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Survey of Spinal Cord Injuries Due to Diving Accidents in Taiwan

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Survey of Spinal Cord Injuries due to Diving Accidents in Taiwan

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Objective: To examine the clinical characteristics of diving-related spinal cord injuries (SCI) in Taiwan.

Methods: This study is a retrospective review of all hospitalized patients with spinal cord injuries due to diving accidents in three rehabilitation centers between January 1982 and July 2002. Demographic data and clinical features were presented and analyzed.

Results: A total of 1216 spinal cord injuries were reviewed, and 16 cases (1.3%) met the inclusion criteria. Their mean age at the time of injury was 26.8 years and 15 (94.0%) of the cases were male. All of the injuries resulted in tetraplegia and 11 (69.0%) were neurologically complete. The most commonly neurological level was C5. The most common vertebral injury level was C5 (50.0%), followed by C4 and C6. All of the injuries occurred during summer and 63.0% occurred in the open water. Associated injuries were rare. A total of 75.0% of the patients underwent surgical treatment and neurological recovery was observed in 37.5% of these cases, of which most were incomplete injuries.

Discussion and Conclusions: The proportion of diving-related spinal cord injuries in our study was lower than most of the previous reports. A higher percentage of traffic accidents and accidental falls, and a reduced popularity of water sports are possible reasons. We observed some typical features of SCI due to diving accidents in our study. Most of the diving accidents occurred among young males, and resulted in mid-cervical injuries with complete tetraplegia. Our results show that injury-preventing strategies need to be emphasized. (Tw J Phys Med Rehabil 2006; 34(1): 11 - 17)

Key words: diving accidents, spinal cord injury, Taiwan

INTRODUCTION

The annual incidence of traumatic spinal cord injury (SCI) has been estimated to be 18.8 per million in Taiwan,[1] and this figure was within the ranges reported in other countries (9.2 to 53.4 cases per million per year).[1-3] The common causes of SCI include motor vehicle acci-

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dents, community violence, recreational activities and occupational injuries.[3] According to a previous study in Taiwan, traffic accidents and falls are the leading causes of SCI, accounting for 46.0% and 44.1% of the total number of SCI cases, respectively, while only 1.2% of all SCI cases were related to sports injuries.[1] Comparatively, the percentage of diving-related SCI cases ranged from 1.2 to 21.0% in other studies, and most of these reported rates were higher than that in Taiwan.[4-6]

Several reports have presented the clinical characteristics of diving-related injuries. Most occurred in the young male population and resulted in cervical injuries.[6-8] Some authors also demonstrated different biomechanical mechanisms of diving injuries.[6,8,9] However, the clinical features of diving-related SCI cases in Taiwan have not been presented in detail. We performed a retrospective study to analyze SCI cases from three medical centers in northern and central Taiwan. The results were compared with those of a previous study and serve as a basis of injury prevention and treatment planning.

MATERIALS AND METHODS

We reviewed retrospectively all acute and traumatic SCI cases admitted to three medical centers, including the National Taiwan University Hospital (NTUH) in Taipei, the Chang Gung Memorial Hospital (CGMH) in Linkou, and the Chung Shan Hospital in Taichung, between January 1982 and July 2002. The three hospitals serve as the major referral hospitals in northern and central Taiwan. There were a total of 1,216 SCI cases during the study period and only cases caused by diving accidents were recruited for the present research. Cases of death-on-arrival, suicide, accidental falls or with a history of previous SCI were excluded.

The medical charts were reviewed by two of the authors to collect the following information: age at onset, gender, sites of the diving accidents, date of injuries, associated injuries, roentgenographic findings of vertebral injuries, surgical treatment, neurological deficits and outcome upon discharge. The locations of the diving accidents were classified as open water (large bodies of water such as rivers, lakes, streams, and ocean) and non-open water (swimming pools).

The vertebral injuries, based on the roentgenographic findings, were classified according to Good and Nickel.[8] Four separate types of osteoarticular injuries have been identified that result from different mechanisms of force. In a Type I injury, or dislocation, the forces are primarily flexion and rotation, which usually result in a forward dislocation of one vertebra upon the next inferior vertebra. In a Type II injury, or fracture-dislocation, the forces are flexion and rotation acting with the addition of an axial load force. In a Type III injury, or anterior wedge compression injury, the forces are primary flexion and axial load, resulting in an anterior wedge compression fracture, or teardrop fracture. Finally, a Type IV, or compression or burst fracture, is caused by fracture of the vertebral end-plate with explosion on the vertebral body.

