Original Article

Spinal cord injuries due to diving accidents

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Study design: Retrospective study and data analysis.

Objective: To investigate and analyse the main features of spinal cord injuries due to diving accidents accepted in our Centre from June 1978 to December 2002.

Setting: Regional Spinal Unit of Florence, Italy.

Introduction: Diving accidents mostly occur in a young and healthy population and most of the patients develop tetraplegia with a severe lifelong disability. From 1978 to 2002, 65 patients with spinal injuries due to diving accidents were admitted to the Regional Spinal Unit of Florence.

Material and methods: A retrospective study was conducted by analysing data stored in our local computerized database. We considered the vertebral injury, ASIA-ISCOS neurological classification on admission and discharge, gender, age at the time of injury, month of injury, treatment of vertebral lesion, length of stay in the Spinal Unit, neurological outcome, and complications. Data were analysed statistically by using the Fisher's exact test and logistic regression.

Results: In all, 62/65 patients were males (95%). Mean age at injury time: 22 years. On admission, 35/65 were neurologically complete ASIA A (54%), while 16 were classified ASIA B, 7 ASIA C and 7 ASIA D, according to the ASIA-ISCOS neurological standard of classification. C6 was the most common neurological motor level (40%) and C5 the most common vertebral injury level. In all, 36/65 (55%) patients underwent surgical treatment. Mean hospitalization time was 5 months. No neurological deterioration was recorded. In all, 20/65 (31%) patients improved neurologically and 16/20 (80%) of those had received surgical treatment. In all, 15/65 (23%) patients had complications and one patient died during the hospitalization period.

Conclusions and discussion: Patients whose vertebral lesions were surgically treated had a better neurological outcome than conservatively treated ones. Teardrop fractures showed worse neurological outcome as compared with burst fractures. Neurological improvement was more present in initially incomplete lesions. Treatment with high dose methylprednisolone during the first 8 h after trauma seemed to influence the neurological outcome positively. Age was also an important factor in influencing the neurological outcome.

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Keywords: spinal cord lesion; diving accident; tetraplegia; outcomes

Introduction

Spinal cord injuries (SCI) due to diving accidents occur mostly in a young and healthy population; most patients spend a long rehabilitation period in hospital and develop a lifelong severe disability.¹ Most of the accidents occur during summertime and are often due to lack of attention.

In diving accidents, including high diving, injuries are mostly located in the cervical spine, generally at the fifth and the sixth vertebra. Diving accident incidence has

been reported to range between 1.2 and 21%^{2–5} of all SCI; the average age is 21 years; most patients are males; and associated injuries are rare^{1,6}

In Italy, the large majority of diving accidents occur at the seaside as a consequence of recreational activities. In our Centre they account for 62% of all sport-related SCI, and 5.6% of all post-traumatic SCI. Most accidents are caused by diving into shallow water. According to Blanksby's study, 89% of injuries occur in water less than 1.52 m deep,² as also stated by DeVivo who found that 57% of lesions occurred when diving into less than 4 feet (1–2 m) of water.⁷ The mechanism of the cervical

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spine injury is generally in hyperflexion and compression. Less frequently, there may be a hyperextension, lateral flexion, or rotation mechanism; these phenomena can also be combined. Generally, the diver strikes his head on the bottom of the pool or sea, but diving injuries can also occur after striking another swimmer or a hidden object under the water. As explained by Torg, 'in axial loading injuries, the neck is slightly flexed and normal cervical lordosis is eliminated, thereby converting the spine into a straight, segmented column.... This results in the cervical spine being compressed between the abruptly decelerated head and the force of the oncoming trunk,... the straightened cervical spine fails in flexion mode and fracture, subluxation, or unilateral or bilateral facet dislocation can occur'.⁸

Studies by Albrand and Walter⁹ have helped to provide some useful advice, such as the following:

- Don't dive in water less than twice your height;
- Don't drink and dive;
- Don't dive into unfamiliar water;
- Don't permit or indulge in horseplay while swimming or diving.

