1998. Following this expiration, the enforcement of ATV regulations was relegated to individual states.[12] Current efforts have proven largely ineffective, with an estimated 81,800 hospital emergency department (ED) visits involving ATV-related injuries in the United States in 2018.[20] Of these injuries, the diagnoses ranged from strain/sprains (11%) and lacerations (10%) to fractures (30%) and internal organ injuries (9%).[20] In addition to the high number of ATV-related injuries, the Consumer Product Safety Commission reported 15,250 ATV-related fatalities between 1982 and 2017 in the United States.[20] With 694 fatalities, the state of California was amongst the top 4 states with the highest number of recorded deaths, falling closely behind Texas (n=773), Pennsylvania (n=702), and West Virginia (n=698).[20]

Despite the widespread recognition of what some consider to be an ATV-related epidemic, California's safety regulation efforts remain limited. On January 1, 2013, the state began requiring that all ATV operators and passengers wear safety helmets.[1] However, in 2015 the law was amended to mandate helmet use only when operating on public land.[2] While there are laws mandating the use of restraints, such as seatbelt/shoulder belt or safety harness, when operating an recreational off-highway vehicle (ROV), there are no laws currently mandating the use of restraints when operating an ATV.[2] In addition to legislative efforts to reduce potential injuries when operating ATVs on public land, the extent to which ATV riders obey mandated safety laws remains a barrier to preventing injuries. A survey of 3,100 adolescents who had operated ATVs found that 81% had been on a public road, and 60% reported never or almost never wearing a helmet.[6] This suggests that in addition to legislative efforts, increased education to improve risk awareness may be useful in reducing unsafe behaviors in riders and operators.

There is extensive literature discussing age and sex related trends in all-terrain vehicle-related injuries, however discussion of specific diagnostic outcomes and the effectiveness of safety precautions remains limited. A database search of the Kids' Inpatient Database (KID) from 1997 to 2006 revealed a 467% increase in the number of ATV-related spinal injuries over the 9-year period, however this study was limited by age range.[16] The primary objective of this paper is to determine the frequency of ATV-associated spinal injuries through multiple age groups. A secondary objective is to evaluate the impact of restraint use on clinical outcome to determine the effectiveness of rider safety precautions. Data was obtained through a trauma database search for the International Classification of Diseases, 10th revision (ICD-10) code of ATV accidents from a regional level 2 trauma center in Palm Springs, California, which serves as the only trauma center within the 8,000 square mile district of "Coachella Valley."

## MATERIALS AND METHODS

A retrospective study was conducted utilizing the Trauma Registry database of a level II trauma center to screen for ATV-related injuries between January 1, 2010 and January 1, 2020. Patients of age 18 or older with acute spinal cord and/or spinal column injury secondary to ATV use were included in this study. The resultant spinal injuries were categorized as fracture, dislocation (including perched or jumped facets), destabilizing ligamentous injury without bony injury, extracranial vertebral artery (VA) injury, traumatic spinal epidural hematoma, and spinal cord injury (SCI) ranging from contusion to transection. Regarding SCI, we specifically focus on clinical SCI which defines patients that have a neurological deficit secondary to their SCI. This is different from patients with radiographic findings such as cord contusion that do not co-exist with any neurological deficits.

For records from 2016–2020, ICD-10-Clinical Modification code V86 was used, capturing occupants and drivers of ATVs. For data 2010–2015, the Trauma Registry was queried for keyword "ATV" in the "Cause of Injury" data field.

Of the original 892 records, 225 patients were excluded due to non-ATV mechanism of injury (including non-ATV off-road vehicles such as dirt bikes, motorcycles, golf cart injuries and injuries secondary to loading ATVs not in operation at that time), with one record excluded as a duplicate entry. All pertinent demographic, clinical and radiographic information was collected and analyzed. The information was analyzed using Microsoft Excel and statistical analytics were tabulated.

## RESULTS

A total of 666 patients were identified with an ATV-related injury in the aforementioned 10-year period. Of those, 228 were diagnosed with a spinal column injury or clinically-represented SCI. The prevalence of spinal injury was therefore 34% (**FIGURES 1** & **2**). Of those patients with spinal injuries, 12 were found to have an injury specifically to the spinal cord resulting in a prevalence of SCI of 1.8%. Regardless of injury specification, the predominant demographics were males (72%) with a median age of 38 (interquartile range [IQR], 26–49) calculated using $\chi^2$ and student's t-tests (**TABLE 1**, **FIGURES 1** & **3**).

