# Complete C4-C5 Dislocation Secondary to Shallow Water Diving in a Child: A Case-Based Update

## *Luxação completa de C4-C5 secundária a mergulho em águas rasas em uma criança: atualização baseada em caso*

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## Abstract

**Introduction** Pediatric spinal cord injury (PSCI) is rare, especially secondary to shallow water diving, with only a few cases recorded in the literature. Due to the low standardization in the diagnosis and treatment of this condition, each of these cases requires a personalized approach.

**Case Description** A 10-year-old female patient presented with tetraparesis and C5 sensory level secondary to spinal trauma due to shallow water diving. Computed tomography (CT) revealed complete C4-C5 dislocation, which led to a neurosurgical approach preceded by an intraoperative manual maneuver to reduce the dislocation. Following complete surgical reduction of the dislocation, the patient presented immediate significant neurological improvement.

**Conclusion** Children need to be warned about diving, as SCI due to shallow water diving has a poor neurological outcome. Despite that, early diagnosis, stabilization, and surgical approach can lead to immediate significant neurological improvement. Considering the peculiarities of pediatric patients and the existence of varying care techniques in the literature, more studies comparing surgical and nonsurgical outcomes are fundamental.

**Keywords**
- pediatric spinal cord injury
- shallow water diving
- cervical dislocation
- spinal trauma management

## Resumo

**Introdução** A lesão medular pediátrica é rara, especialmente secundária ao mergulho em águas rasas, com poucos casos registrados na literatura. Devido à falta de padronização no diagnóstico e manejo desses casos, cada um deles requer uma abordagem individualizada.

**Descrição do Caso** Paciente do sexo feminino, de 10 anos de idade, que evoluiu com tetraparesia e nível sensitivo C5 secundário a trauma raquimedular após mergulho em

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águas rasas. A tomografia computadorizada revelou luxação completa de C4-C5, o que levou a uma abordagem neurocirúrgica precedida por uma manobra manual intraoperatória para redução da luxação. Após a redução cirúrgica completa, a paciente apresentou imediata melhora neurológica significativa.

**Conclusão** Deve-se orientar as crianças quanto aos mergulhos, pois lesão medular secundária ao mergulho em águas rasas não apresenta bom desfecho neurológico. No entanto, o diagnóstico precoce, a estabilização e a abordagem cirúrgica podem resultar em imediata melhora neurológica significativa. Levando em conta as peculiaridades dos pacientes pediátricos e a existência de diferentes técnicas de cuidado na literatura, é fundamental que se conduzam mais estudos de comparação dos desfechos cirúrgicos e não cirúrgicos.

**Palavras-chave**
- ► trauma raquimedular pediátrico
- ► mergulho em águas rasas
- ► luxação cervical
- ► manejo de traumas raquimedulares

## Introduction

Pediatric spinal cord injury (PSCI) is rare, with an estimated incidence of 1.9 to 4.6 per every million people, and only 10% of the cases occur in children younger than 15 years of age.[1] The cervical spine is only involved in 1% of all pediatric injuries,[2] as observed in the case herein reported. Spinal cord injury (SCI) has devastating consequences for the pediatric population due to the life-altering changes it causes, such as psychological limitations and loss of quality of life.[1] Thus, a good understanding of the traumatic mechanisms, patterns of injury, and differences in the management of adults and children with this type of lesion is mandatory for an effective management.[3]

Special attention should be dedicated to SCI due to shallow water diving, defined as diving in water with a. depth of up to 1.5 m.[4] Fall- or dive-related cervical injuries that often lead to tetraplegia and death make up a subgroup of cervical spine injuries that occur mainly due to hyperflexion and compression. Teaching children how to prevent spinal trauma is essential to reduce its incidence. Children with SCI are more likely to evolve with paraplegia or complete injuries than adults; however, their neurological improvement tends to be better.[1] The pediatric population with spinal trauma due to shallow water diving needs rapid evaluation, and the diagnostic and therapeutic flowcharts must be applied accurately and in an individualized manner.[4]

## Case Presentation

A 10-year-old female patient, after shallow water diving, evolved with loss of consciousness and partial drowning. After cardiopulmonary resuscitation by a family member, the child regained consciousness and noticed the development of tetraparesis and sensory loss from the neck down. Upon hospital admission, her tetraparesis was graded according to the Medical Research Council (MRC) scale as 2/5 on the right arm, 1/5 on the left arm, and 1/5 on both legs. Her sensory loss was graded as C5 sensory level. Her classification on the American Spinal Injury Association (ASIA) impairment scale was ASIA A. Computed tomography (CT) showed a complete C4-C5 dislocation and a median fracture in the C4 vertebral body (►**Fig. 1**), which led to a transfer to the regional neurosurgical center.

