

**Papers read at the Annual Scientific Meeting of the International Medical Society of Paraplegia held in Mulhouse, France, in July 1979
(Part II)**

ANALYSIS OF 139 SPINAL CORD INJURIES DUE TO ACCIDENTS IN WATER SPORTS

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Abstract. Between 1967 and 1978, a total of 2587 patients received primary treatment in the Spinal Cord Injury Centre at the University of Heidelberg. In 212 cases the paralysis was caused by sports or diving accidents. Injuries resulting from accidents in water sports totalled 139, 131 (61.7 per cent) of which could be classified as actual diving accidents. These 131 cases consisted of 129 tetraplegias and only 2 paraplegias. In 5 cases, the tetraplegia resulted from high diving and in 3 cases from scuba-diving. The subjects of the analysis are causes of accidents, segmental diagnosis of neurological deficiency symptoms and prognosis.

Key words. Water Sport; diving accidents; decompression accidents.

RECKLESS diving into man-made lakes, non-swimming areas in public out-door or private pools were the most common causes of tetra- and paraplegia as a consequence of recreation activities. (Braakmann & Penning, 1971; Burke, 1972; Glas, 1977; Guttman, 1972, 1976; Kaczmarek, 1964; Kawalramani & Kraus, 1977; Klaus, 1960; Leitholt, 1963; Maury, 1966; Paeslack, 1971; Piotrowsky, 1965; Schneider, 1962; Steinbrück & Paeslack, 1978; Taylor & Blackwood, 1948).

Between 1967 and 1978, a total of 2587 patients received primary treatment in the Spinal Cord Injury Centre at the University of Heidelberg (Table I). Two hundred and twelve (8.2 per cent) of them were sports or diving accidents. Diving accidents were by far the most common causes of spinal cord injuries,

TABLE I

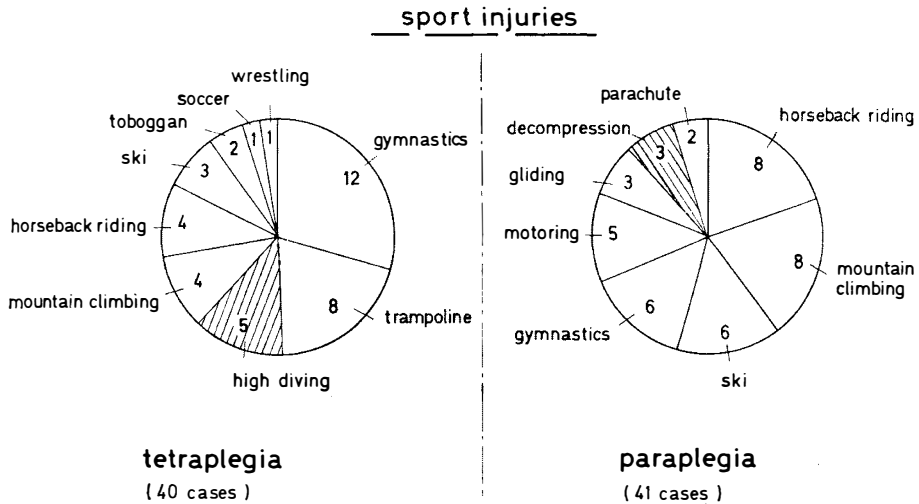
Total number of sports injuries with tetra- or paraplegia

| | |
|----------------------------|-------------|
| Total number of patients | 2587 |
| Sport and diving accidents | 212 = 8.2% |
| Diving accidents | 131 = 61.7% |
| Tetraplegia | 129 = 98.5% |
| Paraplegia | 2 = 1.5% |
| Sport injuries | 81 = 38.3% |
| Tetraplegia | 40 = 49.3% |
| Paraplegia | 41 = 50.7% |

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amounting up to 131 cases (61.7 per cent), 129 of which (98.5 per cent) resulted in tetraplegia and only 2 in paraplegia. In the total of 81 (38.3 per cent) recorded real sports accidents the distribution of tetra- and paraplegia was relatively balanced. Another 8 accidents due to water sports are also contained in this figure: high or springboard diving caused tetraplegia in 5 cases, and in 3 cases paraplegia was caused by skin-diving. The great number of tetra- and paraplegias which received primary treatment in our Centre has been analysed very carefully (Fig. 1).

In comparison with the extremities the risk for the spinal cord in sports is



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FIG. 1
Sports accidents with tetra- or paraplegia.

