A Discussion on Swischuk's Line. Literature Review

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ABSTRACT

Introduction: Traumatic injuries to the upper cervical spine are prevalent in young children. In 1977, Leonard Swischuk published an article on a cervical spinolaminar line to determine the physiological or pathological relationship between the second and third cervical vertebrae (C2-C3). The purpose of this study is to review the available literature on the indications and diagnostic limitations of this line, illustrating this with our own clinical examples. **Materials and Methods:** We conducted bibliographic research on pediatric cervical spinal trauma including the following databases: PubMed (Medline, MedlinePlus and Cochrane), Elsevier, VHL Virtual Health Library of Bireme (which includes Lilacs) and the AAOT Database. In addition, a manual search was carried out, including citations from recently published references and specialty textbook chapters. **Results:** Out of 72 articles, we selected 39 that addressed current epidemiological aspects, as well as others that focused on Swischuk's line and upper cervical spine injuries, which were mostly case reports. **Conclusion:** Swischuk's line is an effective diagnostic tool for evaluating children's spines after trauma or in some syndromic diseases. However, it may not be sensitive in some cases, such as C2-C3 subluxation or facet dislocation. Other complementary radiodiagnostic measures should be applied.

Keywords: Children; Swischuk line; C2-C3 cervical instability.
Level of Evidence: IV

Una discusión sobre la línea espinolaminar de Swischuk. Revisión bibliográfica

RESUMEN

Introducción: Las lesiones traumáticas del raquis cervical superior son prevalentes en la primera y segunda infancia. En 1977, Leonard Swischuk publicó un artículo sobre una línea espinolaminar cervical a efectos de determinar la relación, fisiológica o patológica, entre las vértebras cervicales C2-C3. El objetivo de este artículo es presentar una revisión bibliográfica sobre las indicaciones y las limitaciones diagnósticas de la línea de Swischuk, con ilustración de casos clínicos propios. **Materiales y Métodos:** Se efectuó una investigación bibliográfica sobre el trauma espinal cervical en pediatría que incluyó las bases de datos PubMed (Medline, MedlinePLus y Cochrane), Elsevier, BVS Biblioteca Virtual en Salud de Bireme (que incluye Lilacs) y la correspondiente a la AAOT. También se llevó a cabo una indagación manual o no electrónica por citas de referencias de capítulos de libros de texto de la especialidad de publicación reciente. **Resultados:** Sobre 72 artículos, se seleccionaron 39 relacionados con aspectos epidemiológicos actuales, y otros específicos sobre la línea de Swischuk y lesiones del raquis cervical superior, estos últimos mayoritariamente reportes de casos. **Conclusión:** La línea de Swischuk es una herramienta diagnóstica útil para evaluar la columna cervical infantil en casos de traumatismo y en algunas entidades sindrómicas. Sin embargo, puede no ser sensible en algunas situaciones de subluxación o luxación facetaria C2-C3. Se deberían adicionar otras medidas complementarias de radiodiagnóstico.

Palabras clave: Niños; línea de Swischuk; inestabilidad cervical C2-C3.
Nivel de Evidencia: IV

INTRODUCTION

Traumatic injuries of the cervical spine in childhood have an incidence of 1.5% and a prevalence of over 80%, with a varying distribution according to age: 72.7% in children up to 3 years old, 47.8% between 3 and 8 years old, and 29% thereafter.[1-4] In other words, there is a strong correlation between age and the frequency of high cervical traumatic injuries, with a male-to-female sex ratio of 1.6:1.[1] Several anatomical and physiological fac-

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tors make this region more susceptible to trauma: tissue hyperlaxity, the locking stability of the atlanto-occipital joint, lower muscle tone, and cervico-cephalic volume disproportion. A critical factor is the progressive inclination of the facet joints, which are angled at 30° in the first years of life and 70° in the prepubertal stage. The C2-C3 disc serves as the fulcrum or transitional area between two mobile segments, the craniocervical and subaxial spine. In the early years of life, the upper cervical spine is often the site of ligament injuries, with a prevalence estimated between 25% and 44%.[5] The causes include traffic accidents, falls, sports injuries, non-accidental trauma, and obstructed labor.[2,5-8] The probability of neurological involvement ranges from 35% to 60%, but, unlike in adults, the prognosis for recovery is more favorable.[7,9,10] However, the likelihood of death is significant in early and second childhood, ranging from 16% to 18%, usually associated with traumatic brain injury.[3,9] Several *post mortem* anatomical pathology investigations have documented a variety of injury patterns.[11,12] According to the US National Pediatric Trauma Registry, 50% of these patients showed no radiographic evidence of injury, constituting the so-called SCIWORA (*Spinal Cord Injury Without Radiographic Abnormality)*. [1]

