Surgical Stabilization of C2–C3 Dislocation in Children Younger Than Eight Years

Claudio A. Fernández,[*] María Gabriela Miranda,[*,] María Emilia Moreiro Varela[*,**]**
[*]*School of Medical Sciences, Universidad Nacional de La Plata, Buenos Aires, Argentina*
[**]*Orthopedics and Traumatology Service, Hospital de Niños "Sor María Ludovica", La Plata, Buenos Aires, Argentina*

ABSTRACT
Introduction: Traumatic dislocations of the C2–C3 segment in children are associated with a high risk of neurological injury and even death due to their inherent instability. Once the diagnosis is confirmed, surgical treatment is indicated. We describe a double-fixation technique performed during the same surgical procedure. Initially, reduction and primary stabilization of the C2–C3 segment are achieved using sublaminar cerclage or transfixation with a nonabsorbable suture. Subsequently, osteosynthesis with facet screws is performed. In younger children, minifragment screws and a custom-made plate are used, whereas in older children, standard adult instrumentation can be employed; in both cases, fixation follows the Magerl technique. **Conclusion:** The combined and complementary use of two stabilization techniques provides greater intraoperative safety and yields stable long-term outcomes.
Keywords: Children; C2-C3 dislocation; surgical stabilization.
Level of Evidence: IV

Estabilización quirúrgica de la luxación de C2-C3 en niños menores de 8 años

RESUMEN
Introducción: Las luxaciones traumáticas del segmento C2-C3 en niños conllevan un alto riesgo de daño neurológico e incluso de óbito debido a su inestabilidad. Una vez que se confirma el diagnóstico, el tratamiento indicado es la cirugía. Se detalla una técnica de doble fijación efectuada en el mismo acto quirúrgico. En primer lugar, se practica la reducción y la estabilización primaria mediante un cerclaje sublaminar o transfixión con hilo no absorbible del segmento C2-C3. Posteriormente, se realiza la osteosíntesis con tornillos facetarios. En niños pequeños, empleamos tornillos para minifragmentos y una placa *ad hoc*, en tanto que, en niños mayores, se puede utilizar material de adultos, en ambas situaciones, según la técnica de Magerl. **Conclusión:** El uso combinado y complementario de dos técnicas de estabilización proporciona más seguridad intraoperatoria y resultados estables en el tiempo.
Palabras clave: Niños; luxación de C2-C3; estabilización quirúrgica.
Nivel de Evidencia: IV

INTRODUCTION

According to statistics from the *National Pediatric Trauma Registry* of the United States, traumatic injuries of the cervical spine in children account for 1.5% of all trauma admissions.[1] This represents 60 to 80% of spinal traumatic conditions, including fractures, ligamentous injuries, and combined lesions.[2] These injuries are more prevalent in males, and the etiology includes, in decreasing order of frequency, traffic accidents, falls, sports-related activities, non-accidental trauma, and labor dystocia.[3-7] Upper cervical spine injuries are twice as frequent as those affecting the subaxial segment, following a bimodal distribution at 3 and 16 years of age. However, dislocations are five times more common, with a reported prevalence ranging from 25% to 40%.[1,2] Approximately one third of these children present partial or complete neurological involvement associated with SCIWORA (*Spinal Cord Injury Without Radiological Abnormalities*), with a reported frequency between 4.5% and 35%.[2] Mortality rates

Received on March 10th, 2025. Accepted after evaluation on June 2nd, 2025 • Dr. CLAUDIO A. FERNÁNDEZ • claudioalfredofernandez619@gmail.com https://orcid.org/0000-0003-2350-3885
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are significant in young children with complete neurological deficits, reaching up to 17%.[1] Several anatomical and physiological factors confer increased susceptibility to trauma in this region, including tissue hyperlaxity, particular configuration of the occipitoatlantal joint, reduced muscle tone, disproportion between cervical and cephalic volumes, and decreased inclination of the articular facets. The C2-C3 segment, which represents the transition zone between the mobile craniocervical and subaxial regions, is particularly prone to fractures, pathological subluxations, and dislocations, a phenomenon known as the *fulcrum effect*.[2]

The objective of this article is to describe the surgical strategy and technique used for the stabilization of C2-C3 dislocations in children younger than 8 years of age.

