Cervical spine injuries resulting from diving accidents in swimming pools: outcome of 34 patients

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Abstract Cervical spine injuries after diving into private swimming pools can lead to dramatic consequences. We reviewed 34 patients hospitalized in our center between 1996 and 2006. Data was collected from their initial admission and from follow-up appointments. The injuries were sustained by young men in 97% (mean age 27) and the majority happened during the summer (88%). Fractures were at C5–C7 in 70%. American Spinal Injury Association class (ASIA) on admission was A for 8 patients, B for 4, C for 4, D for 1, and E for 17. There were 23 surgical spine stabilizations. Final ASIA class was A for 6 patients, B for 1, C for 3, D for 5, and E for 18. The mean duration of hospitalization was 21.3 days in our neurosurgical center (mean overall cost: 36,000 Euros/patient) plus 10.6 months in rehabilitation center for the 15 patients admitted who had an ASIA class A to C. Mean overall direct cost for a patient with class A is almost 300,000 Euros, compared to around 10,000 Euros for patients with class D and E. In addition, a profound impact on personal and professional life was seen in many cases including 11 divorces and 7 job losses. Dangerous diving into swimming pools can result in spinal injuries with drastic consequences, including permanent physical disability and a profound impact on socio-professional status. Moreover, there are significant financial costs

to society. Better prevention strategies should be implemented to reduce the impact of this public health problem.

Keywords Cervical trauma · Diving accident · Outcome · Spine cord injury

Introduction

The number of private swimming pools in France is increasing rapidly. During the period from 1997 to 2007, the number of private pools more than doubled. By 2007, there were 1,346,000 swimming pools in France, with a further 45,000 being built each year [18]. The potential market in France is estimated at 7 million pools [18], making it the largest market in Europe. Spain is the second most important market with 600,000 pools and a further 20,000 new pools each year [19]. The risk of accidents in private pools is likely to be higher than in public baths. Authorities have acknowledged this fact, and have successfully reduced the risk of drowning by implementing laws that require the owner of a private pool to install standardized security measures (including a fence and cover). However, the risk of other accidents, e.g. from diving, still remains a problem. Previous attempts to reduce such accidents in Europe have consisted mainly of printed manuals of information describing possible hazards, and suggested methods of reducing the risks.

Serious accidents due to diving into shallow water are rare but potentially devastating. The incidence of spinal cord injuries (SCI) following these accidents has been reported to range between 1.2 and 21% [1, 3, 11, 12, 20]. These injuries occur predominantly in a young and healthy population that is mostly male [1, 4, 6, 8]. Spinal cord injuries as a consequence of diving accidents mainly affect the cervical spine and

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therefore may cause a lifelong severe disability with important social impact and financial costs [3, 4, 15].

There are only few studies in the literature about diving and cervical spinal cord injuries [1, 3, 15]. This study analyzes the initial and follow-up data of all patients hospitalized in our institution for spinal trauma after diving into a swimming pool. The aim of the study is twofold: (1) to analyze and describe the nature of these spinal injuries and (2) to examine the neurological and socio-professional outcome. Our final aim is that there must be more emphasis on accident prevention initiatives, e.g. educational interventions and media campaigns, to minimize the frequency and impact of these accidents.

Clinical materials and methods

Patient population

A retrospective study of all spine injuries admitted to our institution between 1996 and 2006 was performed, using patient information stored in our institution database. As much as 1,362 patients were admitted to the neurosurgery department after cervical spinal injury. Of these, 34 of the injuries resulted from diving accidents. This does not include patients seen in the emergency department who were discharged home within hours of arrival to hospital.

Data collection and follow up

Data collection involved a review of clinical data, surgical records, and postoperative status for each patient. In addition, interviews were conducted with patients, their families, physicians, and the professionals at the center of their rehabilitation. Parameters collected included age, sex, the type of vertebral lesion, ASIA class on admission and on discharge [17], treatment, duration of hospitalization, and socio-professional status. The last follow-up date recorded as the last documented clinical follow-up or phone interview for any social, personal, or professional consequences.

Standard cervical traumatism management

Cervical spine injuries were managed broadly as follows. In the emergency department, patients with proven or suspected cervical spine trauma had a cervical spine radiograph and computed tomography scan. If the neurological examination was abnormal, an MRI was also performed and the patient was admitted to the intensive care unit. In patients with a potentially unstable cervical spine or incomplete neurological injury, surgical treatment was carried out through an anterior or posterior approach, or both. The anterior way consists of a right side cervical

access with corporectomy and installation of Stella[®] Cervical Plate (Scient'X, West Chester, PA 19380, USA) on the broken vertebra. The posterior way consists of installation of OASYS System[®] (Stryker, Kalamazoo, MI 49002, USA). In the absence of an unstable spine, or incomplete neurological injury, the patient was managed conservatively. After discharge from the neurosurgical ward, a long-term follow-up was arranged, using both clinical and radiological examination (i.e. dynamic imaging of the cervical spine in flexion and extension).