The uncertainty generated by certain radiographic aspects of the upper cervical spine in the context of trauma led Leonard Swischuk, a Professor of Radiology in Texas, USA, to publish an article in *Radiology* in 1977. He prospectively investigated the usefulness of a line drawn on radiographs of the upper cervical spine in children, known as the spinolaminar line, or Swischuk's line (SL), whose main objective was to differentiate physiological subluxation from pathological subluxation in the C2-C3 segment, and to diagnose or raise suspicion of isthmic spondylolisthesis of the axis (hangman's lesion) (Figures 1 and 2).[13] To achieve this, he drew a line on a strict lateral radiograph, extending from the spinolaminar junction of the atlas to that of C3. Under normal conditions, the spinolaminar cortex of C2 should align with this straight line, with a tolerance of 1.5 to 2 mm in the sagittal plane, both anteriorly and posteriorly. Cephalically, SL continues harmoniously with the opisthion (Figure 1).

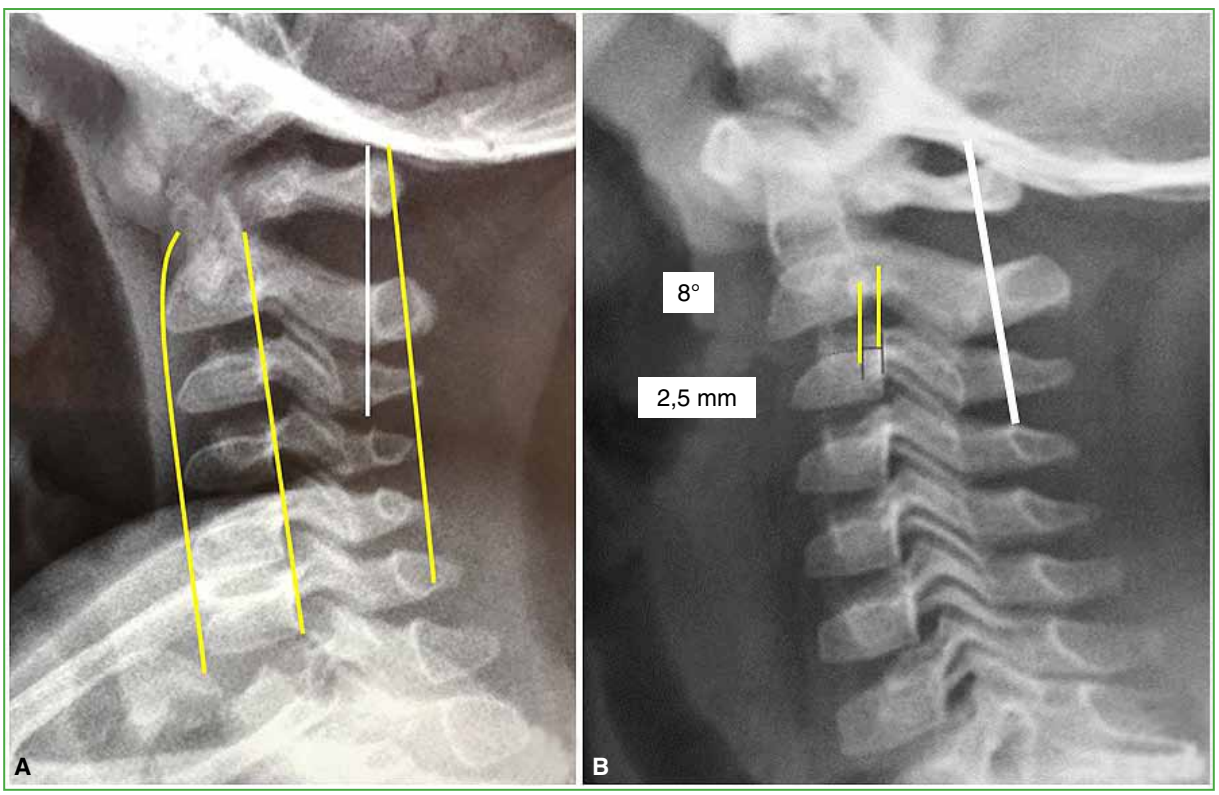

Figure 1. Lateral radiograph of the cervical spine of a 2-year-old boy. **A.** Physiological image: sagittal lines of the vertebral bodies, spinous processes (in yellow) and Swischuk's line (in white), which continues cephalad to the opisthion.
B. Physiological displacement in a 3-year-old child, where the spinolaminar cortices of the first three cervical vertebrae are located above Swischuk's line. There is very mild kyphosis and a C2-C3 displacement of 2.5 mm (within normal parameters).

