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# Our Challenge for 2025

## Dr. Fernando A. Lopreite

Staff of Hospital Británico de Buenos Aires

Instituto Argentino de Diagnóstico y Tratamiento (IADT)

Lecturer at Universidad Católica Argentina (UCA)



Dear colleagues, members of the AAOT community,

We assume this new stage at the helm of the Argentine Association of Orthopedics and Traumatology (AAOT) with great enthusiasm and a firm commitment to strengthening our institution as a benchmark in education, innovation, and professional representation. Our efforts will focus on three fundamental pillars: **continuing education, union strengthening, and national integration.**

### Continuing Education: Adapting to the Present, Projecting into the Future

Medical education lies at the heart of our association. In this regard:

- We will continue holding **virtual Ordinary Scientific Sessions**, enabling active participation from colleagues across all regions.
- We will organize **Extraordinary Scientific Sessions** in various provinces, including Salta, Corrientes, Córdoba, Santa Fe, and Chubut, bringing national experts closer to colleagues in different parts of the country.
- We will launch a virtual International Orthopedics and Traumatology **Update Course**, featuring Spanish-speaking specialists, further establishing AAOT as a regional hub of knowledge.
- We will explore **artificial intelligence** as a key tool in medical education, ensuring we remain at the forefront of technological advancements.

### Union Strengthening: Improving Working Conditions

Collaboration is essential to improving the working conditions and salaries of our colleagues. We will work closely with the **Argentine Association of Orthopedics and Traumatology**, FAAOTEP, the Regional Associations, and SUTYO to achieve effective professional representation through a united effort.

### National Integration: Promoting Equitable Access

Recognizing the need to decentralize our activities and ensure accessibility, we will:

- Reinstate **certification exams** in regional locations in collaboration with CEMC, ensuring equal opportunities for all members.
- Promote in-person activities, such as **hands-on courses with anatomical specimens**, reinforcing the importance of face-to-face interaction for technical and scientific learning.
- Offer **theoretical and practical courses** in different regions of the country.

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### **Institutional Growth: Looking to the Future**

The evolution of AAOT requires us to rethink the use of our headquarters, taking into account virtual platforms and new educational formats. This will be a priority discussion in upcoming assemblies as we seek solutions that best serve our members.

### **Commitment to Academic Excellence**

We will support the AAOT Journal's Editorial Committee in its ambitious goal of achieving **PubMed indexing**—an achievement that would enhance the academic impact of our scientific contributions. We encourage all colleagues to **publish in our journal**.

### **Acknowledgements and a Call to Action**

This project can only succeed with the commitment of every AAOT member. I invite you to actively participate in our initiatives, contribute your ideas, and work together to build a stronger and more relevant association. To conclude, I would like to echo the words of John F. Kennedy: Ask not what the AAOT can do for you, but what you can do for the orthopedic community.

I am deeply grateful for the trust placed in this administration and am confident that, together, we will successfully navigate the challenges ahead.

With gratitude and determination,

# Case Presentation

Juan Ignacio Pérez Abdala, Tomás Scarpaci, José I. Albergo, Germán Farfalli, Luis Aponte Tinao

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*Resolution on page 103.*

## Stress Fracture as a Differential Diagnosis for Bone Sarcomas

### ABSTRACT

A 21-year-old woman presents with a two-month history of left knee pain, associated with walking distances greater than 10 km following a prior period of inactivity. The pain has an insidious onset, is mechanical in nature, and no significant findings are observed on physical examination. Initial radiographs reveal diffuse cortical thickening in the distal metaphysis of the left femur. Computed tomography demonstrates cortical reaction with an oblique fracture line, without involvement of the medullary cavity or soft tissues. Magnetic resonance imaging confirms diffuse bone marrow edema, cortical thickening, and laminar submuscular edema. Based on these findings, a core needle biopsy is performed for histopathological analysis.

**Keywords:** Stress fracture; biopsy; bone sarcoma.

**Level of Evidence:** IV

### Fractura por estrés como diagnóstico diferencial de sarcomas óseos

### RESUMEN

Una mujer de 21 años consulta por gonalgia izquierda de 2 meses de evolución, relacionada con caminatas de más de 10 km, tras un período previo de sedentarismo. Tiene dolor de inicio insidioso, mecánico. No hay hallazgos relevantes en el examen físico. Las radiografías iniciales revelan un engrosamiento cortical difuso en la metáfisis distal femoral izquierda. La tomografía computarizada muestra una reacción cortical con solución de continuidad oblicua, sin compromiso medular ni de partes blandas. La resonancia magnética confirma un edema medular difuso, engrosamiento cortical y edema submuscular laminar. Ante estos hallazgos, se realiza una biopsia por punción para el análisis histopatológico.

**Palabras clave:** Fractura por estrés; biopsia; sarcoma óseo.

**Nivel de Evidencia:** IV

## INTRODUCTION

A 21-year-old woman with no relevant medical history consulted for left gonalgia with a two-month evolution. She reported an insidious onset of pain after abruptly beginning to walk more than 10 km, having previously led a sedentary lifestyle. She had not introduced any changes in her diet, and her clothing corresponded to conventional walking attire.

The pain had mechanical characteristics, increasing with activity and improving with rest but not resolving completely. She was taking conventional analgesics and experienced limitations in performing activities of daily living.

On physical examination, she had a full range of motion without pain but exhibited tenderness on palpation of the medial distal thigh region with mild edema.

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## FINDINGS AND INTERPRETATION OF IMAGING STUDIES

Anteroposterior and lateral radiographs of the left knee and femur were obtained, revealing cortical thickening with diffuse borders at the distal metaphyseal-diaphyseal level (Figure 1).

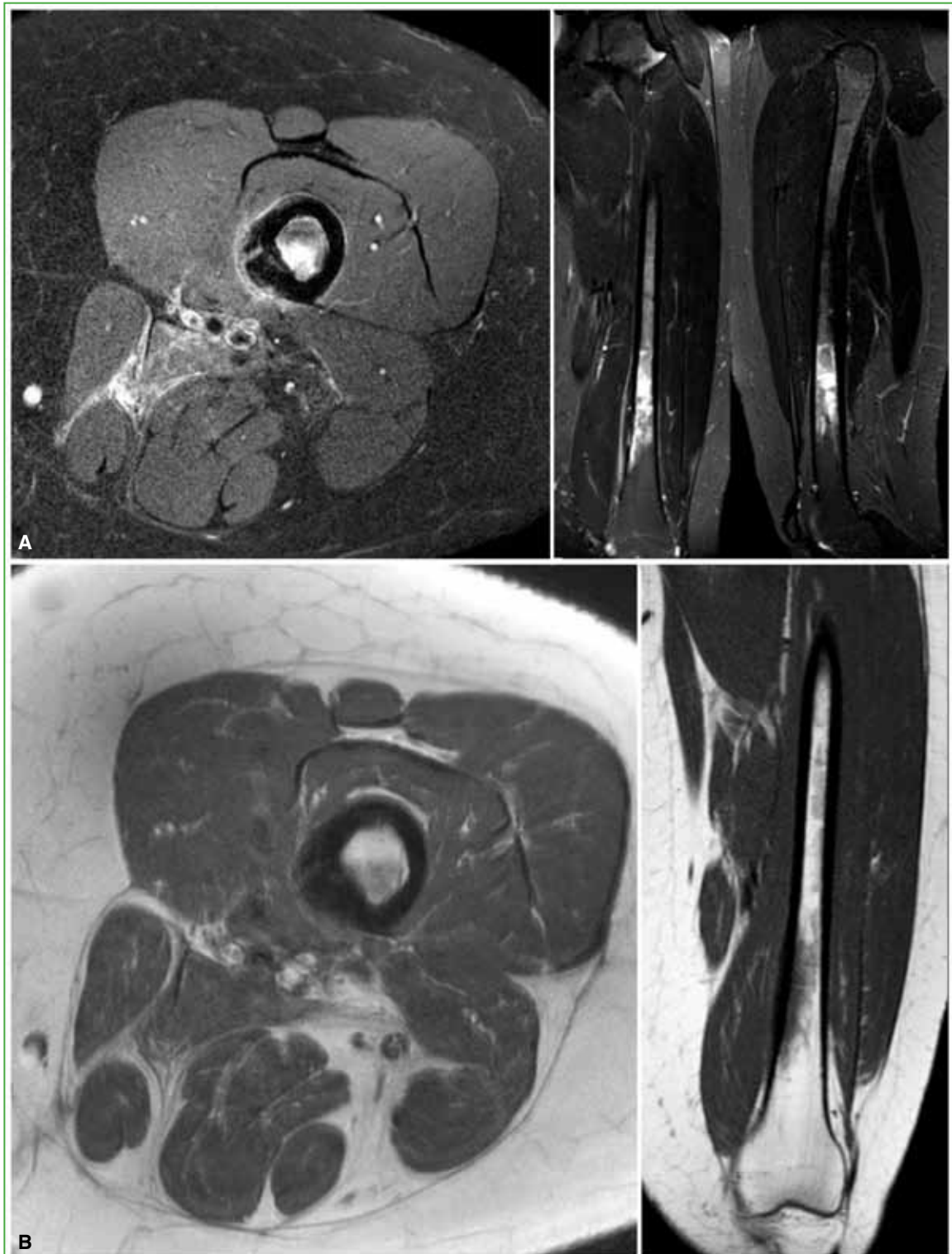


**Figure 1.** Anteroposterior and lateral radiographs of the left knee and femur. Medial cortical thickening with diffuse borders is observed at the metaphyseal-diaphyseal level. No alterations in the bone marrow pattern are evident, and no lytic or blastic lesions are seen in the distal femur.

A computed tomography (CT) scan and magnetic resonance imaging (MRI) without contrast were requested for better lesion characterization (Figures 2 and 3).



**Figure 2.** Computed tomography of the left femur (axial, coronal, and sagittal slices). The cortical reaction in the medial distal metaphysis is seen in greater detail, along with an oblique cortical discontinuity relative to the femoral axis. No involvement of the bone marrow or adjacent soft tissues is detected.



**Figure 3.** MRI of the distal region of the left femur (axial, coronal, and sagittal slices). **A.** STIR sequence: Diffuse bone marrow edema occupying almost the entire medullary cavity without cortical invasion, associated with medial distal cortical thickening and laminae edema in the submuscular plane. **B.** T1 sequence: The bone marrow edema presents the same diffuse pattern. No additional distal lesions are observed.

The CT scan demonstrated a cortical reaction in the medial distal metaphysis of the femur with an oblique cortical discontinuity, without involvement of the bone marrow or soft tissues. MRI revealed diffuse bone marrow edema occupying almost the entire width of the medullary cavity without cortical invasion, along with medial distal cortical thickening and lamellar submuscular edema.

Considering the clinical findings and imaging studies, a multidisciplinary meeting was held, and it was decided to perform a core needle biopsy of the lesion for histopathological analysis.

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# Revision Surgery: Cemented Monoblock Stem Following Failure of Osteosynthesis in Extracapsular Hip Fractures

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## ABSTRACT

**Introduction:** This study presents our experience with revision surgery using total hip arthroplasty with a dual mobility acetabular cup and a cemented stem as a treatment for failed osteosynthesis in extracapsular fractures. **Materials and Methods:** A series of 38 patients operated on by the same surgical team between January 2015 and December 2022 was evaluated. Demographic data and variables related to the patients' clinical evolution up to their last follow-up after revision surgery were collected. Functional outcomes were assessed using the Harris Hip Score, the Barthel Index, and the Visual Analog Scale (VAS). Radiological outcomes were analyzed using the Brooker and Paprosky classifications. Procedure-related complications were also recorded. **Results:** The mean patient age was 81.4 years, with an average follow-up period of 28 months. The mean time from osteosynthesis to revision surgery was 6.5 months. The most frequent femoral defects were classified as Paprosky grades I and IIA. The mean scores achieved were 86.2 (range: 65–96) on the Harris Hip Score, 91.2 (range: 70–95) on the Barthel Index, and 2.05 (range: 0–5) on the VAS. Complications included three cases of prosthetic dislocation (7.8%) and two cases of chronic infection (5.2%), both requiring surgical revision. **Conclusions:** Salvage treatment for failed osteosynthesis in extracapsular hip fractures using total hip arthroplasty with a dual mobility acetabular cup and a cemented stem demonstrates favorable clinical and functional outcomes, with high implant survival rates.

**Keywords:** Revision; failure; osteosynthesis.

**Level of Evidence:** IV

## Cirugía de revisión. Vástago monobloque cementado tras el fracaso de la osteosíntesis en las fracturas extracapsulares de cadera

## RESUMEN

**Introducción:** Presentamos nuestra experiencia en la cirugía de revisión mediante artroplastia total de cadera con cotilo de doble movilidad y vástago cementado como tratamiento ante el fracaso de la osteosíntesis en fracturas extracapsulares. **Materiales y Métodos:** Se evaluó a 38 pacientes operados por el mismo equipo quirúrgico, entre enero de 2015 y diciembre de 2022. Se recogieron datos demográficos y de variables sobre la evolución del paciente hasta el último control clínico después de la cirugía de revisión. La función se evaluó con el Harris Hip Score y las escalas de Barthel y analógica visual. Los resultados radiológicos se analizaron con las clasificaciones de Brooker y de Paprosky. Se registraron las complicaciones asociadas al procedimiento. **Resultados:** La edad media de los pacientes era de 81.4 años y el seguimiento medio fue de 28 meses. El tiempo medio desde la osteosíntesis hasta la revisión fue de 6.5 meses. Los defectos femorales más frecuentes fueron de grados I y IIA de Paprosky. El Harris Hip Score fue de 86,2 (rango 65-96); el puntaje en la escala de Barthel, de 91,2 (rango 70-95) y el de la escala analógica visual, de 2,05 (rango 0-5). Las complicaciones fueron: 3 casos de luxación de la prótesis (7,8%) y 2 de infección crónica (5,2%), que necesitaron revisión quirúrgica. **Conclusiones:** El tratamiento de rescate ante el fracaso de la osteosíntesis de fracturas extracapsulares mediante artroplastia total de cadera con cotilo de doble movilidad y vástago cementado logra resultados clínicos y funcionales con una alta supervivencia del implante.