Results

Patients' data

During the 10-year period from 1996 to 2006, 34 patients (2.5% of a total 1,362 cervical spinal injuries) were admitted to our department for management of cervical spine trauma following an injury sustained while diving into a swimming pool, all swimming pools were private. Interestingly, almost two-thirds of these were admitted in the latter half of this period (with 9 patients admitted from 1996 to 2000, and 25 admitted between 2001 and 2006), perhaps reflecting the recent increase in the number of private swimming pools. These accidents occurred most commonly during the summer, with 88% of cases happening in the three months from June to August. The mean age of the patient was 27 years old (range 13–49) and 33 out of the 34 were males (97%). The mean duration of follow-up was 3.9 years (range: 8.4 months–9.4 years).

Initial trauma and management

On admission, the neurological status of the 34 patients was classified as follows: 8 patients were classified as ASIA A, 4 patients as ASIA B, 4 patients as ASIA C, 1 patient as ASIA D, and 17 as ASIA E. As much as 24 patients (70%) had a lesion in the lower cervical spine (C5–C7); 3 patients in the middle cervical spine (C3–C4), and 5 patients in the upper cervical spine (C1 or C2). One of them had combined injuries in C1 and C2. These data are summarized in Table 1. Associated morbidity was relatively infrequent, but included 13 minor head injuries, 3 cases of pulmonary disease due to inhalation of water, and 2 cases of cardio-respiratory arrest.

A total of 23 patients (68%) underwent surgical treatment. An anterior approach was performed in 18 of these patients, with decompression and fusion using plates and screws. Posterior cervical fusion was performed in 4 patients, again with plates and screws. A double approach was performed only in one patient, who had a laminar decompression of a splinter, followed by an anterior fusion.

Table 1 Type of vertebral lesions according to ASIA initial class

ASIA initial	Type of cervical traumatism						
	Tear drop fracture	Burst fracture	Diabolo fracture	Odontoid fracture	Jefferson's fracture	Corporeal fracture	Isolated luxation
	4 (C5)						
	1 (C4)						
A	1 (C6)	1 (C5)				1 (C5)	
B	2 (C5)	1 (C6)	1 (C5)	1			
						1 (C5)	
C		1 (C7)	1 (C7)			1 (C6)	
D						1 (C3)	
						3 (C7)	
						1 (C4)	
E	1 (C5)	2 (C7)		2	2	1 (C6)	4
Total: 34 patients	9	5	2	3	2	9	4

Ten patients had conservative treatment by ring skull traction followed by the wearing of a halo vest or a collar for at least 2 months.

Outcome

For all patients who survived their injury, no deterioration in neurology was recorded after the original injury. However, several improvements in neurology were noted, mostly in patients with incomplete injuries on admission. Of the 8 patients admitted with a complete neurological injury (ASIA A) on admission, 6 patients did not show any improvement in symptoms or ASIA class. Of the other 2, 1 patient, a 49-year-old patient with a narrow cervical spine and contusion of the spinal cord underwent a laminectomy and on discharge had an improved ASIA score of ASIA C. The last patient of this group died before any surgical treatment. She had a tear drop fracture in C5, a contusion of the spinal cord, and adult respiratory distress syndrome.

The mean duration of hospitalization was 21.3 days (range 9–38; Table 2). Generally, hospitalization was short for patients classified as ASIA D, E. Patients affected by complete spinal cord lesion (ASIA A) stayed in the intensive care unit for an average of 30 days (range 4–45), while patients with an ASIA B score were in the intensive care unit for an average of 18 days. As much as 16 out of the 34 patients developed complications, mostly in patients with ASIA A (11 patients): seven lower respiratory tract infections, three urinary infections, one thrombophlebitis, and three cases adult respiratory distress syndrome.

All patients classified as ASIA A, B, or C were transferred to a center of rehabilitation on leaving hospital. For patients classified as ASIA A, the average hospitalization period (neurosurgery and rehabilitation) was 17 months (range

Table 2 Evolution according to the ASIA class

Class	ASIA initial 34 patients	Evolution → ASIA final						ASIA final 33 patients
		→A	→B	→C	→D	→E	Dead	
A	8	6		1			1	6
B	4		1	1	2			1
C	4			1	3			3
D	1					1		5
E	17					17		18

8–26). For patients with ASIA B and C it was 8 months (range 3–17). Patient outcome is summarized in Table 3.