Overall, the spinal injuries varied in number and classification; however, compression fractures were most common with diagnosis in 103 patients with a prevalence of 45% among spine injuries (**TABLE 2**). Transverse process (TP) fractures were the second most common and seen in 96 (42%) patients. The median number of transverse processes involved was 2 (IQR, 1–3). The median number of spinous processes involved was 2 (IQR, 1–3). The thoracic

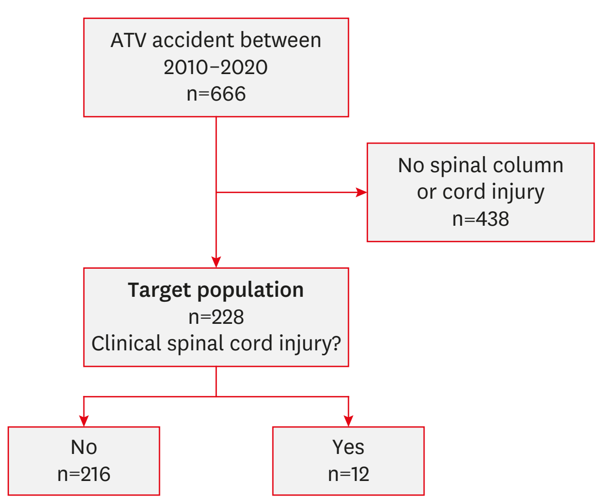


**FIGURE 1.** Trauma database results for our single institution.
ATV: all-terrain vehicles.


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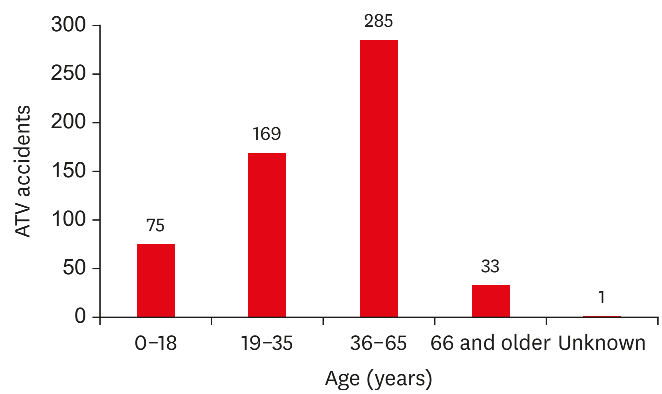


**FIGURE 2.** Age of patients reporting to the institution for ATV-related spinal injury.
ATV: all-terrain vehicles.

**TABLE 1.** Summary of demographic, radiographic, and clinical findings stratified by patients having clinical or no clinical SCI

| Variable | Clinical SCI (n=12) | No clinical SCI (n=216) | *p*-value |
|---|---|---|---|
| Sex (male) | 8 (66.7) | 155 (71.8) | |
| Age (years) | 45 [34–66] | 38 [26–49] | 0.058 |
| VA injury | 3 (25.0) | 5 (2.3) | <0.0001 |
| Epidural hematoma | 2 (16.7) | 9 (4.2) | 0.04 |
| Cord contusion | 10 (83.3) | 11 (5.1) | <0.00001 |
| Restraints | 3 (25.0) | 39 (18.1) | 0.48 |
| Operative management | 9 (75.0) | 34 (16.7) | <0.00001 |
| Predominant ASIA grade | A | E | |

Values are presented as number of patients (%) or median [interquartile range].
SCI: spinal cord injury, VA: vertebral artery, ASIA: American Spinal Injury Association.