**Palabras clave:** Revisión; fracaso; osteosíntesis.

**Nivel de Evidencia:** IV

Received on January 7<sup>th</sup>, 2024. Accepted after evaluation on August 26<sup>th</sup>, 2024 • Dr. JOSÉ F. GARRIDO • garrido.jos1@gmail.com  <https://orcid.org/0000-0002-7581-2404>

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## INTRODUCTION

According to the literature, the rate of revision surgery is projected to increase by 137% between 2005 and 2030,<sup>1</sup> driven by longer life expectancy and higher functional demands among patients. Likewise, primary hip arthroplasty is increasingly performed in younger patients, reducing prosthesis survival time.<sup>2</sup> Aseptic loosening remains the leading cause of femoral revision surgery, followed by chronic infection, periprosthetic fractures, and recurrent dislocation.<sup>3,4</sup> In addition to these etiologies, and despite advancements in osteosynthesis materials, surgical failure in extracapsular hip fractures is not uncommon, often necessitating both femoral and acetabular revision.<sup>5-7</sup>

This study focuses on an elderly patient with high functional demand despite poor bone mineral density, questionable consolidation potential, possible acetabular articular surface involvement, and a proximal femoral bone stock defect.<sup>5,6</sup> In this scenario, two treatment options have been considered: revision surgery through reosteosynthesis or proximal femoral replacement with a revision stem and acetabular component.<sup>8-10</sup>

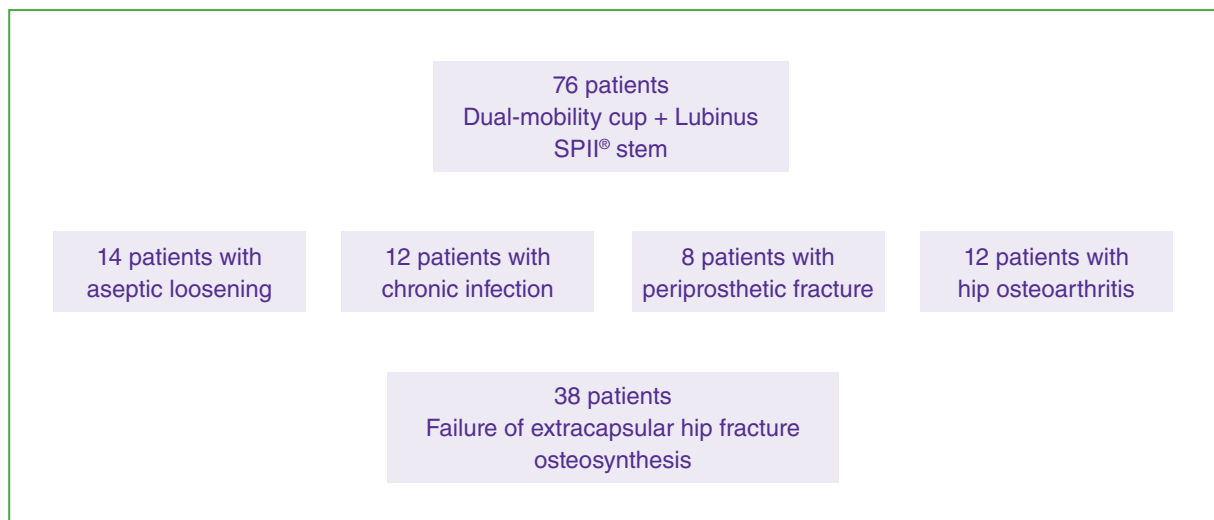
Following the research dynamics established by our center, which previously demonstrated comparable outcomes between dual-mobility and monopolar cups,<sup>11</sup> as well as between cemented monoblock and modular revision stems,<sup>12</sup> this study aims to evaluate the medium-term outcomes of total hip arthroplasty with a dual-mobility cup and a cemented femoral stem as a treatment for osteosynthesis failure in extracapsular fractures.

## MATERIALS AND METHODS

### Demographic Data

A descriptive, retrospective, and analytical study was conducted on patients who underwent revision surgery following failed osteosynthesis for extracapsular hip fractures. The procedure involved a Delta TT One dual-mobility cup (Lima Corporate, Villanova di San Daniele del Friuli, Italy) and a Lubinus SPII® cemented revision femoral stem (Waldemar Link, Hamburg, Germany) between January 2015 and December 2022. All surgeries were performed by the same surgical team.

Inclusion criteria were: age >65 years and revision surgery with the studied prosthesis model performed at our institution following failed osteosynthesis. Patients were excluded if they had undergone primary surgeries for degenerative or dysplastic disease, surgeries for pathological proximal femur fractures, revision surgeries following periprosthetic fractures, or surgeries on both limbs (Figure 1). Demographic, clinical, functional, and radiological variables were recorded.



**Figure 1.** Diagram of inclusion and exclusion criteria.

All patients were evaluated in outpatient clinics preoperatively, postoperatively, and every three months until their final clinical follow-up. Pre- and postoperative clinical and functional outcomes were assessed using the Visual Analog Scale (VAS) and the Harris Hip Score (HHS).<sup>13</sup> At the last clinical follow-up, the Barthel Index was also included.<sup>14</sup>

Demographic variables analyzed included the number of prior surgeries, the interval between the last surgery and the current revision, surgical duration, postoperative transfusion requirements, anesthetic risk classification according to the American Society of Anesthesiologists (ASA) scale,<sup>15</sup> and body mass index (BMI).

The degree of femoral bone defect was assessed using the Paprosky classification<sup>16,17</sup> preoperatively and intraoperatively. At outpatient follow-up, heterotopic ossification was classified according to the Brooker classification<sup>17</sup> while femoral stem viability was evaluated using the criteria of Girard et al.<sup>18</sup> and Engh,<sup>19</sup> considering distal migration >5 mm as stem subsidence.

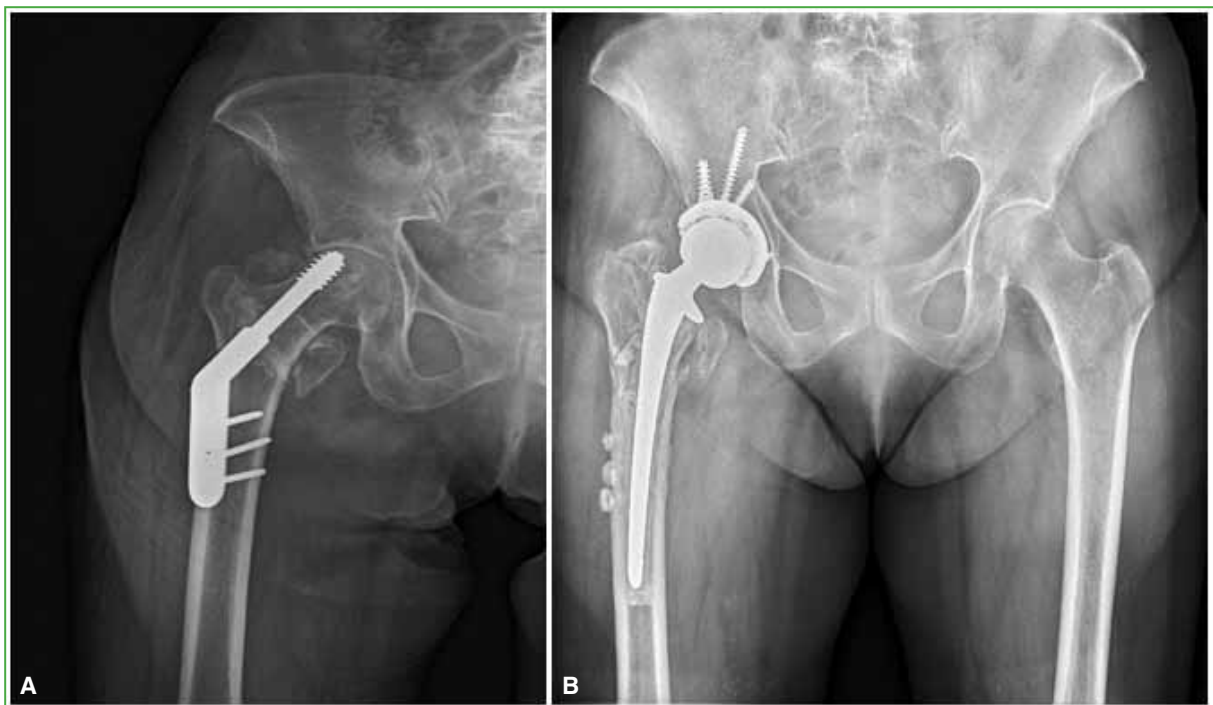
### Surgical Procedure

Preoperative planning involved templating to determine the appropriate stem length and diameter, ensuring at least 4 cm of cortical contact and a minimum of 90% femoral canal occupation. In all cases, the femoral canal was reamed 0.5 mm smaller than the final implant diameter.

Patients received intradural anesthesia and antibiotic prophylaxis with 2 g of cefazolin or, in cases of beta-lactam allergy, 240 mg of clindamycin intravenously.

All surgeries were performed using a posterolateral hip approach. After soft tissue release, osteosynthesis material was carefully removed to minimize additional bone loss.

Trial components were used to assess both acetabular articular surface and the required stem length based on the existing bone defect. The femoral component was cemented before inserting the revision stem, resulting in a hybrid prosthesis approach in which the dual-mobility cup remained uncemented (Figure 2).



**Figure 2.** Anteroposterior radiographs of the pelvis. Revision surgery after failure of osteosynthesis in a hip fracture.

**A.** Cut-out 2 months postoperatively with dynamic hip screw. **B.** Revision femoral stem and dual-mobility cup after 6 months of follow-up.

Postoperatively, isometric exercises were initiated on the first day, with assisted partial weight-bearing beginning on the second day. Patients were discharged following satisfactory clinical and functional evolution.

### Statistical Analysis

Data were analyzed using SPSS 22 and XLSTAT for Windows. Categorical variables were expressed as absolute and relative frequencies, while quantitative variables were presented as means and standard deviations. Normality testing for both quantitative and qualitative variables was conducted using the Kolmogorov-Smirnov test. Comparisons between quantitative variables were performed using Student's t-test, while the  $\chi^2$  test was applied for qualitative variables. Statistical significance was set at 5%.

## RESULTS

We present a series of 38 operated patients (7 men [18.4%] and 31 women [81.6%]), with a mean age of 81.4 years (range 65-100) at the time of revision surgery. Nineteen right (50%) and 19 left (50%) hips were operated on. Twenty-nine patients (74.4%) had undergone surgery only for the initial extracapsular fracture, while in 9 cases (15.6%), it was the third operation on the affected joint. None of the surgeries were bilateral.

The reason for revision surgery was failure following osteosynthesis in extracapsular hip fractures. The mean follow-up period was 28.1 months (range 12-66), and no patient was lost to follow-up. The mean length of hospitalization after surgery was 3.1 days (range 3-4).

Before surgery, 18 patients (47%) were classified as ASA II and 20 (53%) as ASA III. The mean body mass index was 28.8 (range 22-37).

The mean time between osteosynthesis failure and revision surgery was 6.5 months (range 1-26), with 84.3% of the sample undergoing surgery within three months. On the other hand, the mean surgical time was 120.1 minutes (range 90-190). In the last two years, it was reduced to less than 100 minutes, likely due to the learning curve of the surgical team. Finally, the mean postoperative transfusion requirement was 1.4 units of red blood cell concentrate (range 0-5).

### Clinical Outcomes

The mean postoperative VAS score was 1.02 (range 0-5), significantly lower than the preoperative score of 7.66 (range 6-9), indicating a statistically significant clinical improvement ( $p < 0.02$ ).

Regarding functional assessment, the mean preoperative Harris Hip Score (HHS) was 58.39 (range 36-68), classified as a "poor outcome." At the last clinical follow-up, the mean HHS was 84.32 (range 65-96), indicating a "good" outcome, with statistically significant differences between pre- and postoperative scores ( $p < 0.001$ ). No significant differences were found concerning age, sex, or body mass index. However, significantly better clinical outcomes were observed in patients who had undergone only one prior surgery, had a shorter interval between osteosynthesis failure and definitive surgery, had a smaller proximal femoral defect according to the Paprosky classification, and did not experience postoperative complications ( $p < 0.05$ ).

The Barthel Index, assessed at the last clinical follow-up, was 82.63 (range 70-95), corresponding to the category of "moderate dependence." A subgroup analysis revealed statistically significant differences between patients with a postoperative VAS score  $\leq 3$  and those with a score  $> 3$ . Similarly, patients with no ossifications or minimal ossifications according to the Brooker classification had higher Barthel Index scores.

### Radiological Outcomes

Based on the Paprosky classification before and after surgery, 18 patients (47.7%) had a type I femoral defect, 13 (34.2%) had a type IIA defect, and 7 (18.4%) had a type IIB defect (Table). Regarding femoral defects, the longest femoral stem (170 mm) was used in 20 patients (52.6%), the medium-sized stem (150 mm) in 12 patients (31.6%), and the shortest stem (130 mm) in 6 patients (15.7%). Patients older than 80 years and those with a body mass index  $> 30$  had larger femoral defects ( $p < 0.05$ ).