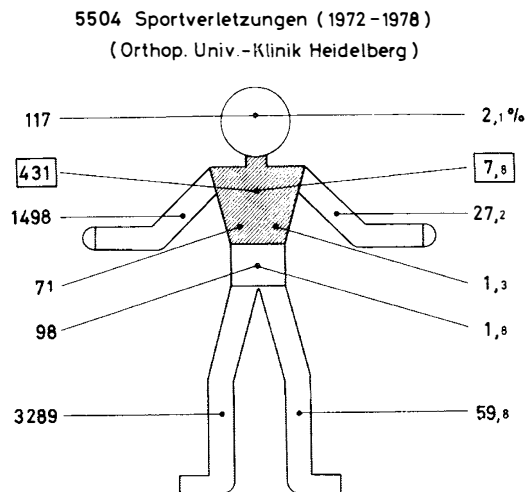


FIG. 2
Localisation of injuries in 5504 sports accidents.

relatively small. This is shown by the statistics on the types of injuries in the total of 5504 sports accidents that received primary treatment in the Orthopaedic Hospital Heidelberg. The spinal cord was only involved in 431 cases (7.8 per cent) (Fig. 2).

In all diving accidents, including high diving, the injuries were located almost exclusively in the cervical vertebrae and were caused by similar accident mechanisms: There were hyperflexion injuries on the one hand (luxation, severe sprain, and compression) and hyperextension injuries on the other (sprain and compression). Cases of hyper-rotation or lateral flexion were rare (Table II). In our total of 131 diving accidents, the diagnosis was almost always combined compression-luxation fracture of the fifth cervical vertebra in 65 cases (49.6 per cent)

TABLE II

Forms and accidental mechanisms in the lower cervical vertebrae

| Lower cervical spine injuries | |
|-------------------------------|-----------------------------------|
| 1. | Hyperflexion injuries |
| | (A) Luxation |
| | (B) Sprain |
| | (C) Compression |
| 2. | Hyperextension injuries |
| | (A) Sprain |
| | (B) Compression |
| 3. | Hyperrotation and lateral flexion |

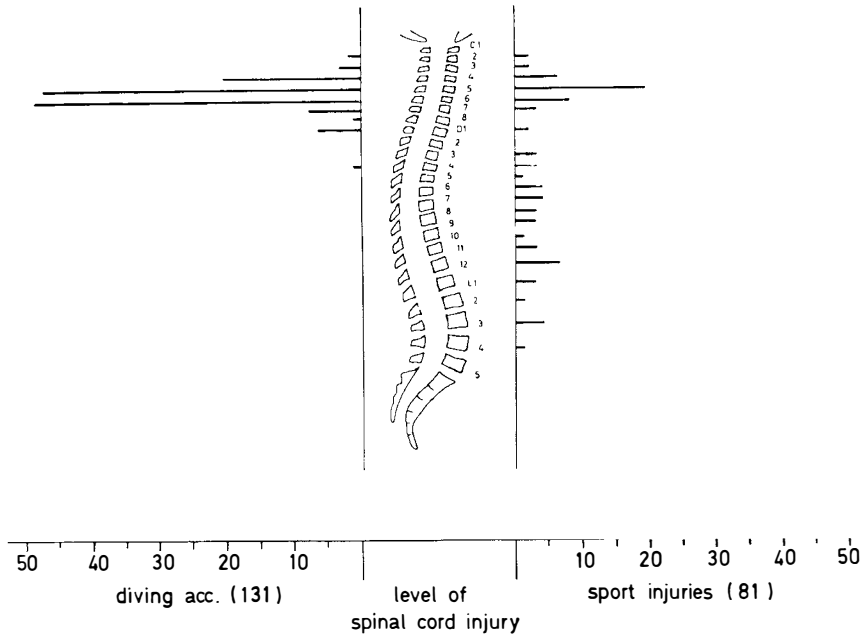
TABLE III

Type of injury and localisation of fracture in 131 diving accidents

| Diving accidents | | |
|-----------------------------|------------------|------------------|
| Localisation vertebral body | Total amount 131 | Percentage 100.0 |
| Fracture CVB 2 | 2 | 1.5 |
| 3 | 1 | 0.8 |
| 4 | 12 | 9.2 |
| 5 | 65 | 49.6 |
| 6 | 34 | 25.9 |
| 7 | 10 | 7.6 |
| Luxation | 3 | 2.3 |
| Neg. Radiology | 3 | 2.3 |

and of the sixth cervical vertebra in 34 cases (25.9 per cent). Pure luxations were only found in 3 cases. Injuries which gave no radiological evidence were equally rare (Table III).