Another helpful recommendation is to link hands, with the arms extended in the diving position, in order to help protect the head and neck when diving into shallow water.²

Blivitch *et al*¹⁰ recommend that 'divers strive to surface in as short a distance as possible by maximizing flight distance and aiming for a low entry angle'.⁹

Therefore education and diving technique appear to be outstanding considerations in injury prevention.

Aim of the study

The aim of this study was to investigate and analyse main features and outcomes of SCI due to diving accidents, accepted in our Centre from June 1978 through December 2002, and find possible correlations among obtained data, such as: age and gender, type and level of vertebral lesion, associated injuries, ASIA-ISCOS neurological classification on admission and discharge, treatment of vertebral lesion, length of hospitalization and complications during treatment, skeletal deformity following the vertebral lesion, and rehabilitation.

Methods

A retrospective analysis of the data stored in the computerized database of the Spinal Unit of Florence, including 1784 in-patients accepted from June 1978 through December 2002, was conducted.

The patients were divided into three groups according to the year of admission: group 1, accepted from 1978 to 1988, group 2 accepted from 1989 to 1998, and group 3 accepted from 1999 to 2002.

The neurological classification was done according to the ASIA-ISCOS standard of neurological classification of spinal cord injury.¹¹

The vertebral injury level was defined as the highest vertebral lesion.

The type of vertebral lesion was defined in one of the following ways:

- (a) *Teardrop fracture*, a term coined in 1956 by Schneider and Kahn,¹² is used to describe a flexion-compression injury of the cervical spine, characterized by compression of the body of the vertebra and displacement of the anterior-inferior corner away from the remainder of the body, and angular displacement of the postero-inferior margin into the spinal canal. This type of lesion could have been classified as stage 4 and 5 of compression-flexion injuries by the Allen-Ferguson¹³ classification: stage 4 (CFS4) is characterized by posterior displacement of less than 3 mm into the vertebral canal of the postero-inferior vertebral body, while in stage 5 (CFS5) the posterior displacement is more than 3 mm. In the series reported by Allen, a neurologically complete spinal cord lesion was present in 38% of CFS4 and 91% of CFS5 injuries.
- (b) *Burst fracture*, characterized as a comminuted vertebral body fracture with varying degree of bone retropulsion into the spinal canal, is caused by a combination of axial load with or without varying degrees of flexion. In the present study all burst fractures registered as stage 3 of vertical compression injuries according to the Allen-Ferguson classification.¹³
- (c) *Pure dislocation without fractures* suggests injury force direction in flexion-distraction, resulting in the failure of the posterior complex and disc, registered as stage 3 of distractive-flexion lesions according to the Allen-Ferguson classification.¹³
- (d) *Other types* of fractures, such as lateral-flexion injuries and compression-extension injuries combined with different degrees of rotation.²⁰

The degree of cervical kyphosis was measured by evaluating, on the plain lateral radiographs, the angle formed by the line drawn parallel to the inferior end plate of the most cephalad vertebra in the sagittal kyphotic curvature and the line parallel to the inferior end plate of the most caudal vertebra of the sagittal curvature. Kyphosis degrees were divided into four groups: (1) no kyphosis present, (2) 0°–10° of kyphosis, (3) 11°–20° of kyphosis, and (4) more than 21° of kyphosis.

All patients underwent dynamic X-rays of the cervical spine at 3 months and 1 year post-trauma in order to assess stability.

Treatments of the vertebral lesions were classified as follows:

- (1) *Conservative*, when no surgical intervention was performed; treatments included axial traction, cervical orthosis or Halo cervical immobilizer.
- (2) *Surgical*, when the patient underwent a surgical procedure by anterior or posterior approach.

By neurological recovery we intend both the improvement of neurological motor level and/or improvement in the ASIA Impairment Scale (from A towards E).¹

Statistical analysis for the significance of the correlation among data was conducted by using the Fisher's exact test for bivariate analysis (Tables 7 and 8) and logistic regression for multivariate analysis.

Results

During the period between June 1978 and December 2002, 1158 patients received their comprehensive care treatment immediately after spinal injury at the Spinal Unit of Florence. Of these patients 65 (5.6%) had their spinal lesion due to diving accidents. A total of 33 patients (51%) were resident in Tuscany and 32 (49%) came from other regions of Italy or from other countries.