**Table.** Proximal femur defect according to Paprosky's classification and relationship to stem length.

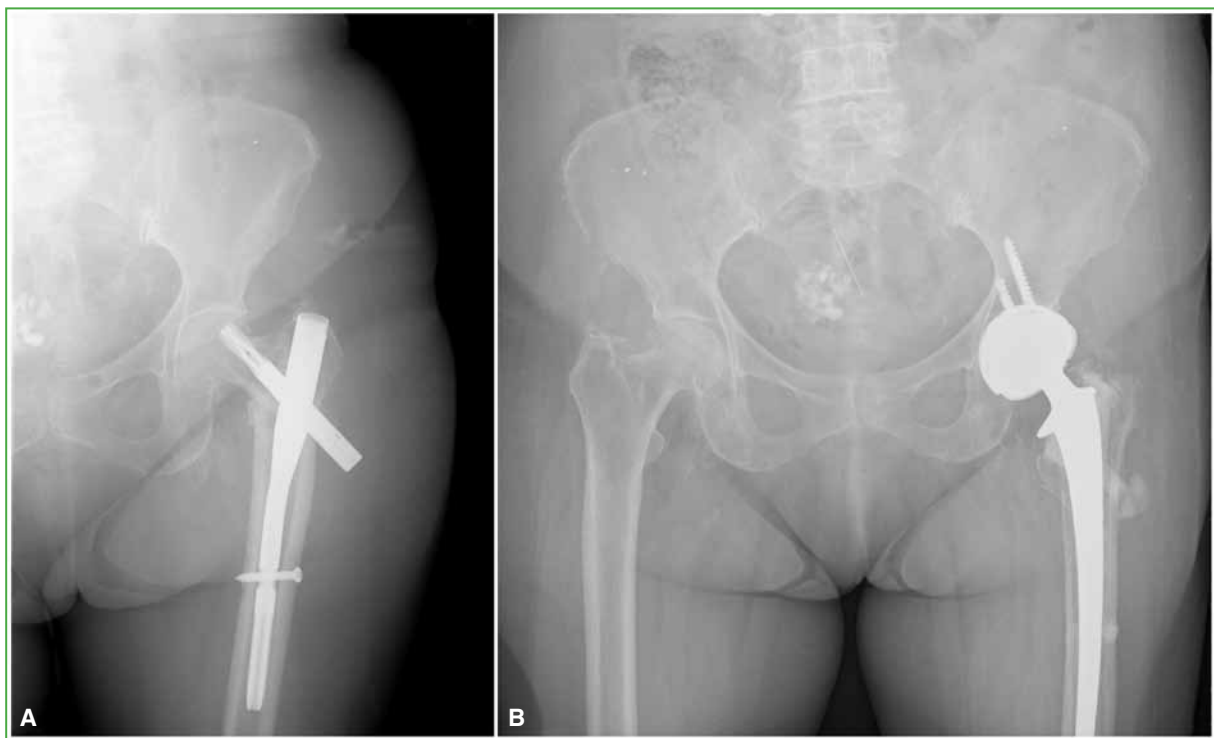
| Paprosky Classification | Number of cases |
|-------------------------|-----------------|
| I                       | 18 (47.7%)      |
| IIA                     | 13 (34.2%)      |
| IIB                     | 7 (18.4%)       |

| Femoral stem length | Frequency  |
|---------------------|------------|
| 130 mm              | 6 (15.7%)  |
| 150 mm              | 12 (31.6%) |
| 170 mm              | 20 (52.6%) |

The type of revision femoral stem was the same in all patients (Figure 3), but the acetabular fitting depended on the acetabular defect according to the Paprosky classification. In 35 patients (92.1%), a primary cup was used for an IIC or lower defect, while in 3 patients (7.9%) with IIIA defects, a revision cup was necessary. All acetabular components had dual mobility, and there were no significant differences in radiological outcomes, with correct integration based on Engh's criteria.

The assessment of heterotopic ossifications using the Brooker classification showed that 26 patients (68.8%) had no ossifications or type I ossifications, while 8 (21.1%) had type II, and only 3 (7.9%) had significant type III ossifications. A significant association was found between the presence of ossifications and VAS scores ( $p=0.01$ ), but no correlation was observed with HHS scores.



**Figure 3.** Anteroposterior radiographs of the pelvis. Revision surgery after failed osteosynthesis of a hip fracture. **A.** *Cut-out* one month after surgery with intramedullary nail. **B.** Revision femoral stem and dual-mobility cup after 10 months of follow-up.

## Complications

During follow-up, 5 patients (13.2%) experienced complications. Two (5.2%) developed chronic infection of the revision prosthesis, requiring two-stage revision surgery, in which the same type of prosthesis was re-implanted in the second stage. Three cases of prosthetic dislocation (7.8%) were recorded: one required surgical revision, while the other two were managed with closed reduction and expectant management. There were no cases of component loosening or postoperative neurovascular injury.

Notably, no patients were lost to follow-up, and there were no reported deaths. The implant survival rate was 92.2%, with 7.8% of the sample requiring re-revision.

## DISCUSSION

Hip fractures remain a global public health concern, frequently encountered in emergency departments<sup>5-7,20</sup> Despite continuous advancements in osteosynthesis materials, failure still occurs, often necessitating reoperation.<sup>20</sup> Femoral revision surgery with acetabular reconstruction is a preferred option in tertiary hospitals for patients with femoral bone stock defects and acetabular involvement, which pose both clinical and surgical challenges.<sup>9,10</sup>

Historically, various revision implants have been used for femoral reconstruction, with limited success.<sup>21-23</sup> Cemented stems have high loosening and migration rates due to issues at the bone-implant interface.<sup>23</sup> Similarly, uncemented porous and biologically coated stems have not demonstrated superior outcomes, with revision rates for aseptic loosening reaching 40% in some series.<sup>24</sup>

Following our center's approach to revision surgery, a combination of a dual-mobility cup and a cemented monoblock femoral stem was chosen for patients with minor proximal femoral defects (types I, II, IIIA). The femoral stem used has a physiological double curvature, smooth edges, and calcar support for uniform cement pressurization. Additionally, its beveled distal region with a reduced diameter minimizes traumatic insertion and intraoperative complications.

Patients with osteosynthesis failure often experience significant declines in quality of life. However, as demonstrated by the postoperative HHS scores in our study, mobility can be restored to a functional level following revision surgery, consistent with previously published findings.<sup>25</sup> Pain relief and improved function allow for a tolerable level of dependence, reducing caregiver burden and enhancing daily living activities.<sup>5,6</sup> The timing of revision surgery following osteosynthesis failure is critical, although it should ideally be performed when the patient is in optimal clinical condition.<sup>5,6,25</sup>

Our clinical and functional outcomes align with the existing literature. Li et al.<sup>25</sup> present a retrospective and descriptive study of 80 patients who underwent surgery after osteosynthesis failure, with a mean follow-up of 10 years and using the same therapeutic approach. The mean HHS was 75.1, with a homogeneous population comparable to that of the present study. When comparing the HHS of our patients with those who underwent other therapeutic options, we found no statistically significant differences. Diranzo-García et al. reported a mean HHS of 82.1 at the last clinical follow-up after evaluating the modular femoral stem option.<sup>12</sup>

In our series, osseointegration between the implant and the bone surface was complete, with no cases of loosening or increased radiolucency at the studied interface. It is true that the femoral defects included in this study were less severe than those reported in other series, where the rate of aseptic loosening reaches up to 20% in patients with a type IIIB femoral defect.<sup>26,27</sup>

Notably, in our study, severe femoral defects were associated with a higher complication rate, as three patients with a type IIB femoral defect required surgical reintervention ( $p < 0.001$ ).

The cumulative survival rate was 92.2% when considering surgical reintervention as a failure, with a minimum follow-up of 12 months in the studied sample. This survival rate and complication rate are comparable to those reported by other authors.<sup>28</sup>

Regarding complications, in the two cases requiring two-stage surgery for chronic infection, the HHS was lower than the mean at the last clinical follow-up due to the more aggressive surgical treatment and the greater number of interventions required in these patients. There was no difference in the outcomes of prosthesis dislocation between the case that required surgical revision and the two cases treated with closed reduction. This is likely due to the good clinical condition of the operated patients compared to the rest, which represents a limitation due to the heterogeneity of the population.

One limitation of our study is the absence of a control group to compare this treatment option with others for osteosynthesis failure. Additionally, the study population is highly heterogeneous, which may introduce biases into the clinical and functional outcomes. However, strengths of our study include the number of cases analyzed, the follow-up period, and the continuity in our center's research line, following several published articles on pelvic and hip pathology.

## CONCLUSIONS

Patients with extracapsular hip fractures are subject to the well-known concept of “one-shot surgery.” However, after failure, their quality of life and functional capacity should not be permanently compromised. In a second-stage approach, acetabular fitting with a dual-mobility cup and proximal femoral replacement using a cemented monoblock stem represents a viable option, offering acceptable clinical, radiological, and functional outcomes.

In appropriately selected patients, revision surgery may extend functional mobility and pain relief, contributing to a better quality of life in the final years.

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# Locked Metacarpophalangeal Joint: Case Series, Anatomical Study, and Literature Review

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## ABSTRACT

**Introduction:** Metacarpophalangeal (MCP) joint locking is a rare condition characterized by the sudden inability to achieve full extension. **Objectives:** To present the results of our case series, describe the anatomical study conducted, and propose a treatment protocol for this condition. **Materials and Methods:** We report on nine patients treated between 2006 and 2023 who sought medical attention for loss of MCP joint extension after performing forceful manual tasks. **Results:** Eight patients underwent surgical treatment, while one achieved joint release through a reduction maneuver. All patients fully recovered their range of motion without complications or recurrences. **Conclusions:** MCP joint locking is an uncommon condition. As a treatment protocol, we recommend initially attempting closed reduction. If surgery is required, a palmar approach for the middle finger or a palmar-radial approach should be used, as these provide optimal exposure of the accessory collateral ligament for release and allow for the resection of the bony spur to prevent recurrence.

**Keywords:** Metacarpophalangeal joint locking; metacarpophalangeal joint; hand; trigger finger.

**Level of Evidence:** IV

## Articulación metacarpofalángica bloqueada. Serie de casos, investigación anatómica y revisión bibliográfica

## RESUMEN

**Introducción:** El bloqueo articular a nivel metacarpofalángico es un cuadro infrecuente que se caracteriza por la pérdida repentina de la extensión máxima. **Objetivos:** Presentar los resultados de nuestra serie de casos, describir la investigación anatómica realizada y proponer un protocolo de tratamiento para este cuadro. **Materiales y Métodos:** Se presentan a 9 pacientes tratados entre 2006 y 2023, que concurren a la consulta por pérdida de la extensión de la articulación metacarpofalángica mientras realizaban alguna tarea manual de fuerza. **Resultados:** Ocho fueron operados y, en uno, se logró el desbloqueo con su respectiva maniobra de reducción. Todos recuperaron el rango de movilidad completo sin complicaciones ni recidivas. **Conclusiones:** El bloqueo metacarpofalángico es infrecuente. Como protocolo, aconsejamos intentar una reducción cerrada y, si es necesaria la cirugía, utilizar un abordaje palmar para el dedo mayor o palmar-radial, ya que expone el ligamento colateral accesorio por destabar y resear el pico óseo a fin de evitar la recidiva del enganche.

**Palabras clave:** Bloqueo metacarpofalángico; articulación metacarpofalángica; mano; dedo en gatillo.

**Nivel de Evidencia:** IV

## INTRODUCTION

Metacarpophalangeal (MCP) joint locking is a rare condition characterized by the sudden loss of both passive and active maximum extension of the MCP joint following a forced fist clench. Mobility in the interphalangeal joints remains unaffected.

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The aim of this article is to present the clinical results of a series of patients treated for MCP joint locking at our institution, to share our anatomical research on this condition, to describe the different classifications used for this entity, and to analyze current treatment options. The goal is to establish a protocol for the management of this condition in daily clinical practice.

We hope to contribute to the biomechanical understanding and adequate treatment of MCP joint locking.

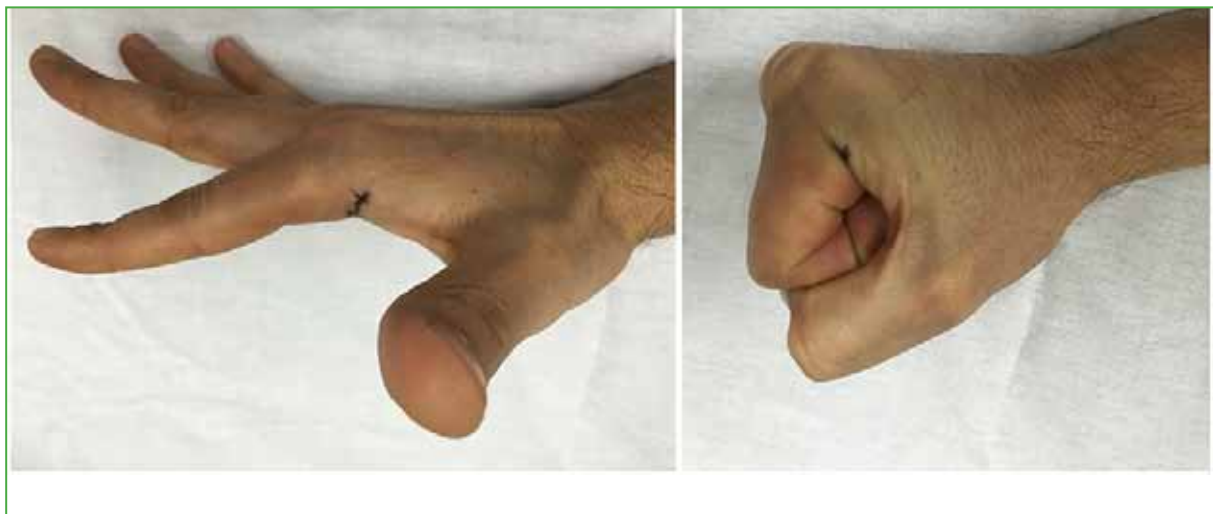
## MATERIALS AND METHODS

We present a case series of nine MCP joint locking events in seven patients treated between 2006 and 2023. The cohort included two women, one of whom experienced bilateral non-simultaneous locking, and five men, one of whom had locking in two fingers of the same hand. The affected fingers were the index finger in eight cases and the middle finger in one case (Table). All patients presented to the clinic due to the sudden loss of maximum extension in the MCP joint while performing tasks involving forced fist clenching (Figure 1).