SURGICAL TECHNIQUE

The patient is placed in the prone position on a silicone mat with lateral supports. The arms are extended and secured to the trunk, and the head is positioned on a silicone headrest to protect pressure-sensitive areas. This position is secured with adhesive tapes fixed to the operating table, and the upper limbs are gently pulled caudally from the shoulders to improve exposure of the cervical region. The iliac crest must remain free and accessible for harvesting autologous bone graft. The entire surgical procedure is supervised by a neurophysiologist using multimodal intraoperative monitoring.

Once the surgical field has been prepared, the affected osseous segment is confirmed using an image intensifier, and the skin is marked with indelible ink. A posterior approach is used. After incision of the skin and fascia, the spinous processes of the axis and C3 are palpated to minimize the extent of surgical exposure. Subperiosteal dissection is extended to the articular processes, which is an important step to prevent unnecessary extension of the fusion area. The dislocation is reduced with extreme care using Backhaus forceps. When reduction is difficult, a small dissector or periosteal elevator may be used to mobilize the facet joints. Primary stabilization is achieved with a suture composed of two strands of non-absorbable Prolene® 2.0 using one of two techniques: 1) double sublaminar cerclage at the C2-C3 level, similar to the Brooks and Jenkins technique but applied at an infradjacent level (Figure 1)[8] or 2) osseous transfixion using a 2.5 mm diameter drill at the spinolaminar junction of the axis. The suture is passed through the drilled tunnel and then curved beneath the spinous process of C3 without crossing the midline (Figures 2 and 3).

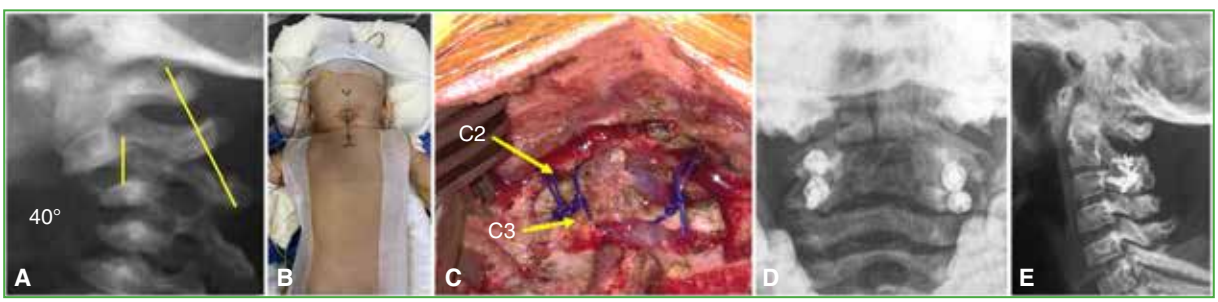

Figure 1. 9-month-old girl with a history of a traffic accident, presenting with central spinal cord syndrome and right hemidiaphragm paralysis. **A**. Lateral radiograph of the cervical spine showing unilateral C2-C3 dislocation with 40° kyphosis. **B**. Prone operative positioning and skin marking. **C**. Intraoperative image after reduction and double sublaminar cerclage of C2-C3 using Prolene® 2.0 suture (blue). **D and E**. Cervical spine radiographs, transoral anteroposterior and lateral views, obtained at 9 years of follow-up. Facet osteosynthesis using 2.0 mm diameter minifragment screws and a custom titanium miniplate.