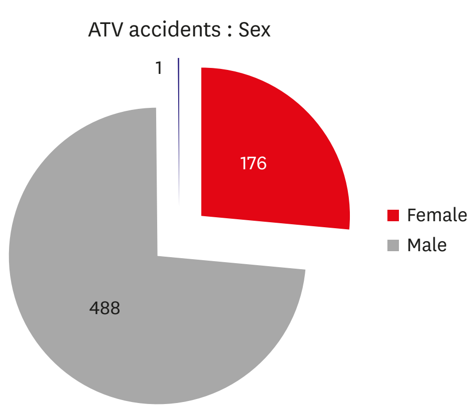


**FIGURE 3.** ATV accidents resulting in an ED visit during a 10-year period, patient sex analysis.
ATV: all-terrain vehicles, ED: emergency department.

spine was the most common region of injury with 40% of bony injuries occurring within the thoracic spine. Patients with SCI had higher rates of cervical spine injury. Fifty-five percent of patients with SCI were diagnosed with a fracture of the cervical spine as opposed to 23% of patients without SCI. 59 (26%) patients had multi region involvement of the spine. Additionally, patients with SCI had ligamentous injury as the most frequently reported injury to the vertebral column with diagnosis in seven (58%) patients. Ligamentous injury was noted in 18 patients, with seven patients (39%) in patients with SCI.

**TABLE 2.** Fracture types (n=228)

| Type of injury* | Number of patients (%) |
|---|---|
| Transverse process fracture | 96 (42.1) |
| Spinous process fracture | 42 (18.4) |
| Facet fracture | 27 (11.8) |
| Pedicle fracture | 14 (6.1) |
| Lamina fracture | 23 (10.1) |
| Pars fracture | 5 (2.2) |
| Lateral mass fracture | 19 (8.3) |
| Compression fracture | 103 (45.2) |
| Chance/Teardrop fracture | 7 (3.1) |
| Burst fracture | 30 (13.2) |
| Displacement/dislocation | 1 (0.4) |
| Dens fracture | 4 (1.8) |
| Atlanto-Occipital dislocation | 2 (0.9) |
| Atlas (C1) injury | 8 (3.5) |
| Ligamentous injury only | 18 (7.9) |

*Injuries are reported as number and prevalence among spinal injuries.

In SCI patients, VA injury was noted in three (25%) patients; by comparison, VA injury occurred in five (2%) patients without SCI, ($p$<0.0001) (**TABLE 1**). Two (17%) patients in the SCI group presented with epidural hematoma versus nine (4%) patients in the non-SCI group ($p$=0.04) (**TABLE 1**). Conversely, on imaging cord contusion was noted in 10 (83%) SCI injured patients, while 11 (5%) of those without SCI were reported to have cord contusion on imaging. American Spinal Injury Association (ASIA) grading was another factor that varied amongst the SCI and non-SCI, with A, and E being most common, respectively (**FIGURE 4**). SCI without radiographic evidence (SCIWORA A-E) refers to clinical manifestations of SCI ASIA grade A through E without radiographic evidence. Of the 12 patients with clinical SCI patients, 75% went to the operating room (OR) for unstable spinal injury and spinal cord compression; whereas 16% of those without SCI went to the OR (**TABLE 1**). There were no reported deaths during hospitalization.

The Trauma Registry database was also queried for patient use of restraints (such as a seatbelt or harness) at the time of ATV accident. Of the 12 patients with SCI, three (25%) were found to be wearing restraints. All 3 patients wore both shoulder and lap restraints. Four patients (33%)

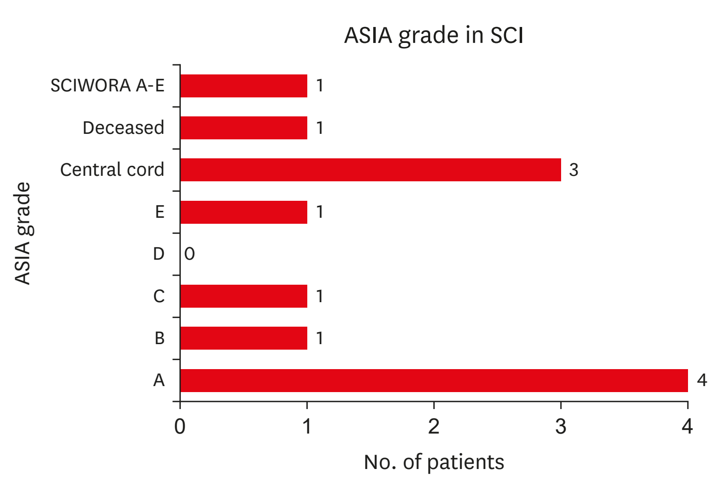


**FIGURE 4.** ASIA grading of spinal cord injuries in our patient selection.
ASIA: American Spinal Injury Association, SCI: spinal cord injury.