The distribution of the cases through the years is represented in Figure 1.

On admission to hospital, 62 patients were tetraplegics, and three were paraplegics (see Table 1)

As expected, most injuries occurred during the summer period, with 72% of cases occurring between July and August.

The mean age of the patients was 22 years, ranging from 14 to 47. In all, 95% were males. There was no difference in mean age between incomplete and complete SCI on admission.

A total of 27 patients (42%) were admitted to the Spinal Unit the same day of the injury, while 38 patients (58%) were admitted later, but never later than 7 days after the injury.

There were only two injuries (3%) involving the third cervical vertebra. Injuries to the fourth cervical vertebral level were recorded in six cases (9%). The fifth cervical level was the most frequently compromised, accounting for 36 fractures (56%). A total of 11 fractures (15%) involved C6, seven lesions involved C7 (11%) and D1 was fractured in one case (2%). One patient (2%) suffered from a pure dislocation C7–D1 and another patient had no vertebral fracture (2%) (Table 2).

On discharge, C6 was the most common neurological level, according to the ASIA-ISCOS standard of neurological classification, being recorded in 26 patients (40%). The highest neurological level was C4, detected in seven patients (11%), as is shown in Table 2.

The vertebral lesions were classified as:

- teardrop fracture, recorded in 40 patients (61%);
- burst fractures, most often in a C7 fracture, recorded in 14 patients (21%);
- other types of fractures seen in nine patients (14%);
- pure dislocation recorded in one patient (2%);
- no vertebral fracture present in one patient (2%).

On admission, 35 patients were classified as neurologically complete (ASIA A), while 16 were classified as ASIA B, 7 as ASIA C and 7 as ASIA D (see Table 3).

In the patients, teardrop fractures resulted in complete neurological lesion on admission in 70% of cases (28/40), while burst fractures resulted in complete lesion (ASIA A) only in 22% of cases (3/12), as shown in Table 4.

Associated injuries were relatively rare: four patients (6%) had head trauma without severe brain damage. 29 patients (45%) were treated conservatively by the use of skull traction for 6 weeks, followed by the use of a collar or Halo Vest worn for 2 more months.

Table 1 Distribution of patients with regard to neurological lesion on admission

	Total admitted to Spinal Unit	Spinal lesion due to diving accidents	%
Complete tetraplegia	231	35	15
Incomplete tetraplegia	259	27	10
Complete paraplegia	420	0	0
Incomplete paraplegia	251	3	1

Figure 1 Distribution of the injuries accepted at the Spinal Unit of Florence in the years between 1978 and 2002

Table 2 Vertebral level and neurological level on discharge

Vertebral level		Neurological level				Dorsal	ASIA E
		C4	C5	C6	C7		
C3	2 (3%)	2 (100%)					
C4	6 (9%)	2 (33%)	3 (50%)	1 (17%)			
C5	36 (56%)	3 (8%)	6 (17%)	21 (58%)	5 (14%)		1 (3%)
C6	11 (15%)		1 (9%)	4 (36%)	5 (46%)		1 (9%)
C7	7 (11%)				3 (43%)	3 (43%)	1 (14%)
D3	1 (2%)					1 (100%)	
Dislocation C7-D1	1 (2%)					1 (100%)	
No fracture	1 (2%)						1 (100%)
Total	65	7 (11%)	10 (15%)	26 (40%)	13 (20%)	5 (8%)	4 (6%)

Table 3 ASIA Impairment Scale classification on admission and discharge (Frankel scale)

	On admission n (%)	ASIA A on discharge	ASIA B on discharge	ASIA C on discharge	ASIA D on discharge	ASIA E on discharge
ASIA A	35 (53%)	32 (91%)	1 (3%)	2 (6%)		
ASIA B	16 (25%)		10 (62%)	3 (19%)	3 (19%)	
ASIA C	7 (11%)			3 (43%)	4 (57%)	
ASIA D	7 (5%)				3 (43%)	4 (57%)
ASIA E	0					0