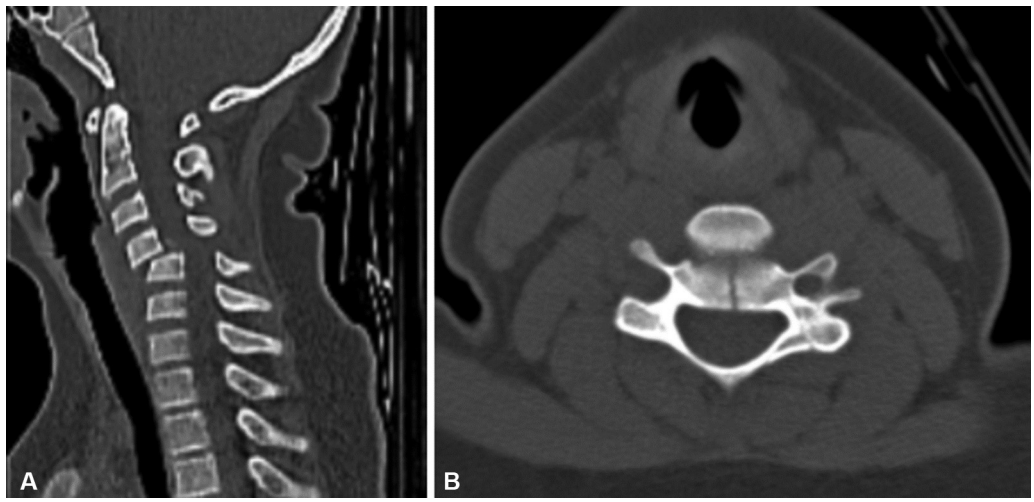


**Fig. 1** Preoperative images. (**A**) Sagittal computed tomography (CT) scan showing complete C4-C5 dislocation. (**B**) Axial CT scan showing a median fracture in the C4 vertebral body.

 

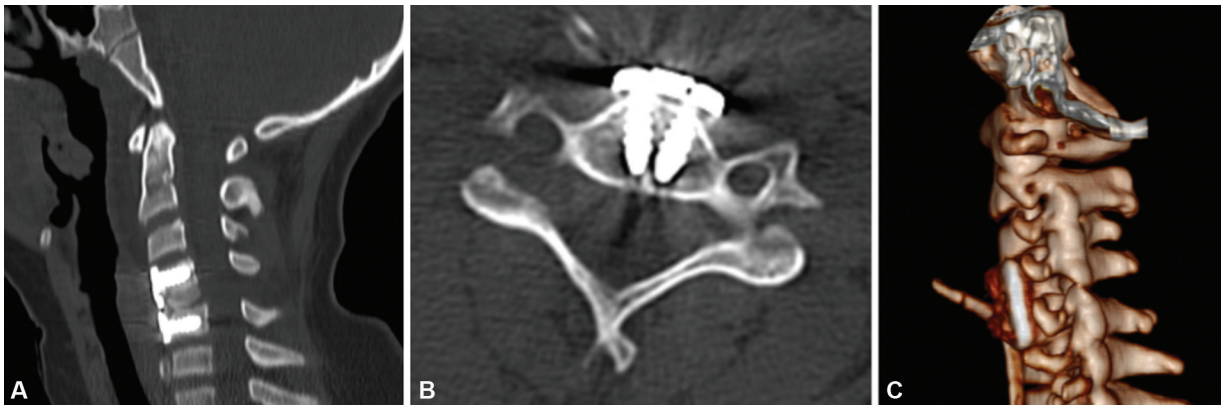


**Fig. 2** Postoperative images. (**A**) Sagittal CT scan showing the correction of the C4-C5 dislocation. (**B**) Axial CT scan showing adequate placement of screws in the anterior cervical arthrodesis (ACA) and C4 median fracture.