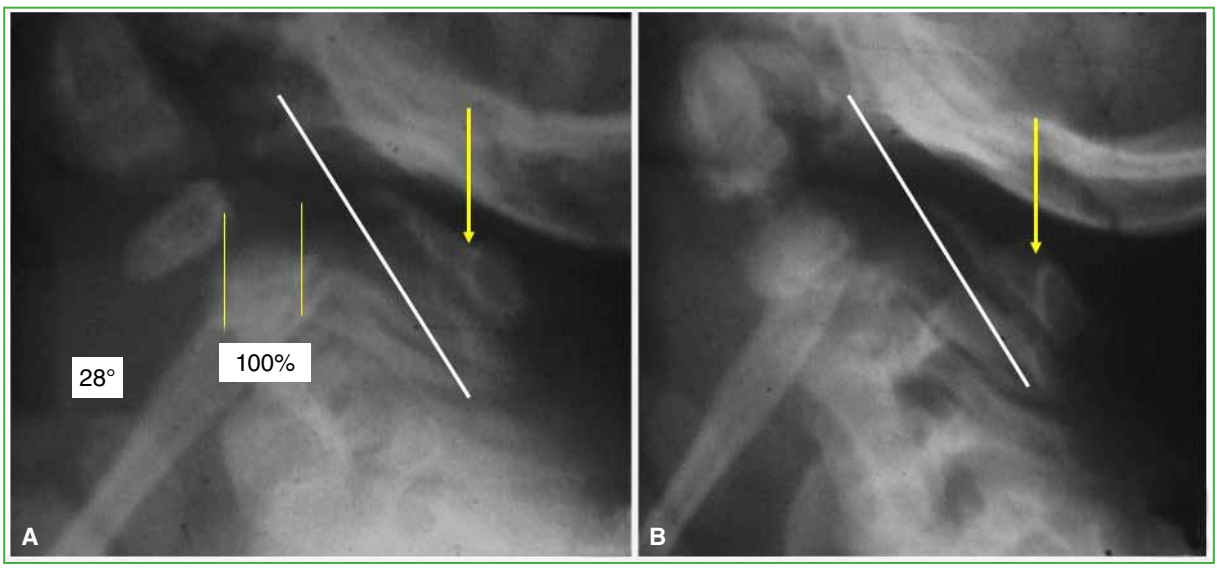

Figure 2. Cervical spine radiograph of a 2-year-old girl following high-energy trauma, showing axis spondylolisthesis without neurological damage. **A.** The axis spinolaminar cortex is markedly posterior to Swischuk's line (white arrow), with 100% displacement of the C2 vertebra and 28° of kyphosis. **B.** Post-reduction under general anesthesia with Minerva plaster cast.

In doubtful situations, a radiographic exposure with slight neck extension should provide an image of absolute normality.[13-15] This radiographic parameter is routinely used by orthopedic physicians in pediatric emergency settings, who attribute to it an almost axiomatic predictive value, supported by numerous publications.[12,16-21] Although the SL was originally drawn on a radiograph, it can also be applied to other imaging studies, such as computed tomography (CT) and magnetic resonance imaging (MRI) (Figure 3).