ASIA A on admission were discharged as ASIA A in 91% of cases, as ASIA B in 3% of cases and as ASIA C in 6% of cases
 ASIA B in admission were discharged as ASIA B in 62% of cases, as ASIA C in 19% of cases and as ASIA D in 19% of cases
 ASIA C on admission were discharged as ASIA C in 43% of cases and as ASIA D in 57% of cases
 ASIA D on admission were discharged as ASIA D in 43% of cases and as ASIA E in 57% of cases

A total of 36 patients (55%) underwent surgical treatment. Posterior cervical fusion was performed in nine patients (two patients were stabilized by sublaminar wires, three patients by Halifax hooks, one patient by the Luque frame and sublaminar wires, and three patients by using plates and screws). Such a posterior approach was performed in only one patient during the past 10 years. In all, 27 patients underwent anterior decompression and fusion, using plates and screws (24 out of 27), or by anterior arthrodesis without instrumentation (3/27 cases) (see Table 5). In the period between 1978 and 1988, 11 patients underwent surgery (41%). From 1989 to 1998, 10 patients out of 22 were surgically treated (45%). In the period between 1999 and 2002, 15 patients of a total of 16 underwent surgery (95%), as shown in Table 6. Such a difference in treatment depends, on one hand, on improved surgical facilities, and on the other, upon the consideration that stabilized patients were much more easily managed by nurses and physiotherapists and could be mobilized earlier from bed, resulting in shorter hospitalization, as later mentioned.

The average hospitalization was 20 weeks. Patients affected by complete spinal cord lesion (ASIA A) stayed in hospital for a mean period of 24 weeks, while patients classified as ASIA B were treated for an average time of 27 weeks. The hospitalization was definitely shorter for

patients classified as ASIA C or D (average length of stay 8 weeks).

The average hospitalization time for surgically treated patients was 19 weeks, while it was 23 weeks for those treated conservatively.

Neurological outcome

No neurological deterioration was recorded. In all, 31% (20/65) patients improved neurologically during hospitalisation; 13 improved with regard to the ASIA Impairment Scale (AIS), five with regard to the neurological motor level, and two patients improved with regard to both AIS and neurological motor level (see Table 7).

On discharge, the group of patients conservatively treated showed neurological improvement in only four cases (14% of the total), all of which were initially incomplete lesions, and the improvement concerned both the neurological level and the AIS. Those surgically treated improved with regard to the AIS, neurological level or both, in 16 cases (44% of the total), as shown in Table 7. Such a difference in neurological outcome was statistically significant.

Neurological improvement, regardless of the vertebral lesion treatment, mostly concerned patients with incomplete lesions on admission (23 *versus* 8%). No

Table 4 Correlation between type of vertebral lesion, ASIA Impairment Scale, treatment of the vertebral lesion, neurological improvement and degree of kyphosis at X-ray control

Type of fracture	Number of patients	ASIA impairment scale on admission	ASIA impairment scale on discharge	Surgical treatment of vertebral lesion	neurological improvement in surgically treated	Kyphosis degree in surgically treated	Conservative treatment of vertebral lesion	Neurological improvement in conservatively treated	Kyphosis degree in conservatively treated
Burst	14	A 3 (22%) B 5 (36%) C 4 (28%) D 2 (14%)	A 3 (21%) B 4 (29%) C 3 (21%) D 3 (21%) E 1 (8%)	4 (29%)	2 (50%)	No Kyphosis 3 (75%) 0°–10° 1 (25%) 11°–20° 0 > 20° 0	10 (71%)	1 (12.5%)	No Kyphosis 6 (60 %) 0°–10° 2 (20 %) 11°–20° 1 (10 %) > 20° 1 (10 %)
Teardrop	40	A 28 (70%) B 8 (20%) C 2 (5%) D 2 (5%)	A 26 (65%) B 6 (15%) C 3 (7%) D 4 (10%) E 1 (2%)	24 (60%)	10 (41%)	No Kyphosis 10 (43%) 0°–10° 5 (22%) 11°–20° 4 (13%) > 20° 5 (22%)	16 (40%)	1 (6%)	No Kyphosis 4 (25 %) 0°–10° 3 (19 %) 11°–20° 4 (25 %) > 20° 5 (31 %)
Other types	9	A 3 (33%) B 3 (33%) C 1 (11%) D 2 (23%)	A 2 (23%) B 1 (11%) C 2 (23%) D 3 (32%) E 1 (11%)	7 (78%)	2 (28%)	No kyphosis 5 (71%) 0°–10° 2 (29%) 11°–20° 0 > 20° 0	2 (22%)	2 (100%)	No Kyphosis 0 0°–10° 2 (100%) 11°–20° 0 > 20° 0
Pure dislocation	1	A 1 (100%)	A 1 (100%)	1 (100%)	0	No kyphosis 1 (100%)	0		
No fracture	1	D 1 (100%)	E 1 (100%)	0			1 (100%)	1 (100%)	No Kyphosis 1 (100%)