The neurological deficits were recorded according to the American Spinal Injury Association (ASIA) Impairment Scale.[10] Those cases of ASIA scale A were defined as complete lesions, while those of ASIA scales B, C, and D were defined as incomplete lesions. Both an improvement of the neurological motor level or an improvement in the ASIA Impairment Scale were considered as neurological recovery.

RESULTS

A total of 16 diving-related SCI cases (1.3%) were identified among the 1,216 cases. Six of the 16 cases were from NTUH, 7 from Chung Shan Hospital, and 3 from CGMH. The demographic data and injury-related variables are listed in Table 1. The mean age at onset was 26.8 years (range: 14 to 39 years) and 15 of the cases were male (94.0%). Eight patients (50.0%) sustained their injuries while diving in rivers, 6 (37.5%) in swimming pools, and 2 (12.5%) in the ocean. All injuries occurred during the summer from May to September. Late afternoon was the most frequently recorded time of injury.

All vertebral injuries were at the cervical spines in the region between C4 to C6 (Table 1). The most frequently injured vertebra was C5, which accounted for 8 fractures (50.0%). Subluxation was observed in 10 cases (63.0%), with most between C4/5 and C5/6.

Table 2 lists the vertebral injuries, resulting neurological deficits and improvement upon discharge from rehabilitation units. Type II injuries (fracture-dislocation)

were most frequent (50.0%) and Type IV injuries (burst or compression fracture) followed (31.3%). All of the cases had significant neurological deficits, with 12 (75.0%) considered neurologically complete and 4 (25.0%) considered incomplete (ASIA scale B). The C5 level was the most common neurological injury level (43.8%), followed by C6 (31.0%) and C4 (25.0%). All of the cases of Type II injuries had complete tetraplegia. Four incomplete tetraplegics had either burst or compression fracture or dislocation only.

No intracranial injury was identified in the 16 SCI patients. In addition, associated extremity injuries or chest blunt injuries were not recorded. Two patients required endotracheal intubation due to near-drowning.

Thirteen (62.5%) patients received their initial treatment at other hospitals before being admitted to the three hospitals considered here. Two patients received megadose steroid therapy and internal fixation. Four patients underwent skeletal traction followed by internal fusion. Nine patients received open reduction and internal fixation. One patient received realignment with skeletal traction and external stabilization. Five of these 15 patients receiving surgical procedure showed neurological improvement before discharge. The only patient receiving conservative treatment also showed some improvement of the neurological deficit. An increased rate of neurological improvement was seen among patients with incomplete lesions (Table 2).

Two of the 4 incomplete tetraplegics and 1 of the 12 complete tetraplegics achieved partial independence in managing their activities of daily living (ADL) in the domains of feeding, grooming, and dressing. Most failed to perform the activities of transfer, toileting, or bathing independently because of inadequate muscle power of the upper limbs. Eleven of the 12 complete tetraplegia needed maximal assistance in almost all ADL. Two of the incomplete tetraplegics achieved exercise ambulation and all of the complete tetraplegics were non-ambulators.

DISCUSSION

The annual incidence of spinal cord injuries (SCI) in developed countries varies from 9.2 to 53.4 per million population.[1-3] Meanwhile, a nationwide survey in Taiwan showed an annual incidence of 18.8 per million population from July 1992 to June 1996.[1] This study disclosed the leading causes of SCI to be traffic accidents and accidental falls, accounting for 46.0% and 44.1% of the injuries, respectively. Sport injuries are infrequent (1.2%) and most are diving-related injuries. Diving accident incidence has been reported to range between 1.2 to 21.0% of all SCI.[4-6] Research by Kiwerski showed that diving injuries comprised 19.8% of cervical SCI in Poland.[11] According to Tator's study, 10.6% of SCI were caused by diving injury.[12] Bailes et al. study showed that

Table 1. Demographic characteristics and injury-related variables of 16 diving-related SCI patients

Variables	Number of cases (%)
Male	15 (93.8%)
Age (years)	
11~15	1 (6.3%)
16~20	3 (18.8%)
21~25	3 (18.8%)
26~30	4 (25.0%)
31~35	2 (12.5%)
36~40	3 (18.8%)
Location of diving accidents	
river	8 (50.0%)
swimming pool	6 (37.5%)
ocean	2 (12.5%)
Month of diving accidents	
May	2 (12.5%)
June	4 (25.0%)
July	5 (31.3%)
August	4 (25.0%)
September	1 (6.3%)
Cervical fracture	
C4	6 (37.5%)
C5	8 (50.0%)
C6	2 (12.5%)
Cervical subluxation	
C3/4	1 (6.3%)
C4/5	3 (18.8%)
C5/6	5 (31.3%)
C6/7	1 (6.3%)

Table 2. The vertebral injuries, levels of neurological deficits and improvement before discharge among 16 diving-related tetraplegics.