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**TABLE 3.** Restraint related findings

| Variable | Clinical SCI (n=12) | No clinical SCI (n=216) |
|---|---|---|
| Use of restraints | | |
| Yes | 3 (25.0) | 39 (18.1) |
| No | 4 (33.3) | 54 (25.0) |
| Unknown | 5 (41.7) | 123 (56.9) |
| Restraint type | | |
| Lap only | - | 1 (2.6) |
| Shoulder only | - | 16 (41.0) |
| Both | 3 (100.0) | 22 (56.4) |

Values are presented as number (%).
SCI: spinal cord injury.

reported not wearing any form of restraints, and 5 (42%) were unidentified (see **TABLE 3**). In the non-SCI group 39 patients (18%) were found to be wearing restraints. Of the 39 patients, 22 (56%) were found to be wearing both lap and shoulder restraints, 16 (41%) with just shoulder restraints, and one (3%) with lap only. Additionally, 54 (25%) non-SCI patients reported not wearing any form of restraint during their accident.

## DISCUSSION

As the popularity of ATVs has increased, so too has their destructive potential. According to the 2018 Annual Report of ATV-related Deaths and Injuries, estimated ATV-related ED-treated injuries mostly affected the arm (29%), head or neck (29%), leg (22%), and torso (21%).[21] In our retrospective review of patients experiencing ATV accidents, spinal column or clinical SCI was highly prevalent, affecting over one-third of patients admitted to our institution in a 10-year period. This was significantly greater than the prevalence seen by Sawyer et al.[16] in a review of the KID (1997, 2000, 2003, and 2006), which reported spinal injury in 7.4% of children and adolescents hospitalized for ATV-related injury. In another retrospective review of 33 patients with neurological injuries associated with ATVs, spinal injuries were seen in 30% of patients, exceeding the 9% reported by Mangano et al.[9] and Russell et al.[13]

Injuries affecting the spinal column in our study's population included fracture and ligamentous injury. Pollack and Pollack[11] conducted a retrospective review of another southern California community hospital, noting that spine fracture represented 6.6% of the total 836 fractures diagnosed in 1,259 patients who presented to the ED for ATV injury. Richards and Loder[12] utilized the national electronic injury surveillance system database and found that from 2002–2015, 25.9% of ED visits related to ATV-related injury was for any bone fracture, with spine fracture comprising 6.4%.[12] Shults et al.[17] reported a similar fracture rate of 28% in a study that used a synonymous method, but limited the patient population to less than 16 years old. Kute et al.[8] previously reported that the spine was involved in 4.4% of total fractures seen in ATV injury over an 11-year period, representing a 4-fold increase over this time. ATV roll over, one of the most common mechanisms of ATV-related injury, is associated with a significant increased chance of spine fracture.[7] Hence, the contemplation of how to reduce injuries is challenging given restraints might not assist the passenger in rollover scenarios, or could even cause more harm. Sawyer et al.[16] echoed the notion of very high prevalence of spinal injuries secondary to ATV accidents finding that among 208 patient admissions for ATV-related spinal injuries, 93% had spinal fracture.


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Amongst the fracture classifications seen in **TABLE 1**, compression fractures were the most numerous, followed by transverse process fractures, spinous process, and burst fractures. Sawyer et al.[15] similarly reported in a review of 29 children with ATV-related spine fractures the most common fracture types were transverse process (28%), compression (21%), and burst (9%). Notably, although spine fractures comprise 1-2% of pediatric fractures, they occur in up to 7% of ATV-related injury to KID, indicative of the high energy nature of ATV accidents.[15] Jordan et al.[7] also conducted a retrospective study on 456 pediatric ATV-related injuries, utilizing the AOSpine classification system. They found that 36 patients had one or more thoracolumbar spine fractures (7.9%), in which A0 (nonstructural injury) like transverse process or spinous process fracture were the most common, followed by A1 wedge compression fracture.[7] Sanfilippo et al.[14] reviewed a database of 8,020 spine consults from 1993–2007 and found that among 32 of 36 spinal injuries related to ATV accidents, 16 (50%) were axial compression or burst fracture.