Table 5 Type of treatment of vertebral lesion and subsequent degree of kyphosis

Type of treatment of vertebral lesion	Number of patients	No kyphosis	0°–10° kyphosis	11°–20° kyphosis	Over 20° kyphosis
Conservative	29/65 (45%)	11/29 (37%)	7/29 (24%)	5/29 (17%)	6/29 (21%)
Anterior fusion	27/65 (41%)	16/27 (59%)	8/27 (30%)	3/27 (11%)	1/27 (4%)
Posterior fusion	9/65 (14%)	3/9 (33%)	0/9 (0%)	1/9 (11%)	4/9 (44%)

Conservatively treated patients developed late spinal deformity (kyphosis) in 62% of cases, while those surgically treated developed late deformity only in 44% of cases

Table 6 Treatment of the vertebral lesions during the period between 1978 and 2002

Year of injury	Surgically treated vertebral lesions		Conservatively treated vertebral lesions	
		%		%
1978–1988	11/27	41	16/27	59
1989–1998	10/22	45	12/22	55
1999–2002	15/16	95	1/16	5

conservatively treated complete lesion improved during hospitalization, while improvement among surgically treated patients was present in five initially complete cases, that regained at least one neurological level but did not change their AIS, and 11 initially incomplete cases that improved both with regard to the neurological level and the AIS (see Table 7).

With regard to the correlation between the timing of surgery and neurological outcome, 11 out of 20 (55%) of those surgically treated within 72 h after the accident improved neurologically, while for those who were surgically treated more than 3 days after trauma, only five patients out of 11 (45%) improved neurologically (see Table 8). Anyway, such a correlation is not statistically significant ($P = 0.447$).

On discharge from hospital, 32 patients (49%) had complete spinal cord lesion according to ASIA-ISCOS classification, 29 were classified as incomplete (44%), and four persons were neurologically intact (Table 3). Out of 29 patients with incomplete spinal cord injury (ASIA B, C or D), 12 had anterior cord syndrome, eight had central cord syndrome, and nine the Brown-Séquard Syndrome (see Table 9).

In order to understand the influence of high dose methylprednisolone (MP) administration according to the NASCIS II and III studies, we analysed the population admitted from June 1994 when we started to apply the protocol as suggested by those studies. In the period from June 1994 through December 2002, we treated 30 patients affected by spinal injuries due to diving accidents, of which 24 were surgically treated, and 20 received high dose MP in the first 8 h after trauma. In all, 15 patients experienced neurological improvement (50%).

In order to judge the influence of both the use of MP and the surgical/conservative treatment of the vertebral lesion, we correlated, by using the Fisher's Exact test,

the use of MP and neurological improvement and, by applying logistic regression, we conducted a multivariate statistical analysis. Even if the number of cases is quite small, we can affirm that the use of MP had a significant positive effect on neurological improvement (Fisher's exact test: $P = 0.005$). The positive effect is confirmed if we consider the effect of the surgical treatment (logistic regression: odds ratio = 17.47654, $P = 0.025$).

Neurological improvement among those who received high doses of MP mainly concerned incomplete lesions (nine out of 10), while only five out of 10 complete lesions improved with time. Neurological improvement in initially complete lesions involved the neurological level exclusively, while for initially incomplete lesions there was improvement both in regaining neurological level and on the ASIA Impairment Scale.