Overall costs

Total costs can be difficult to calculate accurately. However, one indicator that may be easily measured is the direct cost of treatment, i.e. of a day of hospitalization in neurosurgical department (1,200 Euros/day) or rehabilitation center (500 Euros/day). The mean cost of hospitalization in neurosurgical department was 36,000 Euros per patient. Patients who had an ASIA score A, B, or C (15 patients) with a mean duration of 10.6 months in a rehabilitation center have a mean overall cost of 200,000 Euros (255,000 \$) per patient. On this basis, there is a correlation between the ASIA class and the direct costs (Table 3). Mean overall direct cost for a patient with ASIA class A is almost 300,000 Euros (382,000 \$), compared with around 10,000 (13,000 \$) for patients with ASIA class D and E; while the mean overall cost for all patients is 122,000 Euros (155,000 \$).

However, it is also necessary to add the indirect costs of spinal cord injury to society, e.g. the large cost of continuing care following discharge from hospital (potentially for

Table 3 Length of hospitalization and direct costs

ASIA on admission	Neurosurgical Intensive care (Mean days duration)	Neurosurgical department (Mean days duration)	Total (Mean days duration)	Center of rehabilitation (Mean months duration)	Mean overall costs in Euros (dollars)
A	30	8	38	16 (7–25)	286,000 (364,000)
B	18	13	31	7.75 (3–15)	157,000 (200,000)
C	5.5	14	19.5	8.25 (3–17)	147,000 (187,000)
D	0	9	9	0	10,800 (14,000)
E	0	9	9	0	10,800 (14,000)
Mean	10.7	10.6	21.3	6.4	122,000 (155,000)

the rest of the life of the patient) and the cost of losses incurred due to loss of employment and productivity.

Repercussion on professional and social life

The degree of impact on a patient's personal and professional life correlated to their final ASIA class. Notably, 11 divorces and 7 job losses were recorded in this series, that were attributed to the original injury (Table 4). All 7 patients with final ASIA class A and B were being treated for symptoms of depression on the last follow-up. Furthermore, in all of these patients, at least one family member also reported depressive symptoms severe enough to require treatment. The youngest patient in this group is a student, who continues his studies at a medical institute, with the aid of an electric wheel chair. The patient with initial ASIA class of C was lost from follow-up. Of the 5 patients classified ASIA D, 4 felt they had been deserted by their friends and only two of them are now employed in their previous job. The patients with initial ASIA E class had suffered no significant changes to their professional or social life.

Discussion

Circumstances of cervical trauma

Each year in summer months, injuries of the cervical spine increase, mainly occurring in the younger population.

These injuries cause substantial mortality and morbidity, with many patients acquiring a significant and permanent disability [1, 4, 8, 9, 15]. According to different series, the incidence of diving accidents represents from 1.2 to 22% of all spinal cord injuries [1, 3, 11, 12, 20]. In this series, diving accidents comprised 2.5% of all cervical spine trauma admitted to the department. Most patients were male (97%) with a mean age of 27 years; this is in accordance with others series [1, 4, 6, 8]. It is likely that the number of cervical injuries seen in this study is probably underestimated, because minor injuries were not admitted to the department, but seen only in emergency departments or by general practitioners. These minor injuries may have medical and social consequences that are not reported here.

Cervical injuries due to diving occur mainly in swimming pools, with a peak incidence during the summertime. Misjudgments of the water depth and reckless behavior have been cited as common factors in these accidents [5]. Alcohol consumption is also an important risk factor, thought to be contributory in 38 to 49% of injuries in previously published series [2, 3, 8, 10, 14, 15]. Kluger et al. [14] report that 22 patients among 45 who were injured in swimming pools had blood alcohol levels higher than 100 mg/dl. In our study, blood alcohol levels were not available in all the medical reports.

Associated injuries are infrequent in diving accidents [1, 15]. In this series, there were no significant head injuries, but two cases of cardiorespiratory arrest due to water

Table 4 Repercussion on personal and socio-professional life

ASIA final	Personal	Socio-professional
ASIA A: 6 patients	3 Divorced after accident	3 Unemployed
	2 Status marital unchanged	2 Students in institute medico educative
	1 Teenager	1 Is a company head
ASIA B: 1 patient	Divorced after accident	Unemployed
ASIA C: 3 patients	2 Divorced after accident	2 Unemployed
	1 Teenager with his family	1 Student
ASIA D: 5 patients	4 Divorced after accident	2 Unemployed
	1 No data	2 Employed/previous job
		1 No data
ASIA E: 18 patients	No repercussion	No repercussion

inhalation were noted. Finally, an increase in the number of patients treated with cervical spine injury following diving accidents into swimming pools was noted in the period from 1996 to 2006. This could be correlated with the growth of the private pool market in France.