With respect to injury location, we found that the thoracic spine was affected most (40%), and over 25% of our study population had multi-region spine injury. Sanfilippo et al.[14] similarly found that most spine injuries secondary to ATV use occurred in the thoracolumbar spine (64.3%), while one-third occurred in the cervical spine. The observation of multiple spine fractures is indicative of the high energy accidents often associated with ATV-induced injury. This was similar to Sawyer et al.[15] who also reported thoracic spine as the most common region affected (42%), followed by lumbar (32%), and cervical (13%). These authors noted that 45% of the cohort had multiple spine injuries, and when multiple fractures were present, continuous levels were injured in 69% of the cohort. This rate was higher than what was reported by Carreon et al.[3] who reviewed cases of 137 children with spine injuries and found 34% multilevel contiguous and 7% multilevel noncontiguous fractures. When stratifying for age, Sawyer et al.[15] saw that those older than 16 years were more likely to suffer from thoracic spine fracture ($p$=0.008), while lumbar fracture was more common in the younger population ($p$=0.01). The authors postulated that the discrepancy found between these age groups was due to the more adult-like spine characteristics seen in those older than 16 years such as decreased ligament laxity, more vertical facets, and absence of growth centers. Jordan et al.[7] also reported that 86.1% had multiple levels of fracture, with most at contiguous levels. Of the four translational injuries observed in this cohort, 3 of the 4 occurred at the thoracolumbar junction. In contrast to our findings, but similar to those found by Richards and Loder,[12] the majority of injuries occurred in the lumbar spine, with a secondary peak in the mid-thoracic spine. Additionally, >10% of patients with thoracolumbar injury also had concomitant cranio-cervical junction or cervical spine fracture, emphasizing the importance of providers remaining cognizant of other injuries after one is identified.

Patient demographics in our study included majority male adults with ages ranging from 36–65 and median age of 38. This differed from most prior studies which have focused largely on pediatric populations due to adolescents being disproportionately affected. Sanfilippo et al.[14] found a similar distribution of ages for ATV spine injury with age average of 29.4 years and rage of 14–59 years, while other studies have described a mean age of 26 with a standard deviation of 11.[11,14] With the inclusion of both adults and adolescents, Finn and MacDonald[5] reported that 42% of patients with neurological injury secondary to ATV use were still under 20 years old. Age is an important factor to consider given risk factors affecting younger populations of patients. These include lack of motor coordination, physical strength limitations, increased risk-taking behavior, less experience in operating ATVs, and poor judgement. Despite laws restricting use, from 1982–2018, CPSC staff has received reports pertaining to 3,353 ATV related fatalities of children below the age of 16 years old, 21% of the


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total ATV fatalities.[21] Other studies have also found the majority of ATV-related spine injury disproportionately affects males.[5,11,16] Interestingly, Sawyer et al.[15] elucidated that although males in their study were more commonly involved in ATV accidents, females were more likely to suffer a spine injury compared to males at a rate 10.1% vs 6.7% respectively. They postulated that this may be due to vehicle-rider mismatch, leading to circumstances where the rider is less able to prevent roll over and results in more crush injuries.

Among the patients in our cohort with spinal injuries, the number of patients affected by clinical SCI was relatively low at 12, representing a prevalence of 1.8%. When comparing factors associated with SCI, those with SCI were more likely to present with radiographic findings of epidural hematoma ($p$=0.04), cord contusion ($p$<0.00001), and treated with operative management ($p$<0.00001). ASIA grade A (complete cord injury) was most common in the SCI group. Shoulder and lap restraint use was noted in both groups, and although a larger percentage of those with SCI utilized restraints, the difference between the 2 groups did not reach statistical significance, and did not seem to play a major role in distinguishing patients who suffered from neurological deficits from SCI. Interestingly, ligamentous injury was highly associated with clinical SCI along with injury to the vertebral arteries. Injury to the cervical spine was more common in SCI patients further supporting proper protection and clearance of the C-spine while triaging ATV patients. Sawyer et al.[16] reported that in the 2006 KID, 14 patients (7%) had SCI, with the cervical spine being the most affected (50%). Sanfilippo et al.[14] described SCI that resulted in at least a temporary incomplete neurological deficit in 24 of 36 patients, including 11 with complete neurological deficit, 5 with central cord injury, 5 with transient paraplegia, and 1 with conus medullaris syndrome. Smith et al.[18] found that spine injuries in their cohort were generally not associated with neurologic deficits, reporting 26 (12.5%) without vs 4 (1.9%) with neurologic deficit. Other studies have reviewed several cases of SCI as a result of ATV injury affecting the cervical and thoracic cord, resulting in quadriplegia, paraplegia, or severe impairment in patients as young as 7 years old.[9,11,13,19]

