

Spine Trauma Secondary to Diving Accidents: A Seven-year Retrospective Study in Puerto Rico

César M. Carballo-Cuello, MD; Orlando De Jesus, MD, FAANS;
Ricardo J. Fernández-de Thomas, MD; Aixa de Jesús-Espinosa, MS, MPH;
Juan A. Vigo-Prieto, MD

Objective: Review the profile of patients with spinal trauma after diving accidents referred to the Puerto Rico Medical Center. This study intended to develop more awareness of the risks of spinal cord injury after diving.

Methods: The patient's records for diving accident cases referred to our center during January 2014 until December 2020 were assessed retrospectively. The cases were evaluated according to sex, age, vertebral level, and neurological deficit. The Puerto Rico Medical Center is the only level 1 trauma center in Puerto Rico; therefore, this study likely included all the cases of diving injury on the island.

Results: Sixty-five patients with a median age of 29 years were identified consisting primarily of males (94%). The regions affected included the cervical (96%), thoracic (2%), and lumbar (2%) spine. Twenty-seven patients (42%) developed a spinal cord injury secondary to a diving accident. Involvement of the C4, C5, or C6 vertebral level, was significant for the development of a spinal cord injury. Diving accidents occurring at beaches were the most common cause.

Conclusion: In Puerto Rico, there is a yearly incidence of 9.3 diving accidents causing spinal trauma; these accidents most frequently affect the C6 vertebra. These diving accidents mainly occur in young individuals, predominantly at beaches. Most of our patients were neurologically intact after their diving accident, although 42% sustained a spinal cord injury. This study provided a better understanding of this traumatic event and determined its most affected levels, accident sites, and population involved. [*P R Health Sci J* 2022;41(4):222-225]

Key words: Diving accident, Quadriplegia, Spinal cord injury, Spine trauma

Spine trauma after diving occurs mainly in young individuals and can lead to long-term disability, significant morbidity and mortality, prolonged hospital stays, and high healthcare-related costs (1,2). The most common etiologies causing closed spinal cord injury (SCI) are automobile accidents (31%), falls (25%), motorcycle accidents (6.8%), and diving accidents (4.7%) (3). Diving is the fourth most common etiology for SCI, with an estimated incidence of 1.7 to 7.3 cases per year (1,3-5). Diving accidents may cause injury to the cervical spine, most commonly at the fifth cervical vertebra, potentially leading to a diverse range of neurological deficits, depending on the mechanism of injury, the severity, and the affected vertebral column levels (6,7). The extent of neurological injury is usually determined using the American Spinal Injury Association (ASIA) Impairment Scale (AIS) (5,8,9). This scale classifies neurological injury using the letters A through E; AIS A represents a patient with complete sensory and motor deficits below the level of injury, AIS E represents a neurologically intact patient, and AIS B through D represent incomplete deficits below the level of injury. Specifically, AIS B has some sensation preserved but no motor function, AIS C has some motor function preserved, with more than half of the key

muscles having a force of less than 3, and AIS D has some motor function preserved, with more than half of the key muscles having a force of 3 or more. Commonly, diving accidents occur in shallow and unfamiliar bodies of water and are sustained when an individual dives headfirst into that water (1,2,5). Blanksby et al. showed that nearly 80% of these cases occur in shallow water that is less than 5 feet (1.52 meters) deep (10). The injury predominantly occurs in males with a mean age range of 22 to 28 years (1,2,4,5,7). Most injuries usually involve ordinary dives and occur during the summer months and mainly on weekends (2). This study aimed to investigate the profile of patients in Puerto Rico with traumatic spinal injury resulting from diving accidents. The most affected levels, the site of each patient's accident, and the population involved were documented.