**Table.** Population data.

|        | Age   | Sex | Finger           | Side           | Classification |
|--------|-------|-----|------------------|----------------|----------------|
| Case 1 | 31    | M   | Index            | Right          | Idiopathic     |
| Case 2 | 35    | M   | Index            | Right          | Idiopathic     |
| Case 3 | 36    | M   | Index            | Left           | Idiopathic     |
| Case 4 | 21    | F   | Index            | Left           | Idiopathic     |
| Case 5 | 36/40 | F   | Index            | Left and right | Idiopathic     |
| Case 6 | 29    | M   | Index            | Right          | Idiopathic     |
| Case 7 | 84    | M   | Index and middle | Left           | Degenerative   |

M = male; F = female.

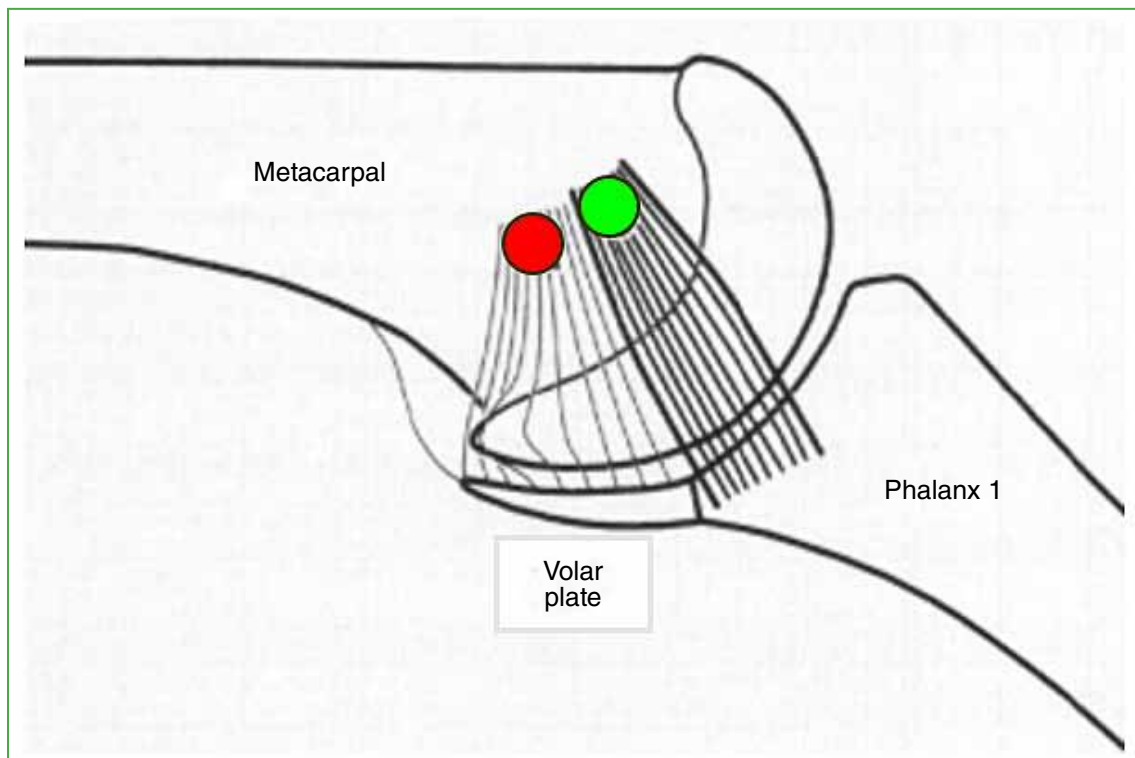


**Figure 1.** Interphalangeal extension and metacarpophalangeal locking in flexion with full fist closure.

Eight patients underwent surgical treatment, achieving joint release via a palmar approach (for the middle finger) or a lateral radial approach (for the index finger) with MCP arthrotomy performed between the volar plate and the affected collateral ligament. This approach facilitated the release of the accessory collateral ligament (ACL) from the protuberance, restoring full range of motion. In all these cases, an osteophyte was identified on the metacarpal head, where the ligamentous attachment causing the lock had occurred. Following ligament release, the bony deformity was resected to prevent future recurrence. In one patient, closed reduction using the Masaharu maneuver was successfully performed, which will be discussed in detail later.

### Anatomic Research

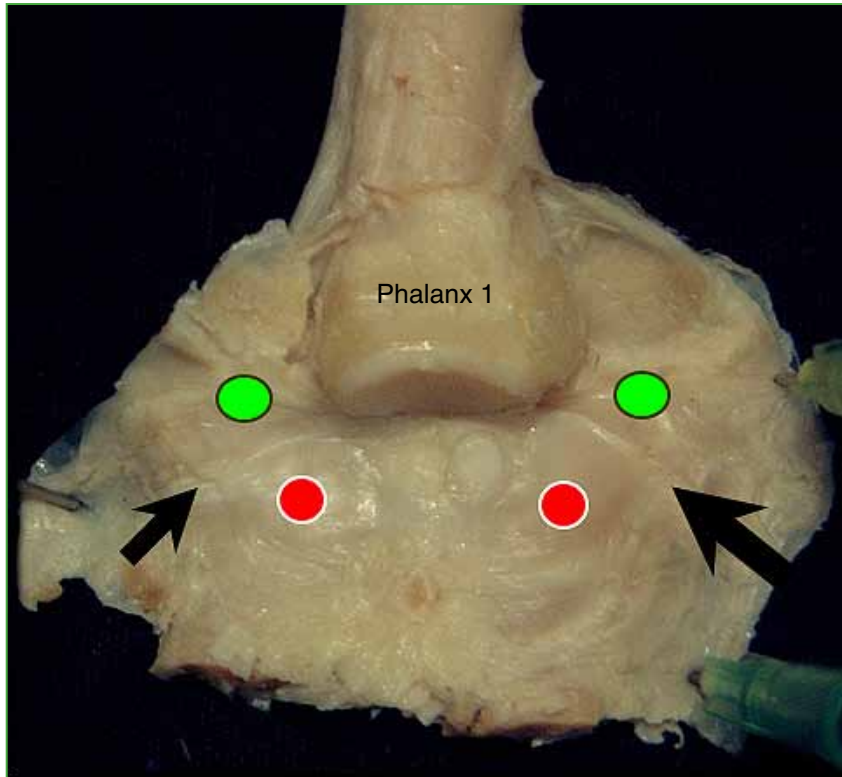
An anatomical dissection of four cadaveric specimens was performed, analyzing 16 MCP joints in triphalangeal fingers (thumbs were excluded). The collateral ligaments of the MCP joint consist of two well-defined fascicles:<sup>1</sup> the phalangeal and the glenoid (also referred to as the accessory) (Figure 2). Both fascicles originate proximally at a lateral tubercle of the metacarpal head. From this point, the phalangeal fascicle extends toward the base of the proximal phalanx, inserting in its most volar aspect, while the glenoid fascicle extends toward and integrates with the volar plate.<sup>2</sup>



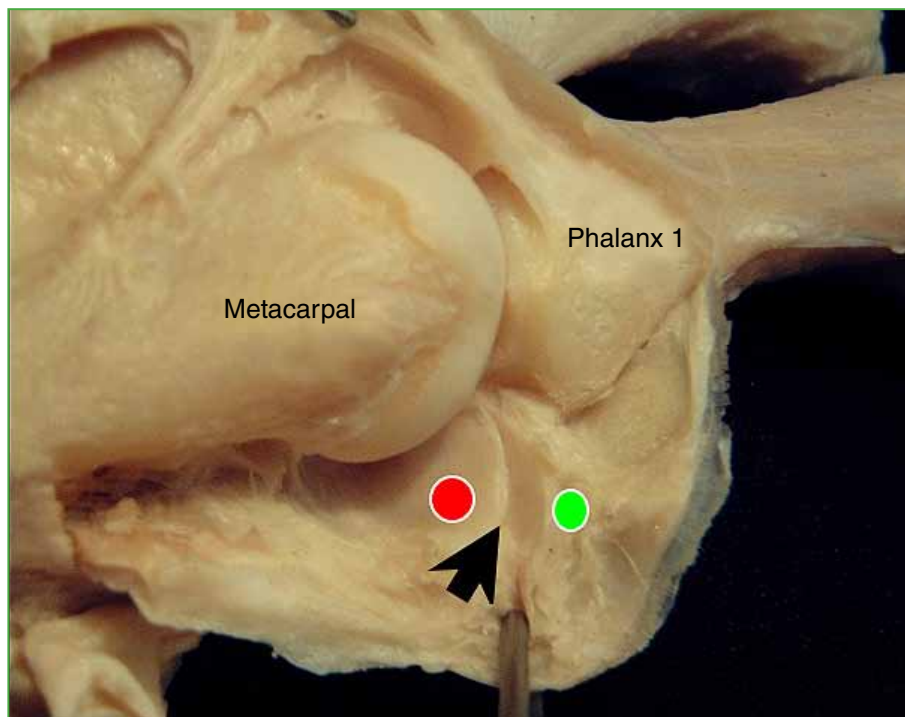
**Figure 2.** Collateral ligaments of the metacarpophalangeal joint.

From a biomechanical perspective, the phalangeal fascicle tightens during flexion, relaxes in extension, and acts as a lateral stabilizer of the joint, whereas the glenoid fascicle serves as a support for the volar plate, forming a fibrous cuff with it.

In our dissections, we consistently observed a groove between the phalangeal and glenoid fascicles of the collateral ligament. This groove was more pronounced and deeper on the radial side of the index and middle finger ligaments (Figures 3 and 4).



**Figure 3.** Difference between the radial and ulnar side in the groove. Dorsal view of the metacarpophalangeal joint.



**Figure 4.** Lateral view of the metacarpophalangeal joint. The arrow marks the groove between the fascicles.

The deep transverse intermetacarpal ligament, which spans the heads of the second, third, fourth, and fifth metacarpals, prevents their separation and stabilizes the collateral ligaments. However, this ligament is absent on the radial side of the index finger and the ulnar side of the pinky finger. Consequently, the collateral ligaments in these areas exhibit greater laxity and mobility.

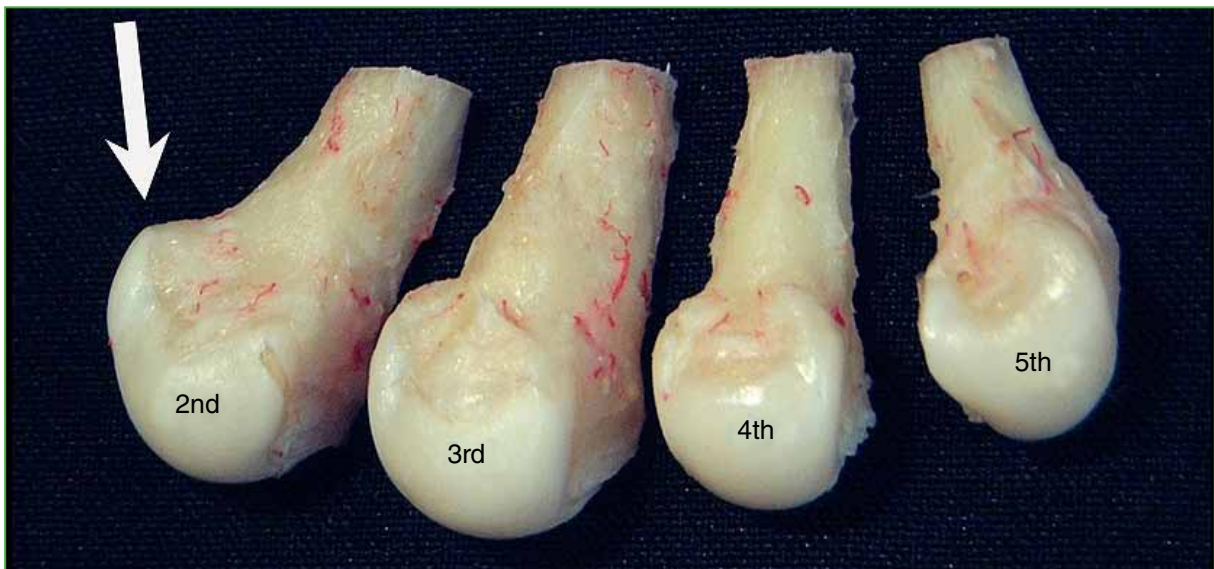
This characteristic predisposes the MCP joint of the index finger to locking when a ‘horn’ deformity of the metacarpal head occurs. Such deformities, first described by Poirier in 1889, can become caught in the aforementioned groove of the collateral ligament. Furthermore, the concave shape of the palm exposes the radial side of the second metacarpal head, the typical location of this deformity (Figure 5).