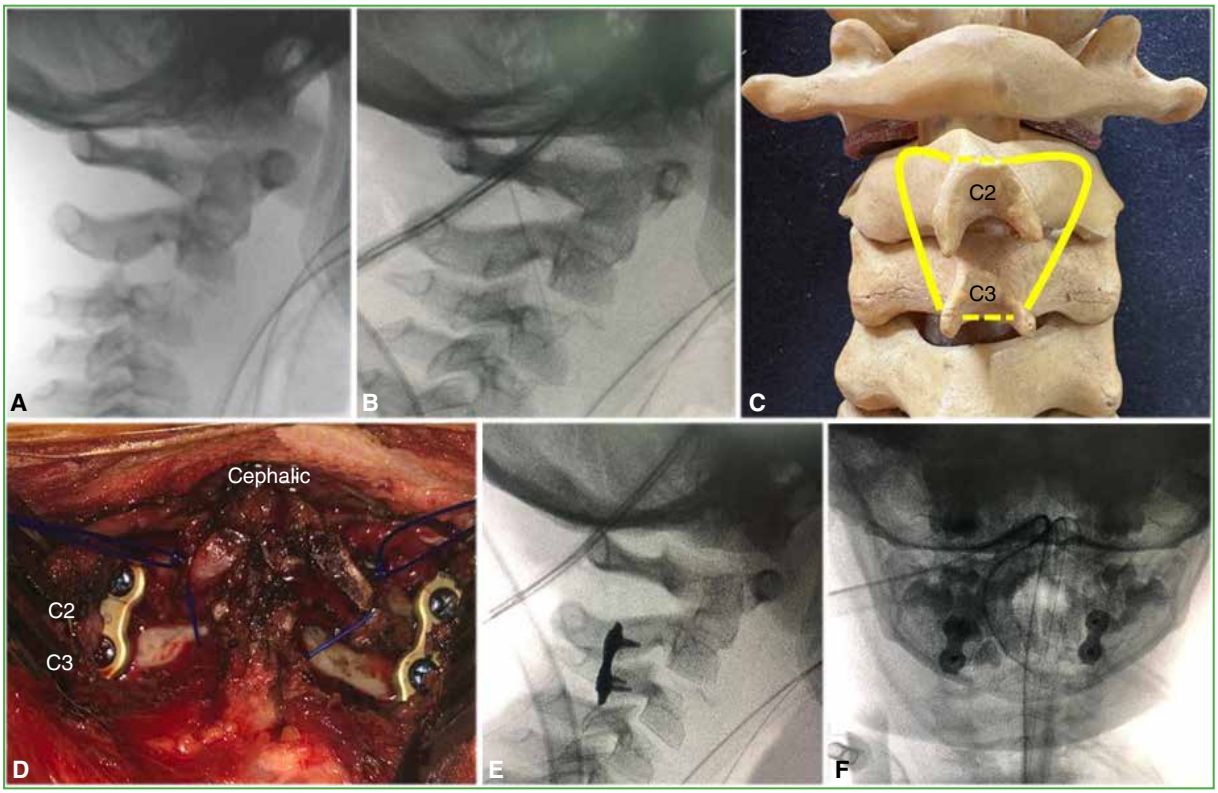

Figure 2. 4-year-old boy with traumatic brain injury secondary to deployment of the front airbag during a frontal collision. **A**. Lateral radiograph of the cervical spine showing C2-C3 dislocation. Note that, in this case, as in Figure 1, the Swischuk line was not sensitive for the diagnosis of significant instability. **B**. Intraoperative radiographic image obtained after reduction. **C**. Plastic model of the cervical spine illustrating the transosseous suture technique at the axis and fixation to the C3 spinous process using a double strand of Prolene® 2.0 suture (yellow). **D**. Intraoperative image showing osteosynthesis similar to that in Figure 1. **E and F**. Anteroposterior and lateral radiographs of the cervical spine.

Both techniques provide sufficient stability to prevent any inadvertent movement during the remainder of the procedure. Osteosynthesis is then performed using C2-C3 facet screws with a diameter of 3.5 mm and standard adult instrumentation or, in patients with very small anatomical dimensions, 2.2 mm diameter mini-fragment screws, combined with a custom plate, according to the Magerl technique. Final radiographic control is obtained, followed by placement of an autologous iliac crest bone graft impregnated with vancomycin. Postoperatively, the patient is fitted with a soft cervical collar or a Philadelphia collar for a period of 8 weeks.