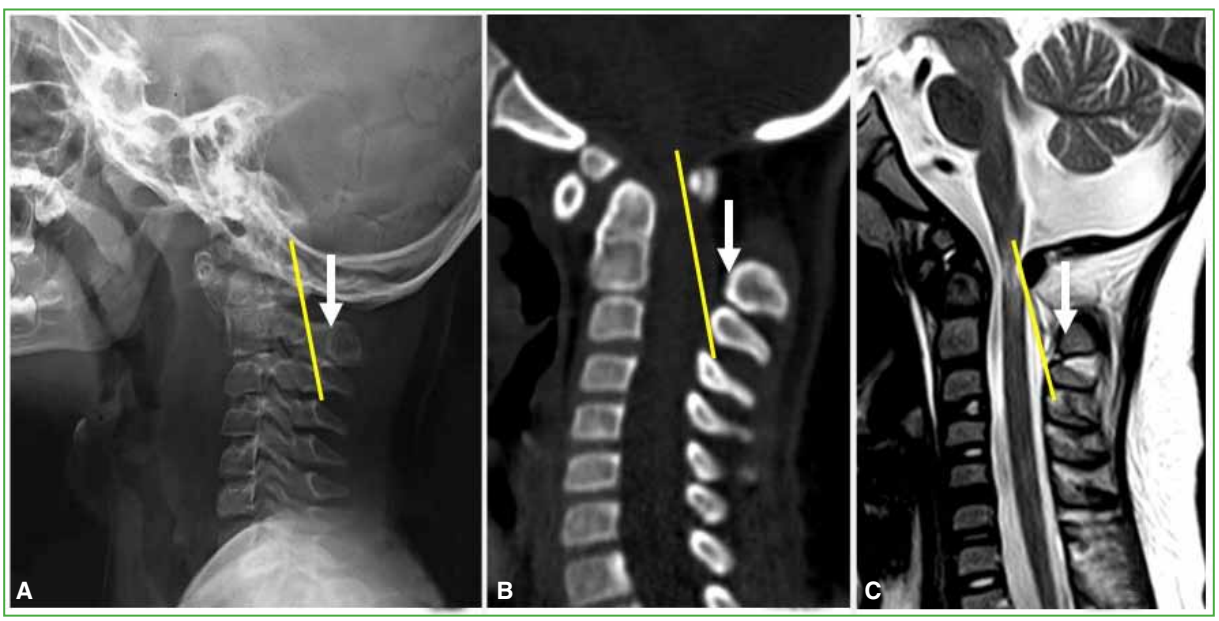

Figure 3. Six-year-old boy with Down syndrome: hypotonia of all four limbs exacerbated by trauma. **A-C.** Radiograph, CT and MRI of the skull base and upper cervical spine, respectively. The SL tracing shows retroposition of the spinolaminar line of the axis, severe C1-C2 instability, and lack of continuity of the SL with the opisthion. There is significant neuroaxis compression and myelomalacia.

Certain traumatic or congenital conditions outside the C2-C3 region, such as fractures or epiphysiolysis of the axis and C1-C2 sagittal instability, can significantly alter the SL (Figures 3 and 4). Observations made after the publication of Swischuk's article, along with insights from our daily practice, motivated this research, which aims to conduct a literature review on the interpretation and diagnostic limitations of the SL, supplemented with clinical case examples.