All these factors make the MCP joint of the index finger the one that anatomically meets all the conditions for this phenomenon to occur.



**Figure 5.** Anatomical alteration predisposing to metacarpophalangeal locking.

In two anatomical specimens, the prominence failed to engage with the groove during maximum flexion due to its rounded edges (Figure 6).

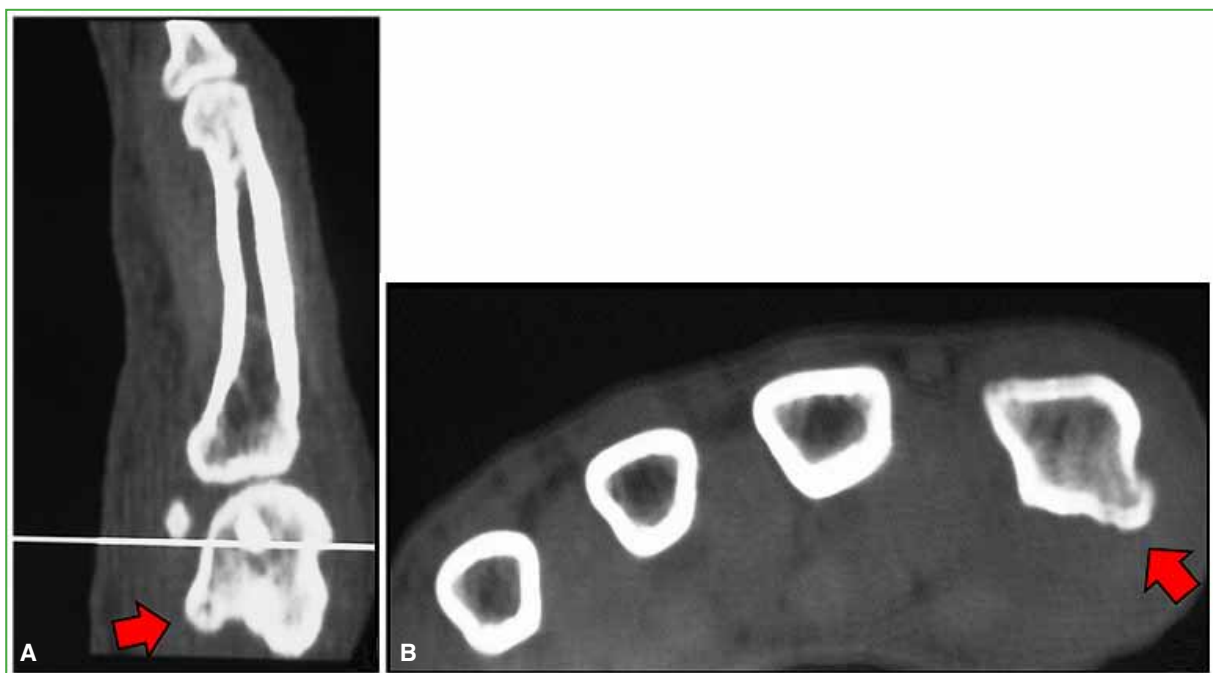


**Figure 6.** Prominence with rounded edges that does not generate engagement.

We hypothesize that a sharp edge and sufficient size (though we have not quantified it) are necessary for the prominence to engage in the groove (Figures 7 and 8). To date, no quantification of the deformity's size has been reported in the literature.



**Figure 7.** A. Oblique radiograph of the hand. B. Magnification at the head of the second metacarpal, note the bony prominence with sharp edges.



**Figure 8.** A. Computed tomography of the hand, sagittal view. The prominence is observed. B. The same image in the axial plane.

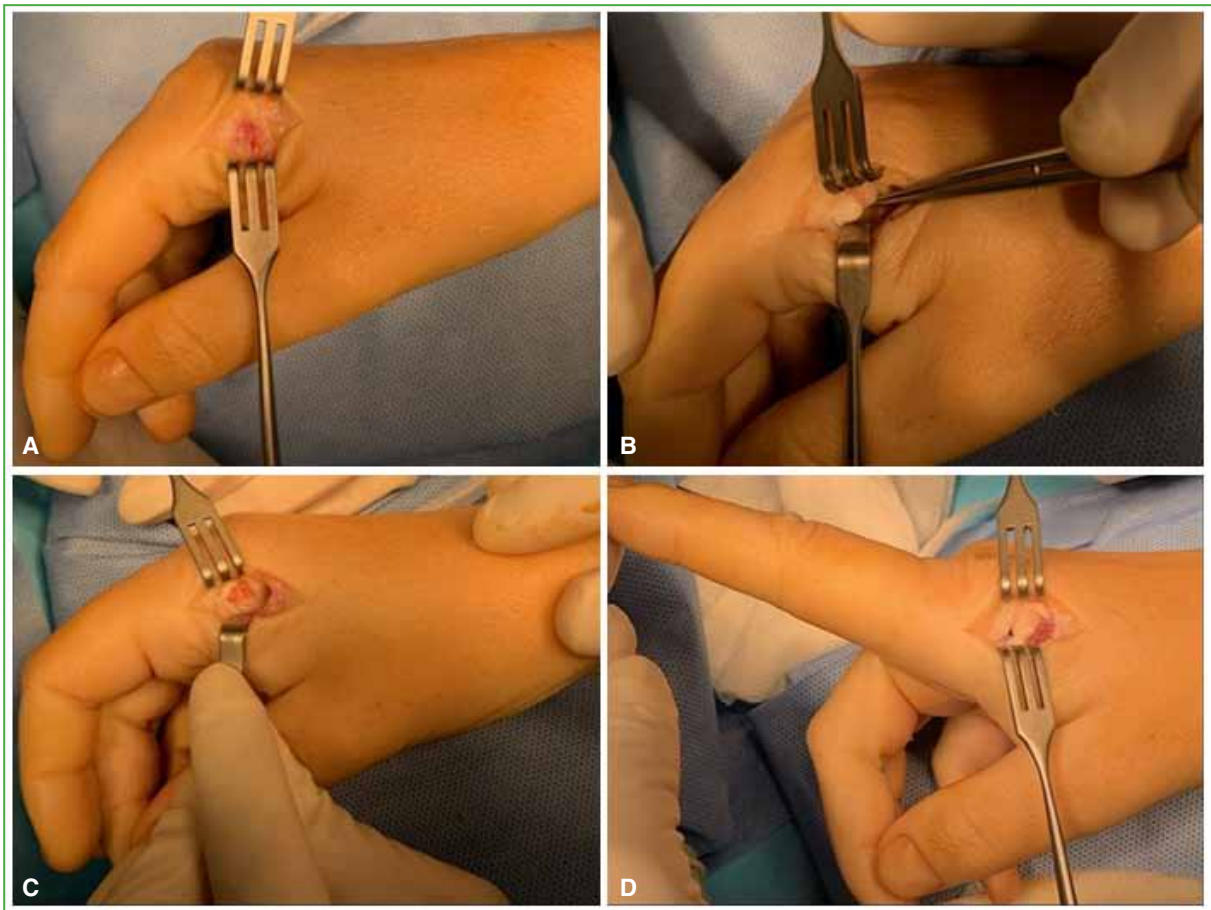
## Imaging Studies

Among the imaging studies requested for patients, we begin with simple anteroposterior, oblique, and lateral radiographs of the hands. The most useful view is the oblique projection of the metacarpal head, which allows visualization of the palmar exostosis (Figure 7). Conventional computed tomography, particularly with 3D reconstruction, can be helpful when radiographs are inconclusive, as it clearly highlights the metacarpal horn (Figure 8).

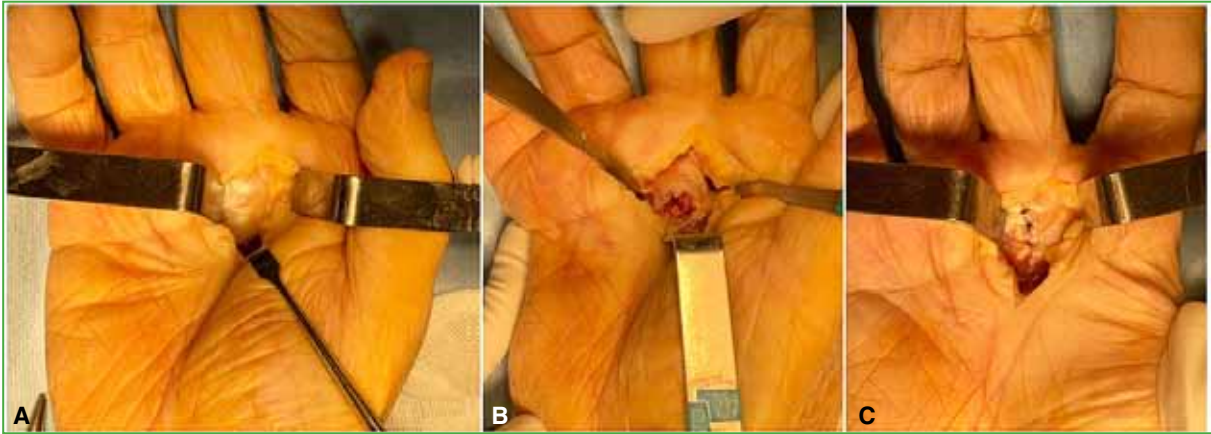
## RESULTS

Surgical treatment was performed in nine cases of MCP locking. The patients in this study were divided into two groups according to age. The average age in the idiopathic group was 41 years, while in the degenerative group, it was 82 years. In the idiopathic cases, the index finger was affected in all instances, and a metacarpal head protrusion was identified as the cause of the condition (Figure 9). One woman experienced a bilateral, non-simultaneous MCP locking, with a two-year interval between the events.

In the degenerative case, the index finger was initially involved and successfully reduced using the disengagement maneuver. However, the middle finger required surgical intervention due to irreducibility (Figure 10).



**Figure 9.** A. Lateral approach to the metacarpophalangeal joint. B. Prominence between collateral ligament bundles. C. Resection. D. Ligament repair.



**Figure 10.** A. Palmar approach. B. Resection of the osteophyte that produced the engagement. C. Closure of the palmar plate.

All patients began active flexion-extension exercises 48 hours after surgery. The outcomes were favorable, with complete flexion-extension achieved and no residual pain reported over time.

The long-term results of the surgical procedure were analyzed, showing no recurrence of the lesion. The range of motion remained complete, with no loss of function or limitations. The patient with bilateral locking reported differences between the two surgeries. She experienced tenosynovitis and joint stiffness in the index finger of her right hand, which required three months of occupational therapy to achieve full fist clenching and unrestricted range of motion (Figure 11).



**Figure 11.** Patient with bilateral locking 2 years after surgery.

## DISCUSSION

MCP locking can be caused by various factors, including entrapment of the glenoid fascicle of the ACL by an abnormal protrusion on the head of the metacarpal. In such cases, the entrapment leads to flexion locking of the MCF joint, preventing full extension of the finger. Although this condition is uncommon, the index and middle fingers are the most frequently affected, accounting for approximately 80% of cases. However, there is limited literature on this entity.

The most common presentation in our case series was flexion locking with the classic symptomatology of an inability to actively or passively extend the MCP joint, full flexion of the MCP joint, and normal interphalangeal range of motion.

In most cases, the cause was an alteration in the shape of the metacarpal head, characterized by a prominent osteophyte or condyle on the radial side, resulting in engagement of the glenoid fascicle (ACL) during MCP flexion. The larger size of the second metacarpal head, combined with the absence of a transverse intermetacarpal ligament on the radial side, may explain the higher frequency of locking in this area.

In our series, no cases of locking were observed on the ulnar side of the MCP joint.

According to the reviewed literature, MCP locking can have different etiologies, including cases where it occurs exclusively in flexion, exclusively in extension, or in both flexion and extension. In MCP locking caused by ACL entrapment, the condition is typically due to entrapment of the radial or ulnar ACL over an abnormal metacarpal protrusion. This protrusion may arise idiopathically or degeneratively, from an osteophyte, or due to conditions such as acromegaly, achondroplasia, bone tumors, or malunited fractures. Cases of ACL fiber laceration, likely caused by repetitive flexion-extension movements, have also been reported. In MCP joint locks occurring in extension, the primary cause is joint entrapment secondary to a tear of the palmar plate. Locks that occur in both flexion and extension are typically due to intra-articular loose bodies, such as those seen in osteochondromatosis.<sup>3</sup> In all cases, alterations in the geometry of the metacarpal head may be the underlying cause of MCP locking.

In terms of differential diagnosis, the most frequent condition that may be confused with MCP joint locking is trigger finger. Unlike MCP joint locking, trigger finger is characterized by locking of the MCP joint, proximal interphalangeal joint, and distal interphalangeal joint in flexion. Therefore, establishing an accurate differential diagnosis is essential to ensure proper treatment.

In 1974, Harvey proposed a classification system that divides MCP locking into three groups: degenerative, spontaneous, and miscellaneous.<sup>4</sup> In the degenerative group, the impingement of the volar plate or collateral ligament to a bony prominence in the palmar region of the metacarpal head is caused by a degenerative osteophyte. Patients in this group are typically older than 50 years, and the middle and ring fingers are most commonly affected, with the index finger rarely involved. Degenerative joint changes are visible on radiographs.