### Surgery

An intraoperative manual maneuver was performed to reduce one facet joint dislocation. Subsequently, the patient underwent a cervical anterior approach (CAA), which enabled, through the use of a intersomatic retractor and the impaction of C4 vertebral body, the reduction of the second joint facet, as well as complete reduction of the dislocation.

We then performed a C4-C5 discectomy using a neurosurgical microscope, ensuring the ablation of the centrally located C4-C5 herniated disc, which had ruptured the posterior common vertebral ligament and compressed the dural sac. Then, the patient underwent an anterior cervical arthrodesis (ACA) using a 25-mm anterior plaque fixed by four 12-mm screws, to properly establish the cervical spine (►**Fig. 2**), combined with an iliac graft insertion at the C4-C5 intervertebral disc.

### Postoperative Course

The following day, the patient was referred for follow-up in the pediatric Intensive Care Unit (ICU), with immediate improvement of one strength degree in each limb. A week later, she was discharged, with adequate physiological parameters and vital signs, and was referred for physiotherapy follow-up.

In the reevaluation after 1 month, the patient preset significant improvement ion terms of the degree of strength: grade 4/5 on both legs and left arm, 3/5 on the right arm, and satisfactory C5 sensory level improvement.

## Discussion and Literature Review

### Epidemiology and Etiologies

Spinal cord injury is a relevant cause of morbidity and mortality that affects mostly young adults of. Although rare, PSCI has severe consequences, especially if not adequately treated, leading to vertebral deformities and, consequently, sagittal imbalance. Compared with adults, PSCI in children presents a higher risk of a variety of complications, such as scoliosis and hip dysplasia.

Falavigna et al.[1] found that most children with SCI were 12- to 17-year-old boys. Furthermore, falls were the most prevalent cause of the injuries, followed by motor vehicle accidents, shallow water diving, assault, and falling off a bicycle. The most common type of fracture was caused by compression, and most cases were of single-level fractures.[1]

Subaxial cervical spine injuries primarily appear after bone consolidation of the cervical spine in children who are submitted to high-energy trauma. In patients over 18 years old, the biomechanical properties of the cervical spine are very similar to those of an adult, which explains why the lesion pattern is similar to that of adults in those cases. Subaxial injuries between C5 and C7 are the most frequent ones. In addition, the death rate is considerably lower than in upper cervical spine injuries.[2]

In the presence of SCI, damage can be primary or secondary. The primary injuries occur at the time of the impact due to a mechanical lesion, and they are usually not reversible. Secondary injury is a continuous process that can take place hours to months later, and the greater contributor to this event is cord hypoperfusion.[3]

The mechanisms of subaxial cervical trauma are classified as compressive or distractive flexion; compressive, distractive or lateral extension; and vertical compression. The injury can be a fracture with or without luxation and a luxation without a fracture. The most prevalent mechanism is flexion combined or not with fracture of the cervical vertebrae.[4]

### Clinical

In children, PSCI can manifest in different ways when compared with adults, mainly because of anatomical differences, such as a greater cervical spine elasticity, due to incomplete ossification of the cervical vertebrae and more elastic ligaments, which often leads to subluxation instead of bone fracture, especially in children younger than 8 years of age.[2,3] The symptoms are related both to the level and severity of the injury. In the case herein reported, the subluxation led to tetraparesis and a C5 sensory level. Pediatric spinal cord injury is associated with neck pain, rigidity of the neck musculature, autonomic disorder, and motor or sensitive symptoms, varying according to the patient's injury, most of the time an incomplete SCI.[3,5] Complete SCI, as presented by our patient, with sensitive or motor deficit below the injury level, is frequently

 

irreversible and leads to devastating consequences.[3] Despite that, our patient is having a satisfactory follow-up since the surgery.