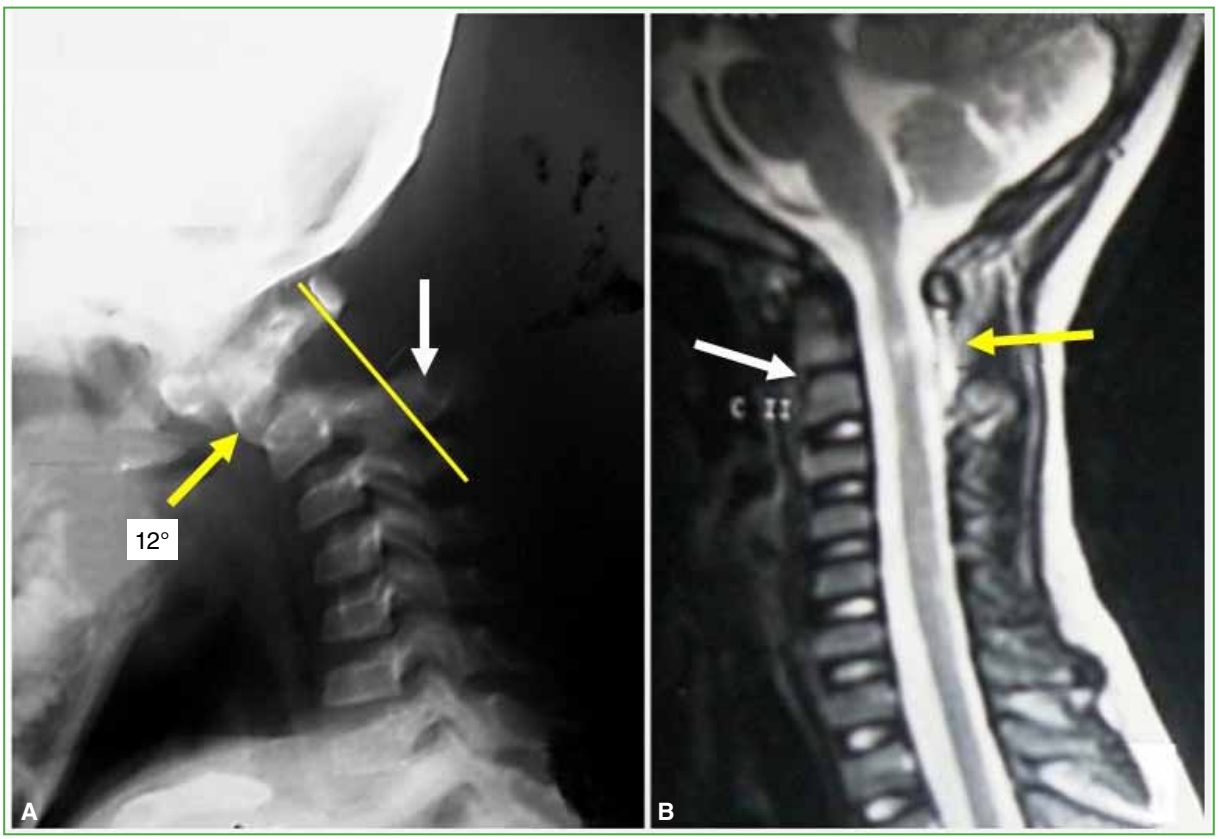

Figure 4. Four-year-old girl who fell from a height, presenting with Frankel D neurological status. Cervical spine images on admission. **A.** Radiograph: dentocentral epiphysiolysis of the axis in flexion, with anterior displacement of the odontoid process (yellow arrow). Kyphosis of 12 degrees, with the spinolaminar line of C2 clearly posterior to the SL (white arrow). **B.** MRI: separation of the dentocentral synchondrosis (white arrow), with posterior and intracanal fluid signal (yellow arrow) and edema of the bone marrow parenchyma.

MATERIALS AND METHODS

The AAOT Library conducted a search for bibliographic references in Spanish and English from 1977 (the year of Swischuk's publication) to the present, using the following databases: PubMed (Medline, MedlinePlus, and Cochrane), Elsevier, BVS Biblioteca Virtual en Salud de Bireme (including Lilacs), and the AAOT's own database. The keywords used were: *pediatric cervical spine injuries*, *Swischuk line*, *C2-C3 pseudosubluxation*, *C2-C3 dislocation in children*, and *false negative* or *false positive cases of the Swischuk line*. We also included articles that were not identified in the electronic search but were found through citation searches of other references, relevant classic historical publications, and chapters from current textbooks on childhood traumatic conditions of the cervical spine. We excluded duplicate publications, older publications on pediatric spinal trauma, those related to conditions not relevant to the search, and articles on vertical spinal disruption or diastasis, given their clear expression in imaging studies. This research is based on a systematic review of the literature.

RESULTS

Thirty-nine references were selected from a total of 72 (Figure 5). The selection included 13 articles on general epidemiological aspects of pediatric spinal trauma published in the last five years, which provided new evidence-based recommendations on the rational use of complementary studies.

Another 18 articles focused on the SL, including its physiological and pathological variants in retrospective clinical cases. However, we did not find any specific references addressing false negative or false positive cases of the Swischuk line. Over the 46 years following Swischuk's article, six pediatric cases of uni- or bilateral C2-C3 facet subluxation or dislocation have been published, four of which involved neurological spinal cord impairment and two were associated with severe traumatic brain injury.[6,13,22-25] Except for one child, all were younger than 10 years (mean age: 3 years; range 9 months to 8 years). Although variable, the neurological status improved in all cases after surgical stabilization, a result previously noted in the literature.[10] Except for two cases, the SL was either unaltered or not sensitive enough to detect instability, despite the presence of epiphysiolysis of the lower end of the axis and significant damage to the posterior capsuloligamentous complex (Table 1, Figures 6 and 7). Two of the eight textbooks consulted were considered classics[11,12] and six were the latest editions of reference books.[16-21] All replicated identical concepts regarding the tracing and diagnostic implications of the SL.