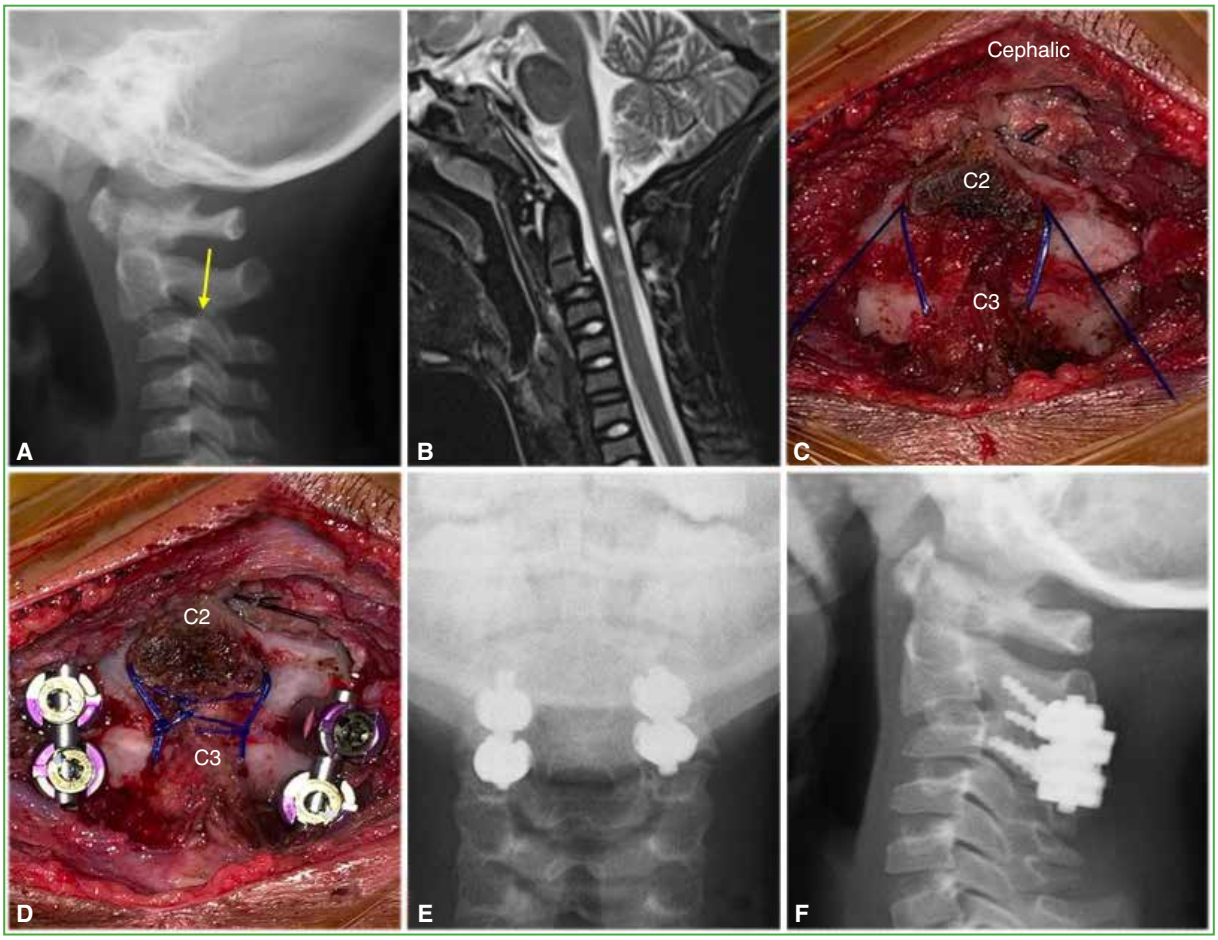

Figure 3. 8-year-old boy, victim of a frontal motor vehicle collision, presenting with pneumothorax, traumatic brain injury, mechanical ventilation for 2 weeks, and central spinal cord syndrome. Referred with a 2-month history. **A**. Lateral radiograph of the cervical spine showing pathological C2-C3 subluxation with minimal facet contact (yellow arrow). **B**. Magnetic resonance imaging showing perivertebral and intramedullary hyperintense signal on T2-weighted sequences. **C**. Intraoperative image showing suture technique as in Figure 2, using blue suture material. **D**. Intraoperative image showing facet osteosynthesis. **E and F**. Radiographic follow-up images obtained 2 years after surgery.

DISCUSSION

Dislocations of the C2-C3 segment are rare and only sporadically mentioned in the literature. Even in publications based on case series derived from database searches in PubMed and Excerpta Medica Database (EMBASE), there are no reports specifically describing C2-C3 dislocation.[1,2,9,10] We identified nine published cases, whose main common feature was marked therapeutic heterogeneity (Table).