Neurological deficiency symptoms after diving accidents centred above all on the fifth and sixth cervical segments. Paralysis occurred below the fifth cervical vertebra in 47 cases (35.9 per cent) and below the sixth cervical vertebra in 48



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FIG. 3

Localisation of neurological lesions in 212 sports and diving accidents.

cases (36.6 per cent). These two segments are particularly injury prone as we have here maximum mobility and very little protection by bones and soft parts combined with minimal flexibility of the marrow in the relatively narrow spinal canal. Thoracic paralysis was found in only two cases (Fig. 3).

The number of juvenile casualties is especially high. We recorded 11 patients of under 15 and 54 (41.3 per cent) between 16 and 20 years of age. The number of accidents with persons under 25 involved amounted to 99 (75.6 per cent) (Table IV). Our total of 131 diving accidents was made up of 125 men and only

TABLE IV
Age distribution in diving accidents

| Diving accidents | | |
|------------------|---------------------|----------------------|
| Age | Total amount 131 | Percentage 100.0% |
| Below 10 | 1 | 0.7 |
| 11-15 | 10 | 7.6 |
| 16-20 | 54 | 41.3 |
| 21-25 | 34 | 25.9 |
| 26-30 | 17 | 13.1 |
| 31-35 | 7 | 5.3 |
| 36-40 | 8 | 6.1 |

6 women. This may suggest that uncontrolled hyperactivity and lack of cautiousness are less common in females.

One hundred and six (80.9 per cent) accidents resulted from diving into man-made lakes and gravel pits with mostly soft muddy ground or from diving into unknown waters or shallow rivers. In the majority of cases, bystanders were quick to rescue the injured person and get medical help. Descriptions of the accident in general are usually quite clear, details on the actual accidental mechanism, however, in particular with respect to the position of the head, can only very seldom be obtained. A short black-out after the impact is reported occasionally

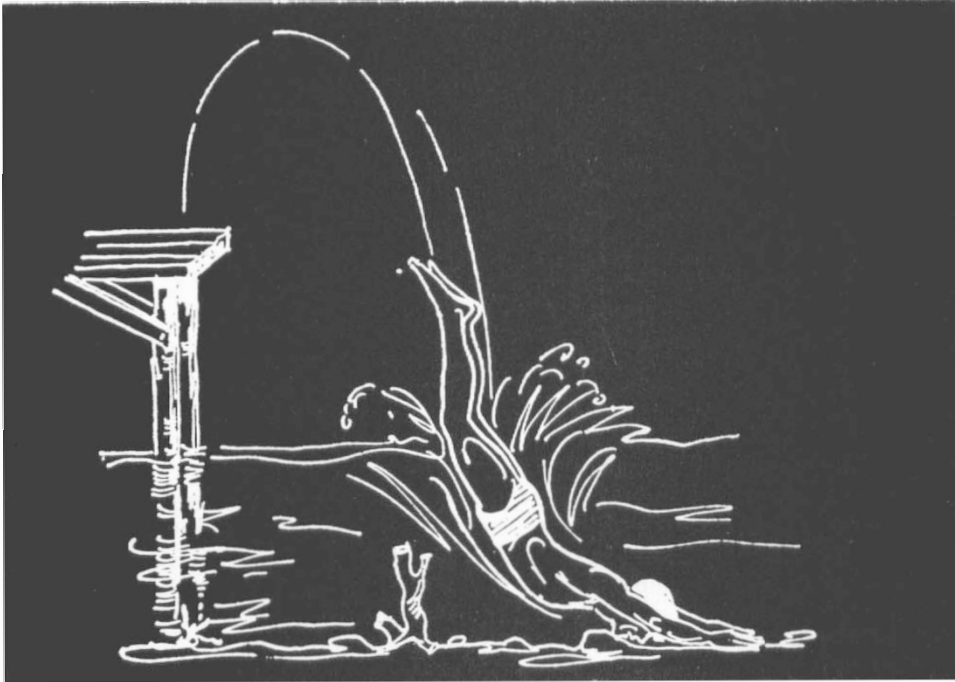


FIG. 4

Mechanism of impact in head-first dives into shallow waters (from HEISS).

whereas descriptions of a violent extension backward of the neck are rather frequent (Fig. 4). The majority of patients had been actively diving and only seldom, the injury resulted from a fall due to slipping or being pushed into the water (Figs. 5 & 6).