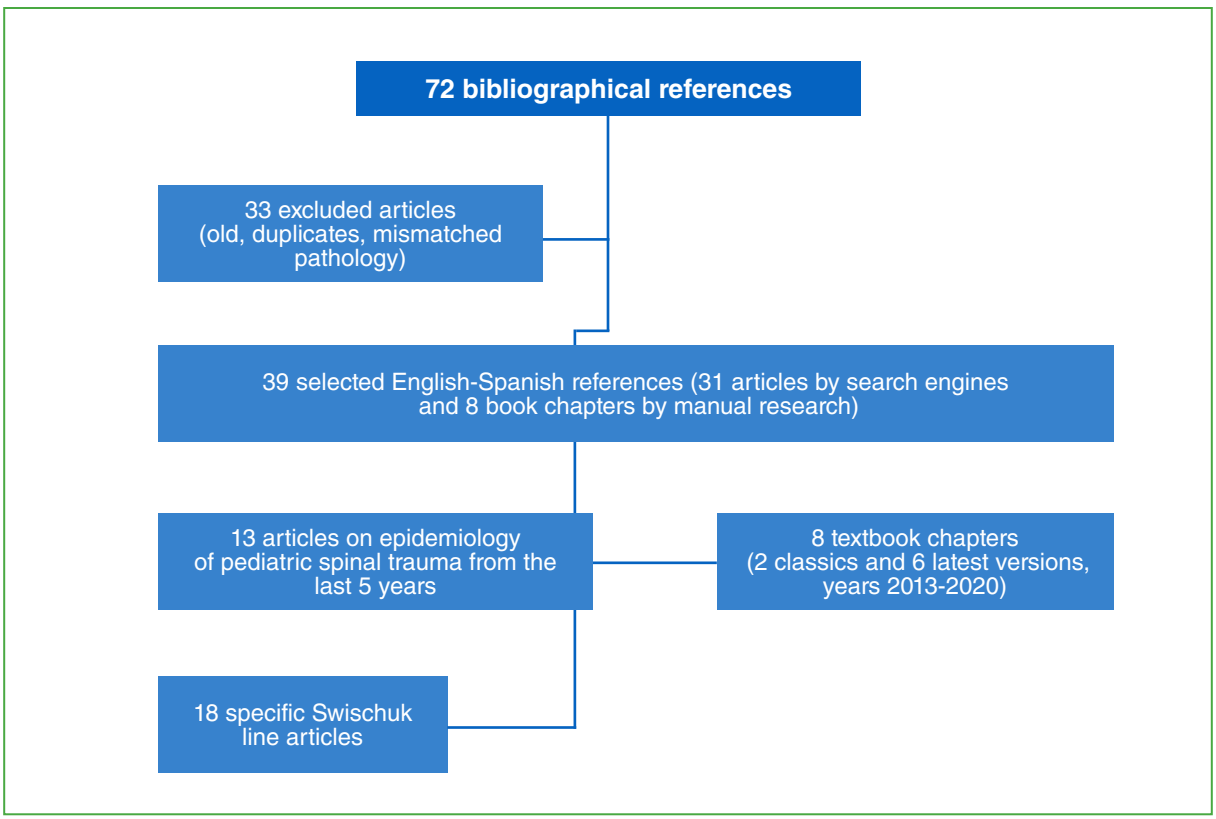

Figure 5. Flowchart of the literature search.

Table. Variability of Swischuk's line sensitivity in published pediatric cases of C2-C3 complex injuries.

	Author	Year	Cases	Age/Sex	C2-C3 Injury	Cause	SL Sensitivity	Neurological status	Treatment	Follow-up (months)
1	Jones and Hensinger [22]	1981	1	20 months/M	Chronic bilateral dislocation	Obstetric trauma	Yes	Severe hypotonia, flaccidity	Sublaminar wiring with C2-C3 wire	12
2	Hamoud and Abbas [2]	2014	1	23 months/M	Bilateral dislocation	Traffic accident	No	TBI, central deficit	C2-C3 Interspinous suture with Vicryl®2.0	63
3	Sellin et al. [34]	2014	1	13 years/F	Subluxation plus facet fracture	Fall	No	Normal	C2-C3 Facet osteosynthesis	14
4	O'Neill et al.1[5]	2021	1	6 years/F	Unilateral subluxation	Sports accident	No	Normal	Reduction under general anesthesia plus halo vest	24
5	Zeng et al.[6]	2022	1	8 years/M	Bilateral dislocation	Traffic accident	Yes	Central deficit, spinal stenosis	C2-C3 Facet osteosynthesis with minifragments	8
6	Fernández et al. [24,25]	2023	1	9 months/F	Unilateral dislocation plus C2 fracture	Traffic accident	No	Central cord syndrome, diaphragm palsy.	C2-C3 sublaminar closure with Prolene®2.0 and facet osteosynthesis with minifragments	96

M = male; F = female; SL = Swischuk's line.