Section of Neurosurgery, Department of Surgery, School of Medicine, University of Puerto Rico Medical Sciences Campus, San Juan, Puerto Rico

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Address correspondence to: Orlando De Jesus, MD, Neurosurgery Section, Department of Surgery, UPR Medical Sciences Campus, PO Box 365067, San Juan, PR 00936-5067. Email: drordejesus@aol.com

Materials and Methods

A retrospective, single-center study was conducted by reviewing the electronic medical records stored at the University of Puerto Rico School of Medicine neurological surgery patient database. A search of the diving-injury cases referred to our level 1 trauma center from 2014 through 2020 was performed. Sixty-five patients who had been so referred during this span of time were identified. The following variables were considered: sex, age, vertebral level, and AIS neurological deficit classification. The sites of these events were identified (beach, pool, river) to determine where said events most frequently occurred. A statistical analysis for categorical variables was performed using Fisher's exact test and a post-hoc multiple comparison test (pairwise tests of independence for nominal data using the Holm-Bonferroni method for P value adjustment). The Institutional Review Board of the University of Puerto Rico School of Medicine approved this study. The Institutional Review Board of the University of Puerto Rico School of Medicine approved this study. Protocol B1620121, minimal risk.

Results

There was a 94% (61/65) male predominance, with a median age of 29 (Q1 and Q3: 20–40; range: 12–72). Fifteen percent of the accidents (10/65) occurred in patients under the age of 18. Spinal injury distributions for our population were as follows: cervical, 63/65 (96%), thoracic, 1/65 (2%), and lumbar, 1/65 (2%). The spinal column vertebral levels involved were as follows: C1 (8/65; 12%), C2 (10/65; 15%), C3 (1/65; 2%), C4 (11/65; 17%), C5 (12/65; 18%), C6 (15/65; 23%), C7 (6/65; 9%), T8 (1/65; 2%), and L1 (1/65; 2%) (Table 1).

Twenty-seven patients (42%) developed an SCI secondary to the accident, while 38 (58%) were neurologically intact. The 27 patients with an SCI had a mean age of 29 (range: 16–53), with a male predominance of 96%. The spinal column levels involved in the SCI patients were as follows: C4 (7/27; 26%), C5 (7/27; 26%), C6 (10/27; 37%), C7 (1/27; 4%), T8 (1/27; 4%), and L1 (1/27; 4%) (Table 1). Involvement of the C4, C5, or C6 spinal column level was significant for the development of

Table 1. Distribution of cases according to the affected vertebral level in the entire population and those with a SCI.

Vertebral Level	Cases (n = 65)	%	SCI (n = 27)	%
Cervical 1 (C1)	8	12	-	-
Cervical 2 (C2)	10	15	-	-
Cervical 3 (C3)	1	2	-	-
Cervical 4 (C4)	11	17	7	26
Cervical 5 (C5)	12	18	7	26
Cervical 6 (C6)	15	23	10	37
Cervical 7 (C7)	6	9	1	4
Thoracic 8 (T8)	1	2	1	4
Lumbar 1 (L1)	1	2	1	4

SCI: spinal cord injury

an SCI (P value < .001). Neither age nor gender was significant in terms of the development of an SCI. The AIS classifications of the patients were as follows: AIS A, 8/65 (12%); AIS B, 1/65 (2%); AIS C, 6/65 (9%); AIS D, 12/65 (19%); and AIS E, 38/65 (58%) (Table 2). Information regarding the site at which a given accident occurred was not available for all the cases, but from those in which this information was available (47 cases), 51% occurred at the beach, 26%, in pools, and 23%, in rivers.

Table 2. Distribution of cases according to the ASIA Impairment Scale.