The American Academy of Orthopaedic Surgeon (AAOS), American College of Surgeons, American Pediatric Surgical Association Trauma Committee, and American Academy of Pediatrics have each published statements reflecting the implicit dangers of ATV use.[12] Each of these have written in favor of limiting ATV use to those 16 years of age and older. Additionally, several prominent individuals have recommended licensing prior to use. Even with such laws, the effectiveness of legislation remains in question. Sawyer et al.[15] reported that 48% of the patients they studied were younger than 16 years, under the minimum recommended age set out by the AAOS. Upperman et al.[22] studied ATV-related mortality and found the states which had the highest pediatric mortality rate did not have significant differences regarding laws pertaining to minimum age, helmet use, or ATV use on roads.[4] Furthermore, other studies have shown that nearly half of injured children in ATV accidents had been in violation of regulatory legislation.[23] The American Academy of Pediatrics in particular suggested recommendations that may help prevent such injuries, for example, the use of helmets, protective clothing, seat belts, roll balls, lowering the center of gravity of vehicles, automatic headlights, speed governors, and passenger seating restrictions.[18] ATV use has resulted in a significant degree of neurological morbidity and mortality, disproportionately affecting young adult males. Physicians, educators, and parents must take proactive measures to raise awareness of responsible ATV use and curb the notion that these vehicles are anything but a prescription for injury with improper handling. Along with appropriate legislation, the legal punishment for violation of laws may need to become more severe in order to promote compliance with the set regulations.

Majority of the recent literature has focused on the risk of ATVs to the pediatric population and there has been sparse data on the causes and specific injury patterns in the spine of adults involved in ATV accidents. Although our study tries to address these issues, there were several limitations to our study. First, our study was limited to a retrospective review of patients at a single center, limiting its generalizability. Secondly, the use of restraints and mechanisms by which they were applied was determined by retrospective chart review of admission records. In fact, there was insufficient data on restraints, hence there was minimal analysis able to be performed. Therefore, this study may only provide a limited assessment on the use of restraints in preventing injury during ATV accidents. Future prospective studies would benefit from collecting variables related to patient restraints and safety equipment as the variables can be collected in real time from emergency medical service providers and patients. Additionally, future studies identifying variables predictive of SCI along with outcomes related to these injuries may be of benefit to providers and patient management.

## CONCLUSION

In this study we highlighted the prevalence of spine injury in the Coachella Valley with several goals in mind. The first was to gain insight on the prevalence of ATV hospitalization caused by spinal injury. The Coachella Valley is popular for ATV activity and as a result the trauma hospital is responsible for the care of these patients. Analyzing the types of injuries and their prevalence in ATV accidents is crucial for patient management and outcomes. Our data suggests that 34% of ATV accidents resulted in spine injury with 1.8% of these patients having clinically present SCI. Both subgroups of patients presented with radiographic findings of cord contusion, epidural hematomas, and VA injury. The SCI group was more likely to have these injuries and 75% of these patients required neurosurgical intervention.

Our second goal was to provide a reproducible methodology for the investigation of spinal injury as a result of ATV accidents. This study stands as the only study that has isolated the population of Coachella Valley ATV accident and spinal trauma. However, the methodology used is one that can be reproduced in different areas with heavy ATV usage. The ease of replication should promote the replication of this methodology in other traumas hospital for patient management.

Lastly, the results of this paper and hopefully, subsequent ones in different regions, can be used for both public education and legislation. Both of these can improve risk awareness and aid in reducing unsafe behaviors in riders and operators. Additionally, government regulation at various levels can be beneficial in preventing ATV accidents and the associated spinal trauma.

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