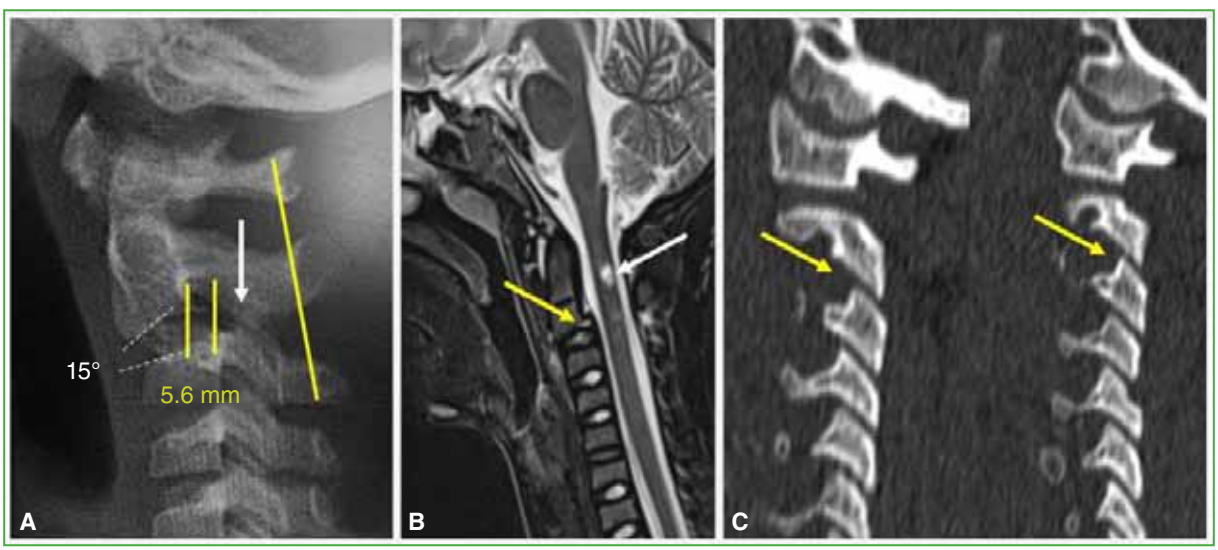

Figure 6. Eight-year-old boy involved in a frontal-impact car accident, presenting with pneumothorax, elevated intracranial pressure (eICP), and requiring mechanical ventilation for three days. The patient exhibited central cord syndrome and flaccid diparesis of the upper limbs with a C4-C5 level injury. Imaging studies of the cervical spine. **A.** Cervical spine radiograph: kyphosis of 15 degrees, sagittal displacement of 5.6 mm (vertical yellow lines) and normal SL tracing. **B.** MRI: Salter-Harris I epiphysiolysis of the axis (yellow arrow), with pre- and intervertebral fluid signal and intramedullary fluid signal. **C.** CT: sagittal paramedian sections showing subluxation of both C2-C3 facet joints.

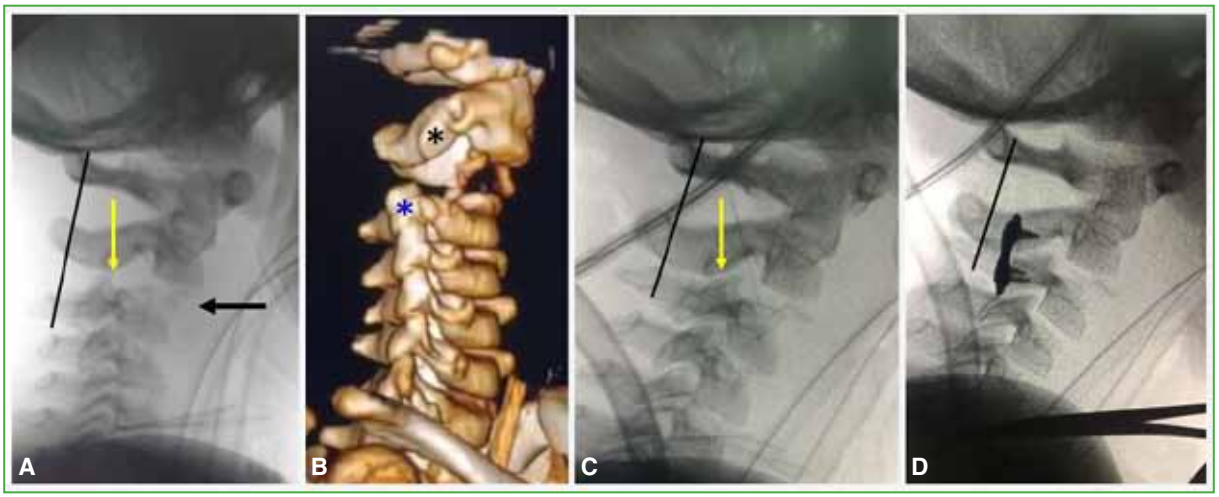

Figure 7. Four-year-old child seated on his mother's lap in the front passenger seat of a car with a seat belt fastened. The car was involved in a frontal collision, with airbag deployment impacting the child. The child presented with Frankel A neurological status on admission, with a metameric injury at the C3 level, diaphragmatic paralysis, hemopneumothorax, and elevated intracranial pressure (eICP). Lateral images of the cervical spine. **A.** Cervical spine radiograph: C2-C3 dislocation, with facet denudation (yellow arrow) and epiphysiolysis of the base of the axis with a small Thurstand-Holland fragment (Salter-Harris II). SL is not sensitive enough to detect this severe instability. **B.** 3D CT: Unlinking of the facets of C2 (black asterisk) and C3 (blue asterisk). **C.** Intraoperative radiograph: reduction showing an adequate facet relationship (yellow arrow). **D.** Posterior facet osteosynthesis with small fragment material.