	Complete tetraplegics (N=12)	Incomplete tetraplegics (N=4)
Vertebral injuries		
Dislocation (Type I)	1	1
Fracture-dislocation (Type II)	8	0
Anterior wedge compression fracture (Type III)	1	0
Compression or burst fracture (Type IV)	2	3
Level of neurological deficits		
C4	4	0
C5	5	2
C6	3	2
Neurological improvement		
Yes	2	4
No	10	0

9.0% of 2,435 spinal cord injuries admitted to the North Western University-Midwest Regional Spinal Cord Injury Unit documented neck fractures from diving accidents.[7] The report of diving accidents account for 62.0% of all sport-related SCI, or 5.6% of post-traumatic SCI in the Regional Spinal Unit of Florence, Italy.[4] Research by Steinbrück and Paeslack showed that 5.1% of paralyses treated between 1967 and 1978 in Heidelberg (n=2,587) were from diving accidents.[13] However, the diving injuries account for only 1.2% of SCI in Japan.[14] Our data indicated that 1.3% of the SCI was caused by diving accidents. This rate is lower than most of the previous reports. The proportion increased when the reporting centers were in close proximity to areas of popular water-sport activity. The low popularity of water-sport and diving or the high percentage of injuries caused by traffic accidents and accidental falls in Taiwan may account for the low percentage shown in our survey.

Young male patients comprise the majority of diving-related SCI, peaking in the third and forth decade in our study and those of other researchers.[12,15] Males are at greater risk of morbidity and mortality from SCI across all age groups.[16,17] They are usually subjected to greater forces of injuries than the elderly and have a greater preponderance of injuries in high impact pursuits. However, we found only one victim younger than 15 years old. McGrory et al. also reported few spinal injuries in children and adolescent patients.[18] Anatomic differences have been used to explain the variation of cervical spine injuries between adults and children. Children have more elastic vertebral ligaments and underdeveloped spinal musculature.[19,20]

Diving injuries tend to occur near open bodies of water in summer.[8,21] Our findings are similar in that two third of the accidents occurred near unsupervised open waters, and all occurred from May to September. The use of alcohol, misjudgments of water depth and collisions with other swimmers were the most common causative factors.[6]

Several forces are involved in a diving injury, including axial-loading, flexion, extension and rotation. Torg postulated a reflex flexion of diving patients when they strike the bottom of a pool. Axial-loading when the head strikes the bottom of the pool usually results in burst fractures. [6,22,23] Hyperextension injuries can result from flat, head-first dives into shallow water, or by trying to slow the dive by suddenly extending the neck just prior to contacting the pool bottom.[9] Rotational force may cause a unilateral facet fracture or dislocation. These data may explain our findings. We used the classification of Good and Nickel to classify the vertebral injuries and found that Type II (fracture-dislocation) and Type IV (compression

or burst fracture) comprised most of the injuries (50 and 31.3%, respectively). These two types of vertebral injuries are assumed to be related to flexion and axial load or flexion and rotation. [8]

Diving injuries are located predominately in the cervical spine, whereas other spinal injuries, such as those seen in mining, logging, or recreational activities, have a greater tendency to occur in the thoracolumbar spine.[3] Our results are consisted with those of previous studies. All of the injuries in our study occurred at the cervical spine, with the most common injury sites over the mid-cervical levels, particularly C5 and C6. The C5 and C6 segments are prone to injury because they form the functional axis of rotation between the head and the trunk and are capable of a large range of motion. The combination of smaller vertebrae and reduced strength in stabilizing osseous/ligamentous/muscular structures makes this region vulnerable to the injury forces.[6,24]

Good and Nickel reported that, among diving-related SCI, 54.0% are complete lesions, 41.0% are incomplete lesions and 54.0% show no neurological deficit .[8] Ratanaubol and Huang, in an eight-year review at Spain rehabilitation center, reported 46.0% complete and 5.0% incomplete tetraplegia.[25] Approximately 75.0% of our subjects had complete tetraplegia, which is higher than previous reports. We assumed that diving injuries with minor neurological deficits may not be referred to the three rehabilitation centers monitored here. Our results showed that cases of fracture/dislocation resulted exclusively in complete tetraplegia, which is consistent with a previous report that complete neurological injury was most often noted in patients with burst fractures and dislocations.[7]

Some SCI have significant associated injuries such as traumatic brain injury or major chest injuries.[3] Comparatively, the percentage of associated injuries in diving-related SCI was relatively lower compared with other SCI causes.[7,26] We observed no associated traumatic brain injury, chest contusion or limb fracture recorded in any of our subjects. However, some unfortunate people who sustained complete tetraplegia may have drowned if no immediate help was accessible. Therefore, we believe that a number of diving injured victims, including those with major associated injuries, drown before they are rescued.