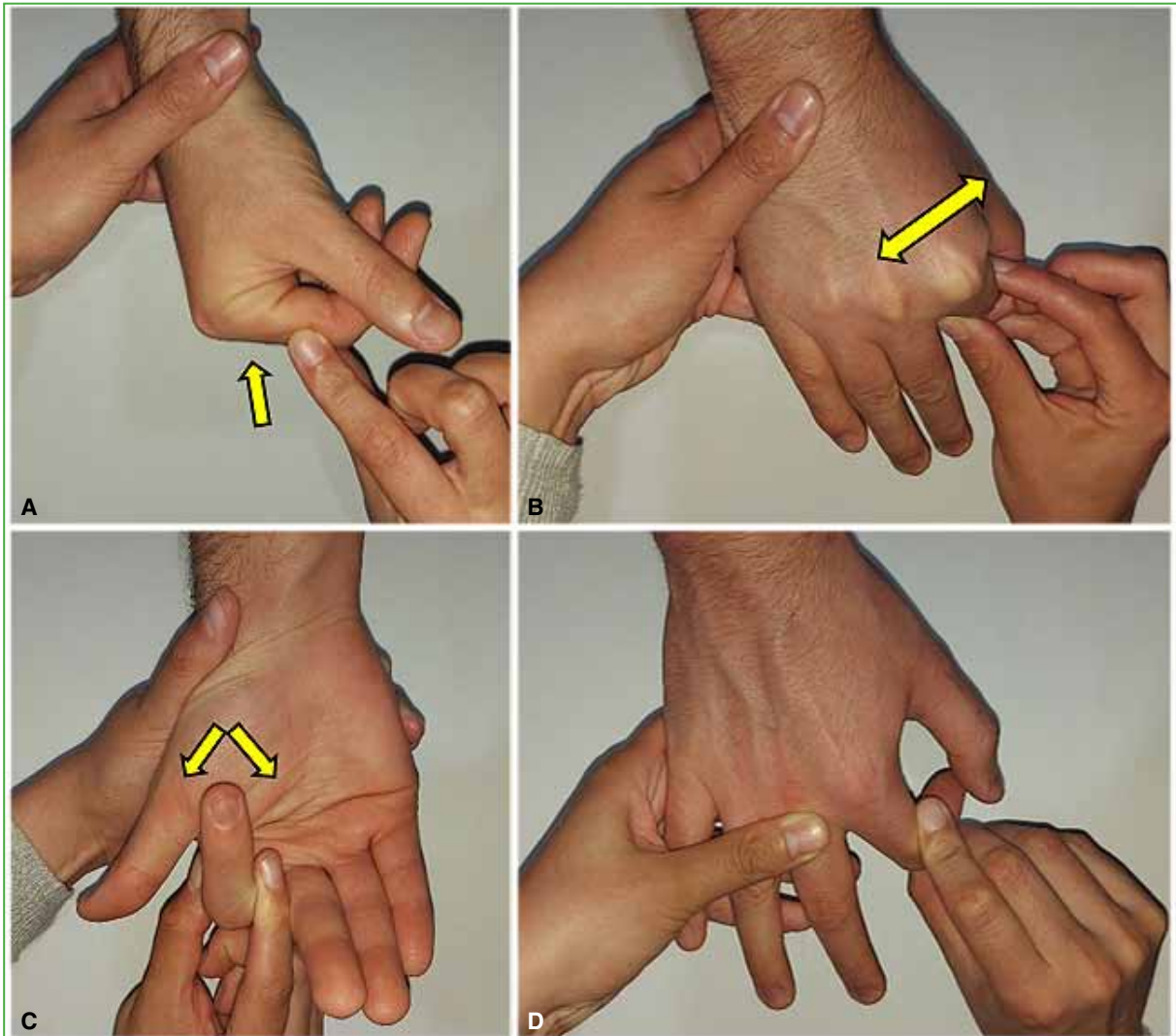
In the spontaneous group, impingement is attributed to anatomical variation. Patients in this group are typically aged 20–50 years, and the index finger is exclusively affected. Radiographs in this group reveal no articular changes but may show prominences of the metacarpal head on oblique projections.

The miscellaneous group includes metacarpal alterations secondary to trauma or congenital causes, as well as intra-articular loose bodies.

There is no consensus in the current literature regarding the treatment of MCP locking. In some cases, manual closed reduction is impossible, and due to the high risk of fractures, surgery is often the initial treatment. Yagi et al.<sup>5</sup> reported a 100% success rate with closed reduction of the joint, whereas other authors, including Langeskiöld,<sup>6</sup> Yancey and Howard,<sup>7</sup> Alldred,<sup>8</sup> and Harvey,<sup>4</sup> have described associated injuries caused by the maneuver and have advised against its use.

In 2000, Yagi et al. introduced an effective closed reduction technique consisting of four steps performed without local anesthesia.<sup>5</sup> The first step involves gradually flexing the MCP joint to allow the ACL to move through the area of engagement (Figure 12A). In the second step, when the joint is in maximum flexion, traction is applied, and radial deviation is performed, which produces an audible ‘click’ in some patients (Figure 12B). The joint is then gradually extended and, with the patient’s help, the radial offset is maintained. In the third step, if reduction is not achieved, rotational movements are applied to the proximal phalanx, transmitting force to the MCP joint and the ACL (Figure 12C). In most cases, disengagement occurs during this step. The fourth step involves gradually extending the joint while maintaining external rotation with the patient’s assistance. No resistance or pain should be felt; if these symptoms occur, the reduction attempt has failed (Figure 12D). When closed reduction is unsuccessful, surgical treatment should be considered.

The palmar approach is one option for surgical treatment. Magnetic resonance imaging studies published by Kim et al.<sup>9</sup> suggest that this approach involves deeper dissection, which restricts access to the bony prominence. Retraction of the digital arteries and nerves is necessary to visualize the surgical field, posing a risk to these structures. Despite these limitations, this approach allows access to both sides of the metacarpal condyle. The radial approach, on the other hand, provides easy access to the condyle on the radial side of the index finger. However, it is only appropriate when the condition is confirmed to be caused by a lesion in this area, as it does not provide access to the ulnar side.



**Figure 12.** A. Metacarpophalangeal flexion. B. Traction and radial deviation. C. Rotational movements from the proximal phalanx. D. Extension with external rotation.

Regarding the treatment of MCP locking due to ACL entrapment, proposed options range from expectant management in mild cases to surgical intervention in severe cases. Excision of the abnormal protrusion may prevent future ACL locking. Treatment should always be individualized based on the etiology and severity of the condition.

## CONCLUSIONS

MCP locking is a rare condition but poses a significant challenge in terms of accurate diagnosis and appropriate treatment. It is often confused with other conditions, making it crucial to include it in the differential diagnosis and to understand its biomechanics for effective management.

Our recommended evaluation and treatment protocol includes starting with radiographs, primarily oblique projections, to evaluate the prominence, and requesting a CT scan as a complementary study. For treatment, we recommend attempting closed reduction as the first step. If surgery is required, we suggest a palmar approach for the middle finger or a palmar-radial approach for the index finger. This allows exposure of the volar plate, which is incised longitudinally along its radial or ulnar border, depending on the ACL to be released. The osteophyte or bony prominence should be resected to prevent recurrence of the impingement.

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# Trends in the Evaluation and Treatment of Tibial Spine Fractures: Perspectives from SAOTI and SEOP Members

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## ABSTRACT

**Background:** Tibial spine fractures are rare injuries in the pediatric population, leading to ongoing debate regarding the most appropriate diagnostic algorithms and treatment strategies. This study analyzed the practices and preferences of pediatric orthopedic surgeons affiliated with the Argentine Society of Pediatric Orthopedics and Traumatology (SAOTI) and the Spanish Society of Pediatric Orthopedics (SEOP) in managing these fractures. **Materials and Methods:** A cross-sectional online survey consisting of 21 questions was distributed to SAOTI and SEOP members in April 2024. Data were collected on demographics, years of experience, case volume, evaluation methods, decision-making processes, and fixation techniques. **Results:** A total of 112 completed responses were obtained (response rate: 28%). Preoperative evaluation was primarily based on radiographs and advanced imaging (99.1% of respondents). The majority of surgeons (58.9%) preferred an arthroscopic approach, with 48.2% using a combination of fixation methods. Surgeons with more than 10 years of experience were more likely to favor surgical treatment for type II fractures. Although nearly 80% of respondents recommended formal postoperative rehabilitation, fewer than one-third routinely used functional testing to determine return-to-sport readiness. **Conclusions:** The survey revealed diverse practices and preferences in the evaluation and treatment of tibial spine fractures. These findings highlight the need for further research and standardization to optimize the management of these uncommon injuries.

**Keywords:** Adolescents; screw fixation; suture fixation; survey; tibial eminence fracture; tibial spine.

**Level of Evidence:** V, expert opinion

## Tendencias en la evaluación y el tratamiento de fracturas de la espina tibial: perspectivas de los miembros de la SAOTI y la SEOP

### RESUMEN

**Introducción:** Las fracturas de la espina tibial son lesiones poco frecuentes en la población pediátrica, lo que ha generado debate sobre los algoritmos diagnósticos y las estrategias terapéuticas más apropiadas. En este estudio, se analizaron las prácticas y preferencias de los cirujanos ortopédicos pediátricos afiliados a la Sociedad Argentina de Ortopedia y Traumatología Infantil (SAOTI) y a la Sociedad Española de Ortopedia Pediátrica (SEOP) en el tratamiento de estas fracturas. **Materiales y Métodos:** Se realizó una encuesta transversal en línea, con 21 preguntas, distribuida a los miembros de la SAOTI y la SEOP en abril de 2024. Se recopiló información sobre demografía, experiencia, volumen de casos tratados, evaluación, toma de decisiones y métodos de fijación. **Resultados:** Se obtuvieron 112 respuestas completadas (tasa de respuesta del 28%). El 99,1% de los encuestados prefirió radiografías e imágenes avanzadas para la evaluación preoperatoria. La mayoría (58,9%) optó por un enfoque artroscópico y una combinación de métodos de fijación (48,2%). Los cirujanos con más de 10 años de experiencia preferían más el tratamiento quirúrgico de las fracturas tipo II. Aunque casi el 80% indica rehabilitación formal posoperatoria, menos de un tercio emplea pruebas funcionales para decidir el retorno al deporte. **Conclusiones:** La encuesta mostró prácticas y preferencias variadas en la evaluación y el tratamiento de las fracturas de la espina tibial. Estos hallazgos destacan que se necesita más investigación y estandarización para optimizar el manejo de estas lesiones poco frecuentes.

**Palabras clave:** Adolescentes; fijación con tornillos; fijación con suturas; encuesta; fractura de la eminencia tibial; espina tibial.

**Nivel de Evidencia:** V, opinión de expertos

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## INTRODUCTION

Tibial spine fractures account for 2% to 5% of pediatric knee injuries, with most cases occurring in patients aged 8 to 14 years.<sup>1,2</sup> The classic mechanisms of injury include forced knee flexion with simultaneous external rotation of the tibia or knee hyperextension with a valgus or rotational force. Because the anterior cruciate ligament (ACL) inserts into the tibial spine, these fractures are often referred to as ACL-equivalent injuries.<sup>3,4</sup> The mechanisms are similar to those of ACL injuries in adults, where excessive traction forces lead to intrasubstance ligamentous injury. However, in children, avulsion fractures occur more easily because the strength of the tibial plateau, which is not yet fully ossified, is lower than that of the ACL.

Tibial spine fractures are uncommon injuries, meaning that few surgeons gain significant experience in their treatment. This lack of exposure presents challenges in assessment, treatment planning, and surgical execution, potentially affecting both surgeon confidence and the ability to manage these fractures optimally. Consequently, there is ongoing debate regarding the most appropriate diagnostic and therapeutic approaches. To better understand this matter, our study aimed to evaluate the management strategies and preferences of pediatric orthopedic surgeons affiliated with two professional societies: the *Sociedad Argentina de Ortopedia y Traumatología Infantil* (SAOTI) and the *Sociedad Española de Ortopedia Pediátrica* (SEOP).

## MATERIALS AND METHODS

### Sampling and Survey Administration

Ethics committee approval was not required, as the study did not involve human subjects. A cross-sectional survey was developed using Google Forms, consisting of 21 questions, and was distributed via email to active members of SAOTI and SEOP. Prior to distribution, the questionnaire was pilot-tested on an independent group of three experienced orthopedic surgeons to ensure it adequately covered current management practices and that individual questions aligned with the study's objectives. The survey was officially distributed in April 2024, with three follow-up reminders sent to improve the response rate. The questionnaire collected information on surgeon demographics, years of experience, volume of cases treated annually, evaluation methods, decision-making processes, and surgical approaches and fixation techniques.

### Data Entry and Analysis

Responses were entered into a database using Google Forms and subsequently exported to the statistical software R-Medic.<sup>5</sup> Continuous variables were tested for normality and are reported as mean ( $\pm$  standard deviation). Categorical variables are presented as counts and percentages. Associations between geographic location, experience, annual case volume, and practice preferences were analyzed. For continuous variables, either Student's t-test or the Mann-Whitney U test was applied, depending on the normality of the data distribution. A 95% confidence interval was used, with statistical significance set at  $p < 0.05$ .

## RESULTS

A total of 112 completed surveys were collected from both societies, yielding a response rate of 28%. All respondents were specialists (with 87.5% having more than 5 years of experience) (Table 1).

Advanced imaging and radiographs were preferred by 99.1% of participants for preoperative evaluation. The majority of surgeons (58.9%) favored an arthroscopic approach, and 48.2% reported using a combination of different fixation methods (Table 2).