AIS	Cases (n = 65)	%
A	8	12
B	1	2
C	6	9
D	12	19
E	38	58

ASIA: American Spinal Injury Association; AIS: ASIA Impairment Scale

Discussion

This study confirmed that diving injuries occur most commonly in the young male population. Prior studies have reported a slightly younger age, that being an average of 28 years (11-14). Ninety-four percent of the patients in our study were males, which is consistent with recent studies reporting a male predominance of up to 98% (14). These findings are expected, as young males are more likely to engage in high-risk behavior while diving. The cervical spine was the most frequently injured area, with 97% of the cases occurring in this anatomical region. Our study showed the C6 as the most common vertebral level involved, with 23% of injuries occurring at this level. Previous studies in the literature have consistently reported C5 as the most common level involved (2,6,7,14-16). However, other studies have indicated that C5 and C6 are the most commonly injured levels, which is consistent with our results (1,4,15). Aito et al. showed that the trauma in 40% of their cases was at the C6 level (1). Our study showed that 89% of the SCI cases of our sample group involved the C4, C5, and C6 levels. Ull et al., found that 85% of their patients had an SCI involving one of these 3 levels (14). In our analysis, involvement of the C4, C5, or C6 spinal column level was significant for the development of SCI. These levels are associated with a narrower vertebral canal and a broad range of motion (2,6). Our study showed that trauma to the C1, C2, and C3 did not usually cause an SCI as no such injury occurred at these levels in our patients. Only one patient had a thoracic spine injury, which is less than has been reported by other studies. In the study by Ye et al., six thoracic cases were reported, representing nearly 10% of the patients in their study (17). Interestingly, none of the patients in our population sustained an injury that affected multiple vertebral levels.

Our study showed an incidence of 9.3 cases per year of spine trauma due to diving accidents, which agrees with previous studies reporting yearly averages of 3.4 to 9.3 such cases

(3,15,18). Only two prior studies have shown a higher incidence. Kiwerski reported an incidence of 15 cases per year (19). Bailes et al. reported 20 cases per year (7). Our study suggests that Puerto Rico has one of the highest incidences of spine trauma due to diving reported in the literature. This finding can be attributed to the fact that all spine trauma patients in Puerto Rico are referred to our level 1 trauma center, which provides care for nearly 3.1 million people. Due to the geographical nature of the small island of Puerto Rico, many towns have easy access to beaches, which can encourage beach activities for the island's population. Our study demonstrated an incidence of four SCI cases per year, which is consistent with previous studies in the literature, which report 1.7 to 7.3 SCI cases per year (1,3-5,8,14,15,18).

In most diving accidents, the SCI occurred due to a hyperflexion and compression injury to the cervical spine (1,10). Diving, which involves leaping headfirst into water, exposes the person who is diving to a potential injury of the cervical spine. In this activity, the neck is slightly flexed, eliminating the regular lordosis and converting the cervical spine into a segmented column that can be easily compressed by the abruptly decelerated head and the mass of the oncoming body (12,20). Other mechanisms involved include hyperextension and rotation of the neck, although the latter is less likely due to how an individual's head impacts objects underwater (1,12). In our review, 58% of the patients had no neurologic deficit (AIS E), while 42% did have a neurological deficit (AIS A–D). Twenty-seven patients sustained SCIs, classified (from AIS A to D) as follows: 30% were AIS A, with complete motor and sensory deficits; 4% were AIS B, with complete motor but incomplete sensory deficits; AIS C was found in 22% of the patients; and AIS D, consisting of a partial motor deficit, was seen in 44%. Thirty percent of our population had an injury severity of AIS A, which is lower than what has been reported by other studies (54 to 65%) (1,2,5). Our SCI rate of 42% is slightly higher than what was reported by Chan-Seng et al, which showed a 34% rate (5). In our study, the SCI patients and the neurologically intact patients had similar median ages. The most frequently affected cervical spine level was C2 in neurologically intact patients compared to the C6 level in SCI patients.