DISCUSSION

The SL is one of the four lines drawn on a lateral cervical spine radiograph after trauma. Specifically, it is the proximal segment that relates the spinolaminar cortices of the first three vertebrae.[16,20] Some authors consider it to have higher diagnostic sensitivity than the sagittal delimiters of the vertebral bodies.[13] Swischuk emphasized its specificity in evaluating the C2-C3 relationship.[13,15] Its practical limitation lies in the lack of ossification of the posterior arch of atlas or its hypoplasia.[13] Anterior displacement of C2 over C3 or physiological subluxation occurs in approximately 22-40% of children under 8 years of age; a second hypermobile segment can be observed at the C3-C4 level in 14% of the same age group.[13,15,25,26,27,28] In 1952, Bailey specified that the physiological displacement of C2 over C3 was 2 mm to 3 mm, a value consistent with Swischuk's parameter.[11,13,15,27,29] Donalson published similar findings in 75% of children with acquired torticollis associated with concomitant C1-C2 rotation.[11] In pathological C2-C3 instability, there is excessive anterior displacement of the spinolaminar line in the axis, which may be traumatic or specifically related to Down syndrome.[30,31] As mentioned above, similar observations have been made in conditions outside the C2-C3 segment. Although Swischuk did not apply his method to these cases, it seems pertinent to describe it for general practitioners, who often encounter these patients in the emergency department and must address their uncertainty.

We found no publications addressing the lack of diagnostic sensitivity of the SL in some cases of C2-C3 instability. This observation is significant as it represents a false negative, meaning the diagnostic tool is not sensitive enough to detect the anomalous phenomenon. Moreover, in more than half of the published cases, the SL tracing was omitted, and Swischuk was not cited in the references. This is a paradox, given that his description is reiterated in numerous articles and textbooks on pediatric spinal trauma.

Finally, in cases of axis spondylolisthesis, the epicenter or fulcrum of motion migrates from the facet joints to the fracture sinus, leading to pathological C2-C3 subluxation. In this circumstance, the spinolaminar cortex of C2 is located posterior to the SL. Far from being pathognomonic, this observation has been reported in Grisel's syndrome of inflammatory etiology, where the C1-C2 relationship remains normal and the axis is undamaged.. [33]

From our literature analysis and empirical observations, we can infer that the SL is a useful radiographic evaluation parameter, but it is insufficient and non-specific. Therefore, it would be advisable to incorporate other radiodiagnostic elements to confirm vertebral instability: translation of C2 over C3 greater than 4 mm or a percentage exceeding 25%, alteration of the axis in kyphosis, increase of the C2-C3 interspinous distance, loss of facet parallelism, and posterior widening of the disc space.[15,16,34] The indication for CT should be selective and justified based on the clinical-radiographic examination, particularly in cases of doubt regarding an abnormal facet relationship.[2,35] Its systematic use is not recommended, given the stochastic effect or carcinogenic effect of radiation in children, which results in one cancer for every 1,000 studies performed due to tissue radiosensitivity and long life expectancy.[3,36,37] For instance, the thyroid gland of a child under six years old receives 200 times more radiation with CT than with conventional radiographic exposures.[37] In a retrospective investigation of 773 polytraumatized pediatric patients evaluated with CT, the prevalence of spinal injury was 2.4%; thus, it was unnecessary in 97.6% of patients.[37] According to a recent expert consensus, CT is warranted as a matter of course when the Glasgow Coma Scale score on admission is ≤8, and it is not recommended when the score is higher.[36] MRI is recommended if there is no improvement or if clinical worsening occurs, but is not a routine methodology given the need for sedation, cost, and significant false positive rates.[36,38,39] Specialty books and many articles addressing cervical trauma in children express similar views regarding SL tracing and the conclusions drawn from it, although we did not find other observations or critical analyses.[9,12,16-21] Some of the works mentioned in this article warn about the potential risk of misinterpreting abnormal findings as normal, especially when the examiner is not an expert in spinal pathology. The main limitations of this study are its retrospective design and the small number of cases documented in the literature.

CONCLUSION

SL is useful for evaluating the upper cervical spine in early and middle childhood in cases of trauma and in some syndromic entities. However, it is not infallible or specific, does not exclude a C2-C3 facet subluxation or dislocation, and may be influenced by overlying segmental abnormalities. Therefore, other quantitative or qualitative radiodiagnostic measures should be incorporated.

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