Subgroup analysis revealed that SEOP-affiliated surgeons showed a greater preference for arthroscopic treatment ( $p < 0.03$ ). While more than half of respondents (58.1%) considered surgical treatment ideal for displaced type II fractures (according to the Meyers and McKeever classification<sup>3</sup>) without associated injuries, this preference was significantly higher among surgeons with more than 10 years of experience ( $p < 0.01$ ) (Table 3). No significant differences were found regarding fixation method preferences based on respondent demographics, experience, or annual case volume. Although nearly 80% of respondents use formal postoperative rehabilitation, less than one-third routinely perform functional testing to determine readiness for return to sport.

**Table 1.** Demographic data of participants

| Variable   |   | n (%)      |
|--|---|------------|
| Country  | Argentina                                 | 67 (60%)   |
|  | Spain                                     | 45 (40%)   |
| Type of hospital practice  | Public                                    | 28 (25%)   |
|  | Private                                   | 21 (19%)   |
|  | Both                                      | 63 (56%)   |
| Post-residency training  | Pediatric orthopedics                     | 86 (77%)   |
|  | Pediatric orthopedics and sports medicine | 21 (19%)   |
|  | None                                      | 5 (4%)     |
| Years of practice as a specialist  | <5  | 14 (12,5%) |
|  | 5-10                                      | 23 (20,5%) |
|  | 10-15                                     | 20 (18%)   |
|  | >15                                       | 55 (49%)   |
| Percentage of practice involving pediatric and adolescent patients ( $\leq 18$ years). | <25                                       | 14 (12,5%) |
|  | 25-50                                     | 8 (7%)     |
|  | 50-75                                     | 20 (18%)   |
|  | >75                                       | 70 (62,5%) |
| Percentage of practice that involves sports medicine                                   | <25                                       | 55 (49%)   |
|  | 25-50                                     | 36 (32%)   |
|  | 50-75                                     | 20 (18%)   |
|  | >75                                       | 1 (1%)     |
| Number of tibial spine fractures treated annually                                      | Rarely (<1)                               | 39 (35%)   |
|  | 1-3                                       | 48 (43%)   |
|  | 4-6                                       | 14 (12,5%) |
|  | 7-9                                       | 8 (7%)     |
|  | >10                                       | 2 (2%)     |
| Number of tibial spine fractures treated in their entire career.                       | <5  | 28 (25%)   |
|  | 5-10                                      | 40 (36%)   |
|  | 10-15                                     | 30 (27%)   |
|  | 26-50                                     | 12 (10%)   |
|  | >50                                       | 2 (2%)     |

## DISCUSSION

The results of this study provide an overview of the current practices and preferences of pediatric orthopedic surgeons in Argentina and Spain regarding the management of tibial spine fractures. All respondents were specialists, and 90% had more than 5 years of experience. However, a relatively low percentage (19%) had formal training in sports medicine and arthroscopy.

**Table 2.** Preference for evaluation and treatment among respondents\*

| Variable  |                                   | n (%)    |
|---|-----------------------------------|----------|
| In the evaluation of a displaced fracture (Meyers and McKeever type II or III), what images do you use for surgical planning? | Radiographs only                  | 1 (1%)   |
|   | Radiographs and CT                | 50 (45%) |
|   | Radiographs and MRI               | 20 (18%) |
|   | Radiographs, CT and MRI           | 41 (36%) |
| In your usual practice: what is the time delay for imaging tests needed to decide on treatment?                               | Same day                          | 29 (26%) |
|   | Less than one week                | 62 (55%) |
|   | 1-3 weeks                         | 20 (18%) |
|   | >3 weeks                          | 1 (1%)   |
| What is your preferred reduction technique?   | Arthroscopy                       | 66 (59%) |
|   | Open ( <i>mini-open</i> )         | 46 (41%) |
| In your service, do you have a specialist in pediatric knee or arthroscopy?   | Yes                               | 80 (71%) |
|   | No                                | 32 (29%) |
| What is your preferred method of internal fixation?   | High-strength sutures             | 30 (27%) |
|   | Cannulated metal screws           | 20 (18%) |
|   | Bioabsorbable screws              | 6 (5%)   |
|   | Harpoons                          | 2 (2%)   |
|   | Combination of the above          | 54 (48%) |
| Immobilization after reduction and internal fixation  | No                                | 2 (2%)   |
|   | Yes, <2 weeks                     | 15 (14%) |
|   | Yes, 2 weeks                      | 43 (38%) |
|   | Yes, 4 weeks                      | 46 (41%) |
|   | Yes, 6 weeks                      | 6 (5%)   |
| Weight-bearing of the operated limb after reduction and internal fixation   | Partial weight-bearing from day 1 | 22 (20%) |
|   | No weight-bearing for 2 weeks     | 30 (27%) |
|   | No weight-bearing for 3 weeks     | 17 (15%) |
|   | No weight-bearing for 4 weeks     | 33 (29%) |
|   | No weight-bearing for 6 weeks     | 10 (9%)  |

(Continúa.)

Table 2. (Cont.)

|   |  |          |
|---|--|----------|
| Rehabilitation (physical therapy) after surgical treatment  | Optional   | 24 (21%) |
|   | Routine  | 88 (79%) |
| How do you decide on the return to sport in a patient who practices sports professionally?  | Upon fracture healing, after regaining range of motion and at least 85% of contralateral limb strength and complete rehabilitation (regardless of time since surgery). | 85 (76%) |
|   | Upon fracture healing, and after completing 10-15 rehabilitation sessions (approximately 3 months)   | 20 (18%) |
|   | Upon fracture healing (approximately 4-6 weeks)  | 7 (6%)   |
| Do you routinely use functional tests (strength, coordination, balance, <i>hop tests</i> , etc.) to decide on the return to sport?                                | No   | 76 (68%) |
|   | Yes  | 36 (32%) |
| In your experience, what is the most frequent complication requiring revision surgery?  | Residual instability   | 49 (44%) |
|   | Arthrofibrosis   | 38 (34%) |
|   | Persistent pain  | 12 (11%) |
|   | Malunion   | 9 (8%)   |
|   | Infection  | 4 (3%)   |
| In an 11-year-old patient with a nondisplaced fracture (type I) with no associated injuries, how would you manage immobilization time for conservative treatment? | Immobilization for 4 weeks   | 70 (62%) |
|   | Immobilization for 6 weeks   | 30 (27%) |
|   | Immobilization for 2 weeks   | 12 (11%) |
| How would you treat an 11-year-old male patient with a displaced Meyers and McKeever type II fracture (intact posterior hinge) with no associated injuries?       | Conservative treatment without attempted reduction   | 5 (4%)   |
|   | Conservative treatment with arthrocentesis and attempted closed reduction.   | 42 (38%) |
|   | Surgical treatment with fixation, sparing the physis   | 59 (53%) |
|   | Surgical treatment with transphyseal fixation  | 6 (5%)   |

\*Values are expressed in whole numbers and percentages. CT = computed tomography; MRI = magnetic resonance imaging.

**Table 3.** Treatment preferences according to demographic location, experience, and annual volume

| Variable                                 |  | Country           |               | p            | Experience in years of practice |             | p            | Annual case volume |           | p             |
|--|--|-------------------|---------------|--------------|---------------------------------|-------------|--------------|--------------------|-----------|---------------|
|  |  | Argentina (n= 67) | Spain (n= 45) |              | <10 (n= 37)                     | ≥11 (n= 75) |              | < 3 (n=87)         | >3 (n=25) |               |
| Approach                                 | Open ( <i>mini-open</i> )                          | 33 (49%)          | 13 (29%)      | <b>0.03*</b> | 14 (38%)                        | 32 (43%)    | 0.63*        | 33 (38%)           | 13 (52%)  | 0.21*         |
|  | Arthroscopic                                       | 34 (51%)          | 32 (71%)      |              | 23 (62%)                        | 43 (57%)    |              | 54 (62%)           | 12 (48%)  |               |
| Fixation method                          | High-strength sutures                              | 19 (28%)          | 11 (24%)      | 0.82**       | 13 (35%)                        | 17 (23%)    | 0.30**       | 23 (26%)           | 7 (28%)   | 0.67**        |
|  | Harpoons   | 0                 | 2 (4%)        |              | 0                               | 2 (2%)      |              | 2 (2%)             | 0 (0%)    |               |
|  | Cannulated metal screws                            | 13 (19%)          | 7 (16%)       |              | 6 (16%)                         | 14 (20%)    |              | 15 (17%)           | 5 (20%)   |               |
|  | Bioabsorbable screws                               | 3 (4%)            | 3 (7%)        |              | 2 (5%)                          | 4 (5%)      |              | 5 (6%)             | 1 (4%)    |               |
|  | Combination  | 32 (48%)          | 22 (49%)      |              | 16 (43%)                        | 38 (50%)    |              | 42 (48%)           | 12 (48%)  |               |
| Treatment for type II, 11-year-old male  | Conservative                                       | 32 (48%)          | 22 (49%)      | 0.23*        | 22 (59%)                        | 25 (33%)    | <b>0.01*</b> | 40 (46%)           | 7 (28%)   | 0.11*         |
|  | Surgical   | 25 (37%)          | 22 (49%)      |              | 15 (41%)                        | 50 (67%)    |              | 47 (54%)           | 18 (72%)  |               |
|  | Conservative - No reduction                        | 4 (6%)            | 1 (2%)        | 0.59**       | 1 (2%)                          | 4 (5%)      | 0.09**       | 4 (4%)             | 1 (4%)    | 0.08**        |
|  | Conservative - Arthrocentesis and closed reduction | 21 (31%)          | 21 (47%)      |              | 21 (57%)                        | 21 (28%)    |              | 36 (41%)           | 6 (24%)   |               |
|  | Surgical – Physio-sparing fixation                 | 40 (60%)          | 19 (42%)      |              | 11 (30%)                        | 48 (64%)    |              | 42 (48%)           | 17 (68%)  |               |
|  | Surgical - Transphy-seal fixation                  | 2 (3%)            | 4 (9%)        |              | 4 (11%)                         | 2 (3%)      |              | 5 (6%)             | 1 (4%)    |               |
| Preferred imaging in displaced fractures | Radiographs only                                   | 0                 | 1 (2%)        | 0.03**       | 0                               | 1 (1%)      | 0.32**       | 1 (1%)             | 0 (0%)    | <b>0.06**</b> |
|  | Radiographs and CT                                 | 26 (39%)          | 24 (53%)      |              | 20 (54%)                        | 30 (40%)    |              | 43 (49%)           | 7 (28%)   |               |
|  | Radiographs and MRI                                | 11 (16%)          | 9 (20%)       |              | 5 (14%)                         | 15 (20%)    |              | 14 (16%)           | 6 (24%)   |               |
|  | Radiographs, CT and MRI                            | 30 (45%)          | 11 (24%)      |              | 12 (32%)                        | 29 (39%)    |              | 29 (33%)           | 12 (48%)  |               |

t test (two independent samples); \*\* Mann-Whitney test. CT = computed tomography; MRI = magnetic resonance imaging.

A notable finding was the high preference for radiographs and advanced imaging in preoperative evaluation. This reflects the importance placed on thorough and accurate injury assessment before determining a treatment plan. Given the mechanism of injury, tibial spine fractures are often associated with meniscal, chondral, and ACL injuries.<sup>6-8</sup> For this reason, MRI is considered mandatory in the preoperative evaluation of these patients. Strikingly, 44% of respondents (39% of SAOTI members and 53% of SEOP members) considered radiographs and computed tomography (CT) necessary for surgical decision-making. However, while these modalities provide valuable information on fragment displacement and comminution, they do not adequately assess interposed structures (intermeniscal ligament, medial meniscus, etc.), associated injuries, or cartilaginous fragments, common in younger children.

Regarding surgical approaches, most surgeons preferred an arthroscopic approach with a combination of fixation methods. This trend suggests a shift toward less invasive techniques and a more individualized approach tailored to each fracture's characteristics. The arthroscopic technique is favored due to its advantages, includ-

ing better intra-articular visualization, removal of interposed structures (intermeniscal ligament, meniscus, etc.), treatment of concomitant meniscal and chondral injuries with minimal morbidity, and improved ACL tensioning.

A systematic review by the Tibial Spine Research Interest Group<sup>9</sup> found no significant differences in rates of nonunion, arthrofibrosis, loss of range of motion, laxity, or secondary ACL injury between different fixation methods. However, some studies report a reoperation rate nearly three times higher with screw fixation.<sup>10,11</sup> 52% of respondents preferred immobilization for 2 weeks or less, while 46% opted for 4 weeks or more. The majority did not allow weight-bearing on the affected limb for 2 to 6 weeks. Previous studies<sup>12,13</sup> suggest that prolonged immobilization increases the risk of arthrofibrosis and delays return to sports. Patel et al.<sup>12</sup> reported that immobilization for more than 4 weeks increases the risk of arthrofibrosis 12-fold. Therefore, every effort should be made to achieve optimal reduction and stable fixation, allowing for early rehabilitation, which promotes faster recovery and reduces secondary complications.

Tibial spine fractures are typically managed conservatively when undisplaced and surgically when completely displaced. However, the optimal treatment for displaced but posteriorly hinged (type II) fractures remains controversial. In our study, 58.1% of respondents favored surgical treatment for these fractures. No significant differences were observed in treatment preferences based on demographics, clinical experience, or annual case volume, suggesting a general consensus among pediatric orthopedic surgeons across different backgrounds. A recent multicenter study<sup>14</sup> analyzed 164 patients with type II fractures treated with both surgical and non-surgical approaches. The study found that while complication rates, reoperation rates, and total range of motion were similar, the non-surgical group had higher ACL laxity, a higher incidence of recurrent fractures and ACL injuries requiring surgery (4.9% vs. 0%;  $p = 0.01$ ). Conversely, the surgical group had a higher rate of arthrofibrosis (8.9% vs. 0%;  $p = 0.047$ ).