Late spinal deformity (kyphosis)

With regard to late spinal deformity (kyphosis), patients conservatively treated developed some sort of kyphosis in 62% of cases, while those surgically treated developed kyphosis only in 47% of cases (see Table 5).

Conservatively treated burst fractures developed kyphosis deformity in 36% of cases: from 0° to 10° in 12% of cases, from 11° to 20° in 12% of cases and over 20° in 12% of cases. In 75% of those surgically treated there was no kyphosis, while only in one case a very light deformity was recorded (between 0° and 10°).

Conservatively treated teardrop fractures resulted in no kyphosis deformity in only 24% of cases, while kyphosis developed in 76% of cases (deformity within 0–10° was present in 24% of cases, between 11° and 20° was present in 24% of cases and over 20° in 28% of cases).

Surgically treated teardrop fractures developed late deformity in only 57% of cases: 0°–10° kyphosis was present in 22% of cases, 11°–20° kyphosis in 13% of cases and over 20° in 22% of cases (see Table 4).

Among the surgically treated patients, those treated by anterior decompression and fusion developed significant kyphosis (over 10°) in only 15% of cases, while those treated by posterior fusion developed significant kyphosis (over 10°) in 55% of cases (see Table 5).

All vertebral lesions, regardless of the treatment and severity of kyphosis, became stable over time, without signs of instability, according to the statement of White and Panjabi,¹⁴ as detected by dynamic X-ray investiga-

Table 7 Correlation between treatment of vertebral lesion, type of neurological lesion (complete *versus* incomplete) and neurological improvement, with regard to neurological motor level and/or ASIA Impairment Scale

<i>Treatment</i>	<i>Neurological improvement</i>	<i>Neurological improvement in complete lesions on admission (ASIA A)</i>	<i>Neurological improvement in incomplete lesions on admission (ASIA B, C, D)</i>
Conservative	4/29 (14%)	0	4/4 (100%)
Surgical	16/36 (44%)	5/16 (31%)	11/16 (69%)
Total	20/65 (31%)	5/65 (8%)	15/65 (23%)

In all, 31% of patients neurologically improved during hospitalization

Neurological improvement was more frequent in patients whose vertebral lesions were surgically treated than in those conservatively treated (44 *versus* 14%)

Statistical analysis results: Fisher's exact test: $P=0.014$: significant 1-sided Fisher's exact test: $P=0.007$: significant

Neurological improvement mostly concerned patients with incomplete lesions on admission (23 *versus* 8%). No complete lesion on admission conservatively treated improved, while improvement concerning those surgically treated was present in five cases that were complete on admission and 11 cases that were incomplete

Table 8 Correlation between time lapse from trauma to surgery and neurological improvement

<i>Time lapse</i>	<i>Number of patients</i>	<i>Neurological improvement</i>	<i>%</i>
0–24 h	9	4	44
25–48 h	6	4	66
49–72 h	5	3	60
4–10 days	11	4	36
More than 11 days	5	1	20
Total	36	16	44

Fisher's exact test: $P=0.447$: statistically not significant

tion, even in the purely ligamentous injuries (flexion–distraction).¹⁵

Hospitalization was mostly uncomplicated, due to the fact that the patients were otherwise healthy young individuals. Complications occurred in 15 patients (23%) and were more severe in patients with complete SCI (one patient died during hospitalization). The most frequent complication was represented by deep vein thrombosis (four cases, of which two were ASIA A and two ASIA B). Other recorded complications were respiratory problems such as pneumonia (three cases, all of them ASIA A), urinary tract infections (two cases, of which one was ASIA A and one was ASIA B), pressure sores developed before admittance to the Spinal Unit (three cases, of which one was ASIA A and two were ASIA B), gastrointestinal bleeding (one case ASIA A, not treated with high dose of methylprednisolone), syringomyelia (one case ASIA A) and allergy reactions (one case ASIA A).