Our study showed that 51% of the accidents occurred at beaches, making it the most common diving-injury site. Other studies have reported a lower incidence (33-35%) of diving accidents at sea (4,14,15). Our finding is most likely due to the high number of beaches surrounding the island, which also boasts a tropical climate, leading to a higher likelihood of diving accidents. A study in China showed that 94% of the diving accidents in that country occurred in swimming pools (17). In our study, only 26% of the accidents occurred in pools. The sites of these accidents are places to target with prevention strategies that may diminish the amount of spine trauma and subsequent SCI. In most cases, these accidents are preventable, and their reduction can save a substantial number of lives and decrease the attendant healthcare costs. Programs aimed at preventing

swimmers from diving into shallow water were implemented nearly 30 years ago (21). A prior study found that in most (75%) pool accidents, depth indicators were not present, and no warning signs had been posted in 87% of them (2). Additionally, in close to 50% of the cases, the accident involved alcohol use, happened during a social gathering, or occurred during the injured person's first visit to the pool where the accident happened (2). In our study, 15% of the cases involved pediatric patients; thus, specific prevention programs should be created to target this population, which can also be at risk.

In Puerto Rico, there is no efficient prevention program to reduce SCI rates that are specifically related to diving accidents. Slogans such as "do not jump into the unknown" have decreased SCIs from 7 to 2 cases per year in Slovenia (22). Our study aimed to obtain a more detailed profile of the patients who suffer from this condition, create awareness in the population at risk, reduce this traumatic event, and, potentially, develop prevention strategies. Schools and recreational facilities should implement preventive programs that dissuade people from diving headfirst into any body of water, as this activity is the leading cause of the majority of the diving accident treated at our center. Visible signs should be placed at the pertinent recreational facilities to avoid headfirst diving. This study was a retrospective review, which represented a limitation to the information obtained. In 28% of the cases studied, we could not obtain the site of the diving accidents, which may limit the efficacy of our prevention strategies.

Conclusions

In Puerto Rico, there is a yearly incidence of 9.3 diving accidents causing spinal trauma, most commonly affecting the C6 vertebra. In neurologically intact patients, the most frequently affected vertebra was C2. Diving accidents most commonly occur in young individuals who dive headfirst at beaches. Most of the patients in our population were neurologically intact after sustaining a diving accident, although 42% had an SCI, with AIS D and AIS A being the most common deficits. This study provided a better understanding of this traumatic event and determined its most common affected levels, accident sites, and population involved. We believe that the results of our study can be used to increase awareness of the issue of diving accidents, thereby resulting in their decrease. In addition, the data we have compiled will serve to enhance current SCI prevention programs.

Resumen

Objetivo: Revisar el perfil de los pacientes con trauma espinal después de accidentes por zambullida (tirarse en un cuerpo de agua) referidos al Centro Médico de Puerto Rico. Este estudio tuvo la intención de desarrollar una mayor conciencia de los riesgos de daño al cordón espinal por zambullida. Métodos: Los expedientes de pacientes por casos de accidentes de

zambullida referidos a nuestro centro durante enero de 2014 hasta diciembre de 2020 fueron evaluados retrospectivamente. Los casos se evaluaron según el sexo, la edad, el nivel vertebral y el déficit neurológico. El Centro Médico de Puerto Rico es el único centro de trauma de nivel 1 en Puerto Rico; por lo tanto, este estudio probablemente incluyó todos los casos de lesiones por zambullida en la isla. Resultados: Se identificaron sesenta y cinco pacientes con una mediana de edad de 29 años que consistían principalmente de hombres (94%). Los niveles afectados incluyeron cervical (96%), torácico (2%) y lumbar (2%). Veintisiete pacientes (42%) desarrollaron daño al cordón espinal secundario al accidente. El daño a la columna vertebral a nivel C4, C5 o C6 fue significativo para el desarrollo de daño al cordón espinal. Los accidentes de zambullida en las playas fueron la causa más común. Conclusiones: En Puerto Rico, hay una incidencia anual de 9.3 accidentes de zambullida que causan traumatismos en la columna, afectando con mayor frecuencia a la vértebra C6. Estos accidentes de zambullida ocurren principalmente en individuos jóvenes, predominantemente en las playas. La mayoría de nuestros pacientes estaban neurológicamente intactos después de sufrir un accidente de zambullida, aunque el 42% sufrió daño en el cordón espinal. Este estudio proporcionó una mejor comprensión de este evento traumático y determinó sus niveles más afectados, los sitios de accidentes y la población involucrada.

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