Several authors have reported their experiences. Jones and Hensinger performed C2-C3 wire cerclage in a 20-month-old child.[3] Sakayama et al. used an identical technique combined with halo vest immobilization for 8 weeks.[11] Hamoud and Abbas performed a transosseous suture using absorbable material through the spinous process of the axis, linking it to that of C3 in a 23-month-old child. They did not add arthrodesis and prescribed immobilization with a Philadelphia collar for 8 weeks.[12] Sellin et al. stabilized the C2-C3 segment using facet screws in an adolescent.[13] O'Neill et al. performed reduction under general anesthesia and indicated halo vest immobilization in a 6-year-old child.[14] Finally, Zeng et al. used facet osteosynthesis with screws and minifragment plates, combined with autologous bone grafting, in an 8-year-old child.[15] Chen et al. placed small-fragment osteosynthesis material in the subaxial spine of a 22-month-old child.[16] We agree with other authors who recommend selecting the type of osteosynthesis based on tomographic measurement of the facet joints.[17]

Table. Case series, epidemiological and clinical variables, and treatments reported in the literature.

Author (year)	Cases	Age/Sex	Lesion of C2-C3	Cause	Neurological status	Treatment
Jones and Hensinger[3] (1981)	1	20 months/M	Chronic bilateral dislocation	Obstetric trauma	Severe hypotonia, flaccidity	Sublaminar-spinous wire cerclage C2-C3
Sakayama et al.[11] (2005)	1	4 years/F	Bilateral dislocation	Traffic accident	Frankel B	Sublaminar cerclage C2-C3
Hamoud and Abbas[12] (2014)	1	23 months/M	Bilateral dislocation	Traffic accident	Traumatic brain injury, central deficit	Intervertebral suture C2-C3 Vicryl® 2.0
Sellin et al.[13] (2014)	1	13 years/F	Subluxation + facet fracture	Fall	Normal	Facet osteosynthesis C2-C3
O'Neill et al.[14] (2021)	1	6 years/F	Unilateral subluxation	Sports accident	Normal	Reduction under general anesthesia + halo vest
Zeng et al.[15] (2022)	1	8 years/M	Bilateral dislocation	Traffic accident	Central deficit, vertebral artery stenosis	Facet osteosynthesis C2-C3 mini-fragment instrumentation
Fernández et al. [6,7] (2023)	1	9 months/F	Unilateral dislocation + C2 fracture	Traffic accident	Central spinal cord syndrome, diaphragm paralysis	C2-C3 sublaminar cerclage Prolene® 2.0 and mini-fragment facet osteosynthesis
Fernández et al.[5] (2024)	1	4 years/M	Bilateral dislocation	Traffic accident	Frankel A	C2 spinous suture and C3 cerclage Prolene® 2.0, 2 mm diameter mini-fragment facet osteosynthesis
Fernández et al.[5] (2024)	1	8 years/M	Bilateral subluxation	Traffic accident	Central spinal cord syndrome	C2 spinous suture and C3 cerclage Prolene® 2.0 and facet osteosynthesis diameter 3.5 mm

M = male; F = female.

The technique used in our cases follows a defined surgical strategy consisting of the following steps: 1) limited exposure of the affected segment; 2) reduction; 3) primary stabilization using non-absorbable suture material; and 4) facet osteosynthesis combined with bone grafting for definitive segmental stabilization.

Due to the lack of specific pediatric instrumentation, osteosynthesis systems designed for minifragment fixation were used. These systems are commonly employed in adult surgery of the long bones of the hand or foot. This approach was applied in a 9-month-old girl and a 4-year-old boy. In an 8-year-old patient, osteosynthesis material designed for adults was used. Double sublaminar cerclage at the C2-C3 level was performed in a 9-month-old girl with a lacerating soft tissue injury that facilitated passage of the suture material (Figure 1). However, for primary stabilization purposes, transfixion suturing through the spinous process of the axis, with the suture curved beneath the C3 spinous process and secured with an appropriate knot, is sufficient and safe. Regardless of the treatment modality, all authors reported stable long-term outcomes. Finally, McGrory and Klassen reported extension of the fusion mass in 38 percent of 42 children who underwent cervical spine arthrodesis for fractures and dislocations.[18]

In summary, we consider C2-C3 dislocation to be an unstable injury with a potential risk of neurological compromise and death. The sequential and combined use of two stabilization techniques provides greater intraoperative safety and yields stable outcomes over time.

Conflict of interest: The authors declare no conflicts of interest.

M. G. Miranda ORCID ID: https://orcid.org/0000-0003-4949-9407
M. E. Moreiro Varela ORCID ID: https://orcid.org/0009-0000-5590-9738

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