Up to 15 of our cases received surgical treatment for their spinal injuries, and two received megadose methylprednisolone as a supplementary treatment. Because of limited case numbers and retrospective design of the present study, it is difficult to evaluate the effects of different treatments. The initial management of an acute injury begins with immobilization of the spine at the scene. Megadose methylprednisolone is one of the few potential pharmaceutical treatments for neurological dysfunction among SCI. Realignment with skeletal traction is recommended for patients with a dislocation or subluxation. Any patient who showed symptomatic deterioration, progressive subluxation, or instability at the fracture levels would be a candidate for internal fusion. [22,24,27]

Unfortunately, the rate of recovery of neurological function was low among diving-related SCI, ranging from 4.0% to 9.0%.[22] The improvement usually consisted of one level only, which is believed to be due to resolution of the spinal cord traumatic edema.[7] Our results showed that those cases of incomplete tetraplegia had higher percentage of neurological improvement, which is compatible with results of a previous study.[4]

The physical disabilities of tetraplegics are devastating and permanent. Efforts are best directed toward SCI prevention. We concur with suggestions made by other authors. The importance of educational programs concerning the hazards of diving into shallow water should be emphasized and warning signs should be mandatory at public pools, beaches, and private swimming areas. [6,15,23] Most patients sustained injury by direct impact to the vertex when diving into shallow water. Almost double the individual's height in water depth is required for complete deceleration of the body while diving from deck level or higher. Therefore, shallow swimming pools are dangerous for diving.[6] Safety practices such as stirring up the water surface and protecting the head with the arms crossed are recommended.[23]

CONCLUSION

We have compiled the clinical features of diving-related SCI by a retrospective study. Only 1.3% of all SCI were diving-related in these medical centers. They occurred predominantly among young male subjects. All of the diving-related SCI patients presented as tetraplegia,

and 75.0% were complete lesions. Fracture/dislocation and burst/compression fracture were the most common types of vertebral injuries. Fifteen of the patients underwent surgical intervention and the neurological improvement was seen in only 37.5% of all the patients. The importance of educational programs concerning the hazards of diving into shallow water should be emphasized to prevent such devastating injuries.

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台灣地區跳水意外造成脊髓損傷之調查

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近來台灣跳水運動逐年盛行，常造成頸椎嚴重及持久性的傷害。國外相關發表之研究報告眾多，而國內對於跳水造成脊髓損傷之調查研究並不完整，因此本研究之目的在於探討台灣地區跳水造成脊髓損傷之臨床表現與型態分佈。

本研究收集了台灣大學醫學院附設醫院、林口長庚紀念醫院、中山醫學大學附設醫院自 1982 年至 2002 年期間因脊髓損傷的病例，共計 1216 例。其中 16 例因跳水造成脊髓損傷，占 1.3%。平均年齡 26.8 歲。15 例(94.0%)是男性。意外皆發生於夏季。大部分(63.0%)發生在無人監視的開放水域。所有病例皆造成頸椎受傷導致四肢癱瘓，最常發生脊椎骨受傷部位為 C5 (50.0%)，其次為 C4 與 C6。神經學上，C5 為最常發生之脊髓損傷部位。沒有人併發其他部位之受傷。75.0% 之病患接受外科手術治療。而 37.5% 之患者有神經學上之恢復，大部分見於不完全性之脊髓損傷患者。相較於國外研究，台灣地區因跳水造成脊髓損傷之比例偏低，探討原因，可能與國內跳水風氣較不盛行，反而與較多車禍與意外跌落之病例有關。其臨床表現與型態分佈與國外報告相似。鑒於頸椎脊髓損傷所造成傷害之永久性與廣泛性，應加強傷害防範措施與教育。（台灣復健醫誌 2006；34(1)：11 - 17）

關鍵詞：跳水意外(diving accidents)，脊髓損傷(spinal cord injury)，台灣(Taiwan)

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