Conclusions and discussion

It is well known that patients with SCI due to diving accidents are young and otherwise healthy individuals. In our study 95% were males with a mean age of 22 years. This corresponds with other investigations.^{1,4,16,17}

The incidence of diving accidents has been reported to vary between 1.2 and 22% of all SCI.^{4,5,16,17} In our

Table 9 Neurological syndromes on discharge from Spinal Unit

	<i>Number</i>	<i>%</i>
Complete: ASIA A	32	49%
Incomplete: ASIA B, C and D	29	45%
Brown–Sequard syndrome	9	31% of total incomplete
Central cord syndrome	8	28% of total incomplete
Anterior cord syndrome	12	41% of total incomplete
Neurologically intact: ASIA E	4	6% of total lesions

study they represent 5.6% of all patients admitted to our Centre. Of the patients 70% had their accident during full summertime (July and August) which corresponds to the main Italian holiday season.¹⁸

Almost always, the neurologically involved spinal segment is located in the cervical portion. C5 has the highest frequency of probability to be injured and most multilevel injuries included the C5 vertebra.² Teardrop fractures have most often been associated with major neurological motor deficits such as a complete spinal cord injury or an anterior cord syndrome, usually due to a compression of the anterior portion of the spinal cord by retropulsion of fragments of the vertebral body. Even if in most cases we cannot correlate the post-trauma imaging with the neurological outcome, due to the varying dynamics of trauma during the accident (the imaging gives us the picture of the spine and the column only at the end of the traumatic process),¹⁹ burst fractures may more frequently result in a less-encroached canal if compared to teardrop fractures. The usual mechanism of neurological injury in teardrop fractures is a sudden compression of the anterior region of the spinal cord by retropulsion of postero-inferior corner of vertebral body, probably resulting in higher insult on the vascular structure and nervous tissue of the spine.

In the present study 26/40 (65%) patients with teardrop fractures were discharged from hospital with

a neurologically complete lesion and nine out of 13 (69%) patients with incomplete SCI had an anterior cervical cord syndrome.

C6 was the most common neurological level and, at discharge from hospital, 43 patients (66%) were motor complete (ASIA A and B).

Among the incomplete spinal cord injuries (ASIA B, C and D) Anterior Cord Syndrome was the most common (Table 9). This result is similar to other studies conducted by Good *et al*⁶ and by Bailes *et al*.¹

We found that patients who underwent vertebral surgical fixation had a better neurological outcome: 44% of the surgically treated patients improved neurologically, while only 14% of those who received conservative treatment improved. This difference was highly statistically significant (Table 7). Neurological improvement with regard to the Asia Impairment Scale occurred mostly in initially incomplete lesions, while in complete lesions (ASIA A) the reported improvement concerned only the recovery of neurological level.

Patients who received surgical treatment within 72 h after the accident improved neurologically more than patients who received surgery at a later time, but such a difference is not statistically significant ($P=0.447$). Four patients recovered completely, from ASIA D on admission to ASIA E on discharge: two of them received surgical treatment and two received conservative treatment.

Surgical treatment warrants better results with regard to late spinal deformity especially when performed with an anterior approach. Conservative treatment is complicated by a high incidence of late deformity of the cervical spine, although we were not able to detect any form of chronic spinal instability even in flexion-distraction injuries.

The hospitalization time was 4 weeks shorter for the patients who underwent surgery. If surgery is performed, active rehabilitation may start earlier.

Hospitalization was relatively uncomplicated, no serious concomitant injuries were present and the patients could therefore be mobilized early in their hospital course.

We can conclude that, in our experience, patients affected by initially incomplete spinal cord lesions (ASIA B, C and D) due to a diving accident had a better outcome if their vertebral lesion was surgically treated by using an anterior approach. The full recovery observed in four ASIA D admitted cases, was not influenced by the type of treatment (surgical *versus* conservative). Some degree of improvement of the neurological condition, with regard only to the neurological level, has been observed also in initially complete lesions (ASIA A). Such improvement appears to be facilitated by the early surgical intervention. If surgical decompression is performed early and is associated with the use of methylprednisolone according to NASCIS study protocol, it appears, in our study, to result in a better neurological outcome and a shortening of the length of hospitalization.

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