Types of cervical injury and treatment

Injuries of the cervical spine due to diving accidents generally occur from striking the head on the bottom of the pool [11]. The most frequent mechanism is flexion with or without axial compression [2], this mechanism can explain all cases of our study seen in Table 1. The head strikes the bottom of the swimming pool and massive axial force acting upon the neck in flexion results in fracture, subluxation, and unilateral or bilateral facet dislocation of cervical vertebrae. We did not notice a mechanism by hyperextension of the cervical spine, but it may also occur, this is a less common cause of spinal cord injury [5]. Following a fracture, displacement of fragments may injure the spinal cord, especially the anterior part. Injury most commonly occurs at the level of the C5–C7 vertebrae (80% of injuries in our series), due to the mobility of these segments [1, 3, 8, 10, 15, 21]. In our study, a complete neurological injury was most often noted in patients with burst fractures and dislocations, as in Bailes's study [3]. However, a study by Aito [1], found that the tear drop conformation of fracture was most frequently associated with major neurological motor deficit. Upper cervical spine injuries are rare in diving accidents [3]. In our study only 5 patients had injuries in C1 and C2.

In the emergency department, CT scanning is the main investigation used to detect spine fractures and to plan their management [13, 16]. MRI may also be utilized, if a neurological deficit is noted. When surgical treatment is employed, the technique may vary according to the surgeon. Although cervical anterior approach was the most common approach, there was no relationship between types of fractures and treatment methods. The choice of the surgeon was the only parameter between the anterior or posterior way. The target is always the same, i.e. to stabilize the spinal column, preventing further injury and allowing early mobilization and a more rapid rehabilitation [1, 15, 16]. In this series, the anterior approach was more frequently used (55%). This is consistent with other series [1, 15].

Socio-professional outcome

Every summer, spinal cord injuries from diving accidents result in physical disabilities that can have catastrophic knock-on effects for the professional and social life of patients. This study found a correlation between ASIA

class and socio-professional outcome. A higher ASIA class was associated with more severe repercussions on professional and social life, including job losses and the breakdown of relationships and marriages. Despite medical and surgical advances in the management of these injuries, the socio-economic impact is still highly significant [3–5, 7, 15]. Repercussions related to social life were seen not only in the patients, but also in their family members. Among patients with initial neurological deficits with ASIA class A, 50% lost their jobs, 50% became divorced from their spouse, and, during their hospitalization, 100% of patients were noted to be clinically depressed. In addition, there is an immense financial cost to society. Over and above the intense and prolonged involvement of hospital and rehabilitation services, costs are also incurred due to funding for continuing care, handicap pensions, etc. and from a loss of productivity and tax contributions.

Prevention

Studies looking at the prevention of diving accidents lay emphasis on education, and raising awareness of the dangers of negligence and reckless behavior in swimming pools [4, 7, 8, 15]. Important advice includes “don't dive into unfamiliar water”, “don't permit or indulge in horseplay while swimming or diving”, “link hands with the arms extended in the diving position”, and “don't dive in water less twice your height”. The ThinkFirst program recommends that water should be at least 11-feet deep for safe diving (<http://www.thinkfirst.ca>). Diving into clear water is also cited as important, allowing immersed objects to be identified and avoided. Alcohol should be avoided while swimming and diving as over half of all serious diving incidents occur when the diver has been drinking. The dangers of diving from rooftops, balconies, retaining walls, slides, or other pool equipment must also be emphasized.

We recommend that major prevention efforts must be launched at the beginning of every summer to reduce the impact of this public health problem. Strategies could involve compulsory installation of warning signs and educational programs in schools. Another option is regular media campaigns [2, 3, 8], as utilized by the “*Impact soudain/dive smart*” campaign in Canada, which used television and radio broadcasts to get the message across.

Conclusions

Every year, especially in summer, diving accidents in swimming pools result in severe spinal cord injuries with profound physical, social, and professional repercussions. In addition, there are staggering economic implications for

the individual and to the society as a whole. Despite advances in the hospital management of these injuries, the implementation of an effective prevention strategy is also essential if we are to reduce the incidence and impact of these potentially catastrophic accidents.

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