Special dives like the swan or swallow dive are particularly dangerous because the arms are not stretched out above the head but towards the side. The extreme is the so-called 'wooden soldier' where the diver holds his arms close to his sides and darts torpedo-like into the water several metres deep. The head is completely unprotected and the impact on the ground—almost always entailing hyperflexion—transfers the total kinetic energy on to the cervical vertebral column. Twenty-five of the accidents took place in public outdoor or private swimming-pools. This ratio seems to have been rising considerably in recent years. Causes of accidents recorded here were diving into the non-swimming area or on to the bottom of the

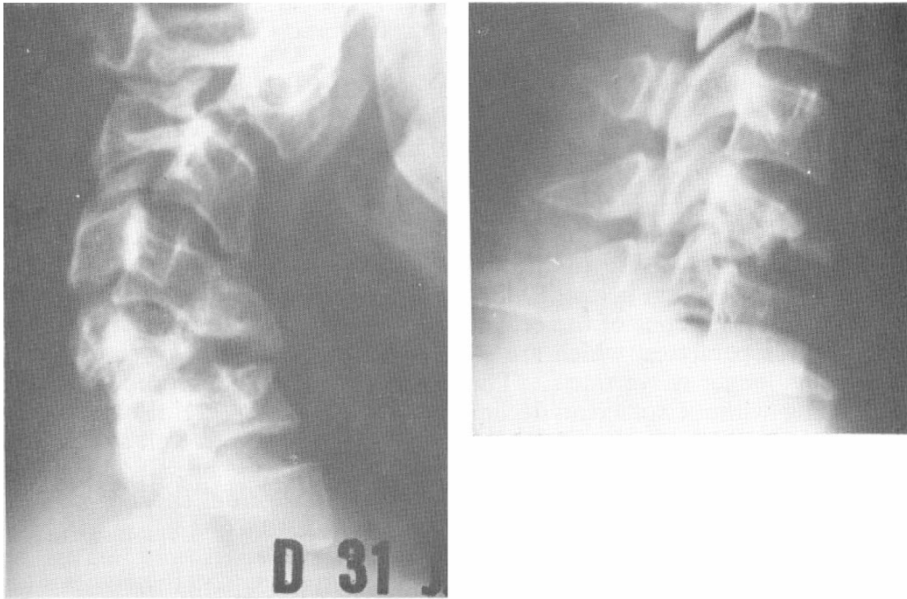


FIG. 5

J. D., aged 29. Accident due to diving into man-made lake; compression fracture of fifth cervical vertebra—2 years after the accident. *Present condition.* Severe compression-luxation fracture of fifth cervical vertebra with dorsal dislocation, ventral tilting of fourth cervical vertebra, osseous bridging between fourth and sixth vertebrae. Considerable gibbosity. *Diagnosis.* Complete tetraplegia below fifth/sixth cervical vertebrae. Condition after laminectomy of third to sixth cervical vertebra.

FIG. 6

F. S., aged 18. Dive into man-made lake; severe compression fracture of sixth cervical vertebra and dorsal luxation opposite to seventh cervical vertebra. *Diagnosis.* Complete tetraplegia below seventh cervical vertebra.

pool or on top of another swimmer. Accidents also happened on slides, above all as a consequence of sliding down head first with the arms held close to the sides. Alcohol was involved in several incidents and often times, divers had jumped down from higher levels for 'showing-off' reasons.

In the cases of the 5 high and springboard divers the accident was attributed to shallow pools and also to mistakes on the part of the divers themselves. The head always hit the bottom. Impact on the water surface has not become known to be the cause of any severe injury, a fact that had also been observed by Schneider in his study of cliff-diving in Acapulco.

While in relation to the total number of patients treated scarcely 10 per cent of tetraplegics and 4 per cent of paraplegics died, there was only 1 death resulting from a diving accident paraplegia. Reasons for the promising prognosis are the young age, good physical condition and—as compared to traffic accidents—the relatively small number of cases with multiple injuries. Consequently, the duration of treatment after diving accidents was clearly shorter than the normal rate. It is furthermore worth while looking at 3 cases of paraplegia caused by decompression accidents in skin-diving. Sport diving has become increasingly popular in recent times and scuba gear is rented at many holiday resorts without