Cervical spine damage must be remembered in cases of associated injury pattern, unconsciousness, cervical rigidity, intense neck pain, or neurological syndromes secondary to radiculopathy or myelopathy. Children usually present lower levels of neurological damage than adults.[3]

### Diagnosis

In cases of suspicion of PSCI, imaging is fundamental. Radiographic evaluation using the criteria of the National Emergency X-Radiography Utilization Study (NEXUS) is controversial, and it is only recommended in children above the age of 9, due to its low sensitivity below this age group. Computed tomography has greater sensitivity compared with radiography, but it has limited advantages. It should be performed in cases in which radiography does not confirm, but raises a high suspicion of PSCI, if there are focal neurological signs or paresthesia in the arms or legs. It is also noteworthy that children are more likely to present SCI without radiographic abnormalities,[6] which requires further investigation. Magnetic resonance imaging (MRI) is the best imaging method to evaluate these cases, and it can assess ligament damage that may go unnoticed on the CT, but it is necessary to consider the longer time required for image acquisition and its limited availability, which may be inadequate for unstable patients in certain scenarios.[2,3]

### Initial Stabilization

The Advanced Trauma Life Support (ATLS) principles apply to the first approach to cervical PSCI. Immobilization in a neutral position must be performed at the scene of the accident and maintained until the patient can be fully assessed in an in-hospital setting. Immobilization prevents instability, resulting in a scenario in which the neurological deficit does not progress during the transfer of the child. Traditionally, similarly to adults, children with possible cervical SCI have been transported using a spinal board with a cervical collar applied, with blocks on both sides of the head and a tape to immobilize it. As young children have heads that are proportionally larger than their bodies, when lying on a spinal board, their heads tend to assume a significant flexion degree. That issue can be addressed by using an occipital recess.[3]

Preventing hypotension is mandatory during the resuscitation phase to prevent cord ischemia, and appropriate organ support in an ICU is necessary for the subsequent management. A detailed exam should be performed to stratify PSCI patients using the ASIA impairment scale to determine the functional impairment caused by the injury.[3]

Due to the fact that children have greater elasticity when compared with adults, immobilizing the cervical spine in children is a difficult task. The rigid collar is important to achieve temporary external fixation, even though a certain degree of rotation still occurs, and the upper and middle cervical spine regions tend to be more susceptible to movements. The halo device for external fixation is usually problematic in children. The Minerva body jacket precludes the necessity of pins, avoiding potential complications resulting from the use of the halo device; however, there is evidence that it is as beneficial as the halo only in middle and low cervical spine stabilization.[3]

### Surgical Management

First, according to the current guidelines, there is no evidence to support the use of potentially neuroprotective agents (such as steroids) or methods such as hypothermia to treat PSCI.[7] Considering this scenario, surgical fixation is required in some cases, as we have performed in our patient, to provide bone stability and spinal cord protection. The indications include non-reducible deformities, unstable injuries, progressive deformity, and decompression of neural tissues.[5] Although the internal fixation principles are similar in children and adults, the potential growth of the pediatric spine needs to be considered, as instrumentation can affect normal growth and change the physiological curvature of the spine.

Anterior and posterior subaxial instrumentation and other techniques are being used more frequently in pediatric patients. There are few moderate or high-quality studies regarding the use of these techniques in children. Low-profile anterior plating has been applied in children as young as 3 years old. Shacked et al.[8] used the CAA for autograft arthrodesis of cervical segments in pediatric patients, as we have performed in our case, and advocate a more widespread use of the CAA as the procedure of choice in traumatic PSCI, as this technique provides direct visualization of the lesion, which enables effective repair and stabilization, and significant long-term neurological improvement.

The surgical decompression timing for PSCI is another topic of discussion. A retrospective study[9] that included 73 children with traumatic SCI with indication for surgery concluded that surgical management should be performed immediately in children with neurological disfunction following the trauma.

### Prognosis

Children must be followed up closely to monitor possible complications after the surgery. In patients whose spine has the potential to grow after the procedure, long-term and frequent follow-up is necessary, as instrumentation may lead to deformities.[3] There are few observational studies[10] that have analyzed long-term outcomes, but they are promising. A multicenter study[11] assessing the long-term effects of rigid instrumentation and surgical fusion found that most of patients (95%) presented complete or significant resolution of the neurologic symptoms.

## Conclusion

Children need to be warned about diving, as SCI due to shallow water diving has a poor neurological outcome. Despite that, early diagnosis, stabilization, and surgical approach can lead to immediate significant neurological improvement. Considering the peculiarities of pediatric patients and the existence of varying care techniques in the literature, more studies comparing surgical and nonsurgical outcomes are fundamental.

 

### Declaration of Patient Consent

The authors state that written informed consent regarding the publication of any potentially identifiable data included in this article was read and signed by the patient.

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### Conflict of Interests

The authors have no conflict of interests to declare.

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