any attention being paid to basic theoretical knowledge on physical principles, general risks and dangers and often without any practical training. Hence, the number of severe accidents is very high. In 1975 in West Germany alone, there was an alleged number of 200 skin-diving fatalities (Glas). When diving into greater depths with scuba gear nitrogen dissolves in the blood serum and diffuses into the various tissues, showing special affinity to the lipid-containing nervous system. The saturation depends on the depth and duration of submergence; a certain rate of ascent must be observed therefore, once zero-time has been fully exploited. Due to quickly falling external pressure too rapid ascent can lead to the formation of bubbles in the tissue fluids and in the blood. Skin tingling and bends (pain in the joints) belong to the minor symptoms—the by far greater risk consists in possible lesions of the central nervous system with cerebral and spinal dysfunctions or paralyse, which are especially critical for the lower part of the body with its longer nerve tracts. The accidents resulted from repeated diving and surfacing without sufficient decompression periods. Careful observance of decompression tables and checking of the diving equipment as well as the refusal to go for record dives should therefore be basic principles especially for all those who did not receive any training in this particularly dangerous sport.

Descriptions of cases of decompression accidents

Dr C., aged 26. Diving down to 40 metres. Time shortage and insufficient air reserves for surfacing. Non-observance of decompression period. After surfacing pain in the large joints and paresthesia, followed by ascending paralysis, first only in the left, later also in the right leg. Complete paraplegia after $1\frac{1}{2}$ hours. Treatment in compression chamber after 7 hours.

Diagnosis: paraparesis below seventh dorsal vertebra.

Sch. A., aged 29. Too rapid ascent from diving at 45 metres. Defective diving equipment. Ten to 15 minutes after surfacing pains in the back muscles. Immediate descent to 3 metres under surface with repeated exchange of scuba gear. After 1 hour, tingling sensation and trembling of the legs and increasing myokinetic paralysis mainly on the left side. Treatment in the compression chamber every day for over 2 weeks.

Diagnosis: Incomplete paraplegia below twelfth dorsal/first lumbar vertebrae.

H. H., aged 24. Diving at 48 metres. Rate of ascent not observed. At once severe pain in the arms, recompression; after surfacing, pain also in the legs. Immediate treatment in compression chamber with remaining weakness in the left leg. Three weeks later, again diving down to 46 metres, in zero-time. After surfacing, however, pain in the lungs. In the afternoon, again diving down to 37 metres. Despite correct rate of ascent—very likely due to the previous damage and the second diving—weakness in the right leg, progressing rapidly. Treatment in compression chamber.

Diagnosis: Incomplete paraparesis below eighth dorsal vertebra.

Over 16 million people belong to the 'Deutsche Sportbund', the West German Sports Association, alone. The total number of sports accidents is high, the percentage of tetra- or paraplegias, however, is fortunately low. Since most accidents result from lack of cautiousness, great importance must be attached to the prevention of accidents.

Regular public warnings at the beginning of the swimming season in the mass media and the posting of signs at lake shores are indispensable. Careful checking of the diving apparatus, meticulous training and observance of all safety rules play a significant part especially for the diver.

SUMMARY

Between 1967 and 1978 a total of 2587 patients received primary treatment in the Spinal Cord Injury Centre of Heidelberg. Two hundred and twelve (8.2 per cent) of the cases were caused by sports and diving accidents. From the accidents resulting from water sports there were 131 diving accidents, 5 high diving and 3 from scuba-diving.

RÉSUMÉ

De 1967 à 1978 au total de 2 587 patients à été traités au Centre de Paraplégiques de Heidelberg à la phase aiguë. 212 (8.2%) des cas ont été blessés à la suite d'accidents de sport et de plongée. Parmi les accidents dus aux sports aquatiques on a noté 131 accidents baignade, 5 plongeurs, 3 accidents de décompression.

ZUSAMMENFASSUNG

Im Zentrum für Querschnittgelähmte der Univ. Heidelberg wurden insgesamt 2587 Patienten zwischen 1967 und 1978 erstbehandelt. Bei 212 (8,2%) war die Lähmung Folge eines Sport- oder Badeunfalls. Insgesamt 139 mal waren die Unfälle Folgen des Wassersports. Um eigentliche Badeunfälle handelte es sich 131 mal (61,7%), dabei waren 129 Tetraplegien und nur zwei Paraplegien. 5 mal kam es zu einer Tetraplegie beim Turmspringen und 3 mal zu einer Paraplegie beim Tauchen. Über Ursachen, Höhe der neurologischen Ausfallserscheinungen und Prognose wird berichtet.

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