The widespread use of formal postoperative rehabilitation among respondents underscores the importance of active recovery strategies. However, the low frequency of functional testing to assess return to sport raises concerns about whether current rehabilitation protocols optimize long-term functional outcomes. This highlights potential areas for future research and protocol refinement.

This study has limitations that should be considered. The survey was distributed only to SAOTI and SEOP members, potentially introducing selection bias by excluding other pediatric orthopedic surgeons with different perspectives. This limits the ability to extrapolate our findings internationally or to other surgeon populations. Secondly, responses are based on self-reported practices, which may be subject to recall bias or response bias. Surgeons might report practices they perceive as more acceptable or ideal, affecting the accuracy of the data collected. Thirdly, although the survey included 21 questions, it may not have addressed all relevant aspects of tibial spine fracture management. Important variables, such as complication management, that could influence the clinical practices and treatment decisions of pediatric orthopaedic surgeons could have been omitted. Finally, while statistical analyses were conducted to explore associations among variables, the sample size may not have been large enough to detect significant differences in some comparisons, potentially limiting the robustness of certain findings.

This study highlights the variability in clinical practices regarding tibial spine fractures among pediatric orthopedic surgeons. While common trends emerged—such as the widespread use of advanced imaging and preference for less invasive surgical approaches—there were also areas of variability in clinical practice. These findings emphasize the need for continued research and interdisciplinary collaboration to refine therapeutic strategies for these injuries, ultimately improving long-term outcomes for pediatric patients.

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# Carpal Injuries Associated With Distal Radius Fractures: Arthroscopic-Tomographic Correlation

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## ABSTRACT

**Introduction:** Distal radius fractures are among the most common fractures. Associated intercarpal injuries have been reported in up to 70% of cases. If undiagnosed or untreated, these injuries can negatively impact functional outcomes. The aim of this study was to establish a correlation between computed tomography (CT) and arthroscopy in diagnosing intercarpal injuries associated with distal radius fractures. **Materials and Methods:** We retrospectively analyzed 146 patients (aged 18–65 years) with distal radius fractures who underwent arthroscopically assisted surgery. Preoperative radiographs and CT scans of the wrist were evaluated. Triangular fibrocartilage complex (TFCC) injuries, ligament and osteochondral injuries, and carpal bone fractures were assessed based on pre-established imaging criteria, with arthroscopy serving as the diagnostic gold standard. The diagnostic accuracy of CT for these injuries was determined. **Results:** For TFCC injuries, CT demonstrated a sensitivity of 84%, specificity of 65%, positive predictive value (PPV) of 77%, and negative predictive value (NPV) of 10%. For scapholunate ligament injuries, sensitivity was 61%, specificity 62%, PPV 60%, and NPV 63%. For osteochondral injuries, sensitivity was 55%, specificity 87%, PPV 22%, and NPV 97%. **Conclusion:** There was no statistically significant correlation between CT and arthroscopy for the preoperative diagnosis of intercarpal injuries associated with distal radius fractures.

**Keywords:** Distal radius fracture; computed tomography; arthroscopy; associated injuries; intercarpal ligaments.

**Level of Evidence:** II. Diagnostic study

## Lesiones del carpo asociadas a fracturas del radio distal: correlación artroscópico-tomográfica

## RESUMEN

**Introducción:** La fractura del radio distal representa una de las fracturas más frecuentes. La prevalencia de lesiones intercarpianas asociadas llega al 70%. Estas lesiones impactan en los resultados funcionales cuando pasan desapercibidas durante el diagnóstico y el tratamiento. El propósito de este estudio fue establecer una correlación entre la tomografía computarizada y la artroscopia para diagnosticar lesiones intercarpianas asociadas a fracturas del radio distal. **Materiales y Métodos:** Se evaluó retrospectivamente a 146 pacientes de 18 a 65 años, con fractura del radio distal, operados con asistencia artroscópica y estudiados con radiografías y tomografía computarizada prequirúrgicas. Se evaluaron las lesiones del fibrocartilago triangular, ligamentarias y osteocondrales, y las fracturas de los huesos del carpo, según criterios imagenológicos preestablecidos, tomando como patrón de referencia diagnóstico a la artroscopia. Se determinó la precisión diagnóstica de la tomografía para estas lesiones. **Resultados:** Para lesiones del fibrocartilago triangular, la sensibilidad fue del 84%; la especificidad, del 65%; el valor predictivo positivo, del 77% y el valor predictivo negativo, del 10%. Para lesiones del ligamento escafolunar, la sensibilidad fue del 61%; la especificidad, del 62%; el valor predictivo positivo, del 60% y el valor predictivo negativo, del 63%. Para lesiones osteocondrales, la sensibilidad fue del 55%; la especificidad, del 87%; el valor predictivo positivo, del 22% y el valor predictivo negativo, del 97%. **Conclusión:** No hubo una correlación estadísticamente significativa entre la tomografía computarizada y la artroscopia para el diagnóstico prequirúrgico de lesiones intercarpianas asociadas a una fractura del radio distal.

**Palabras clave:** Fractura de radio distal; tomografía computarizada; artroscopia; lesiones asociadas; ligamentos intercarpianos.

**Nivel de Evidencia:** II. Estudio diagnóstico

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## INTRODUCTION

Distal radius fractures (DRFs) account for approximately 25% of fractures in the pediatric population and 18% in elderly patients.<sup>1</sup> The classic literature reports an increasing incidence of DRFs across all age groups, with a stable trend in recent years.<sup>2</sup> This trend, along with the high healthcare costs associated with treating the injury and its complications, highlights the importance of comprehensive and timely diagnostic and therapeutic management.<sup>3</sup>

Approximately 16% of patients with DRFs report persistent wrist and hand pain even one year after injury, which is attributed to a multifactorial etiology.<sup>4</sup> Cheng et al. associated this chronic pain with factors such as ulnar impaction due to poor reduction, lack of ulnar styloid consolidation, triangular fibrocartilage complex (TFCC) injuries with or without distal radioulnar instability, intercarpal ligament injuries, and chondral damage.<sup>5</sup> Ligament injuries have been reported in up to 70% of cases.<sup>6</sup> The scapholunate ligament (SLL) is the most important intercarpal ligament; its injury causes instability, leading to a specific pattern of osteoarthritis and residual chronic pain.

Diagnosing these lesions before surgical treatment is challenging. This difficulty arises from the inability to perform a thorough clinical evaluation due to pain and soft tissue edema. Additionally, literature reports diagnostic limitations of both radiography and computed tomography (CT) in detecting such injuries. Although radiographic signs, such as widening of intercarpal joint spaces, distal radioulnar joint incongruity, or disruption of Gilula's lines, may suggest associated soft tissue injuries, radiographs have been found to be moderately reliable for diagnosing ligament injuries and are better for ruling out rather than confirming them.<sup>7</sup>

Grabl et al. reported a specificity and sensitivity of 84% and 69%, respectively, for radiographs in diagnosing scapholunate ligament injuries concomitant with intra-articular DRFs.<sup>8</sup> Suzuki et al. evaluated the intra- and interobserver reliability of radiography and CT for detecting carpal ligament injuries associated with DRFs, using arthroscopy as the confirmatory method.<sup>9</sup> They found moderate intraobserver and poor interobserver reliability for radiographs, in contrast to the acceptable results obtained with coronal CT slices. However, current evidence is insufficient to accurately determine the extent of these injuries and guide therapeutic management.

Although alternative imaging methods such as CT with intra-articular contrast, MRI, or stress radiographs exist, they are not routinely used due to their costs and the need for contrast administration.

The aim of this study was to determine whether a correlation exists between CT and arthroscopy in diagnosing lesions associated with DRFs. As a secondary objective, we sought to establish the incidence of carpal injuries in this type of fracture.

## MATERIALS AND METHODS

A retrospective, observational cohort study was conducted. Data analysis was performed using the PECTRA® system, accessing medical records, imaging studies, and surgical reports. Radiographs and CT scans with multiplanar reconstruction were reviewed, with specific measurements performed to detect potential carpal injuries based on clearly established criteria. These findings were then compared with those documented in surgical reports.

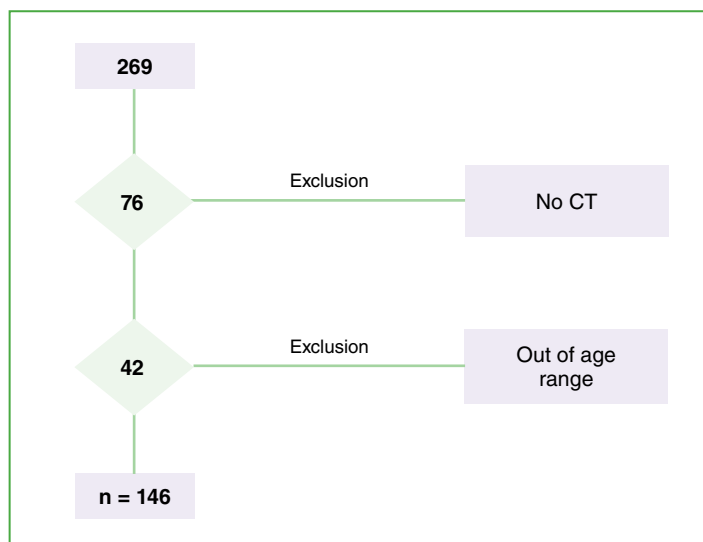
A total of 269 patients with DRFs who underwent open reduction and internal fixation with an anatomical locking plate and arthroscopic assistance between January 2012 and December 2022 were retrospectively analyzed. All surgeries were performed by the same expert-level surgeon, according to J.B. Tang's classification, alongside the institution's Upper Limb Surgery team.<sup>10</sup>

Patients aged 18 to 65 years were included. Preoperative imaging included standard wrist radiographs (anteroposterior, lateral, and oblique views) and CT scans in neutral rotation. CT images were obtained at 1 mm intervals and reconstructed in sagittal, axial, coronal, and 3D views. Patients with pathological fractures, bilateral fractures, severe osteoporosis, previous ipsilateral wrist conditions (trauma, fractures, or rheumatic diseases), or open fractures were excluded (Table 1). Stress radiographs were not performed to rule out partial or occult ligament injuries (predynamic instability).

Based on the inclusion criteria, 146 patients were selected: 72 men and 74 women, with a mean age of 46.9 years. All fractures were classified according to the AO classification and analyzed for CT signs of associated injuries (Figure 1).

**Table 1.** Summary of initial characteristics

| n = 146    |  |
|------------|--|
| Age        | 49.6 (19-65)   |
| Sex        | Male 72 (49%)<br>Female 74 (51%)   |
| Evaluation | Radiographs in three projections: anteroposterior, lateral, and oblique<br>Computed tomography with multiplanar reconstruction |
| Treatment  | Reduction and osteosynthesis with anatomical volar locking plate<br>Arthroscopic assistance                                    |

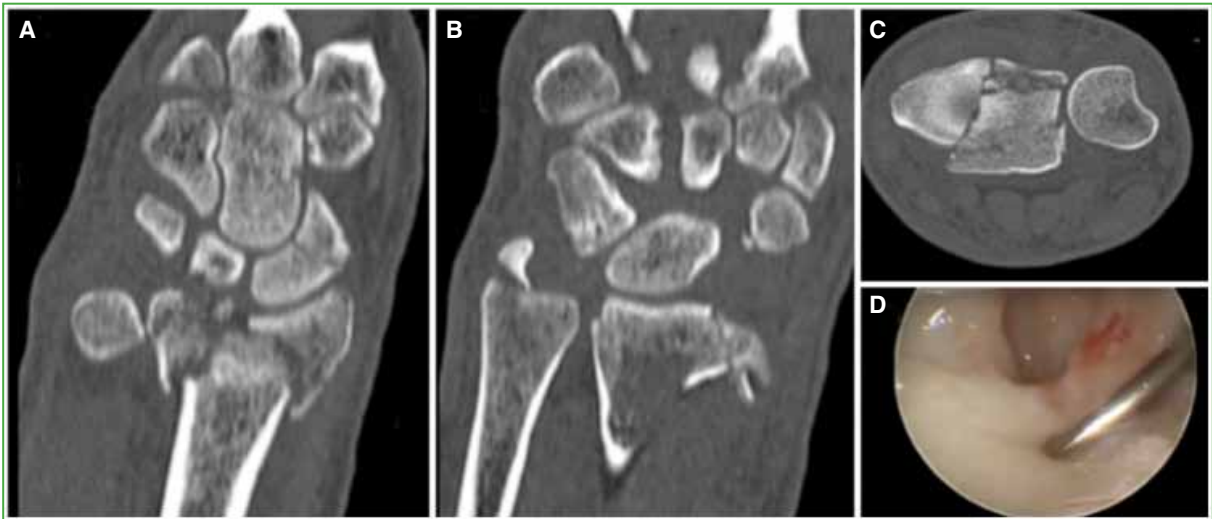
**Figure 1.** Selection of patients according to the inclusion criteria.

The institutional protocol, which evaluates injuries from ulnar to radial and from proximal to distal, was used for assessing associated lesions. TFCC injury was defined as a fracture at the base or apex of the ulnar styloid, a fracture of the lunate facet of the radius, or distal radioulnar joint incongruity (Figure 2).

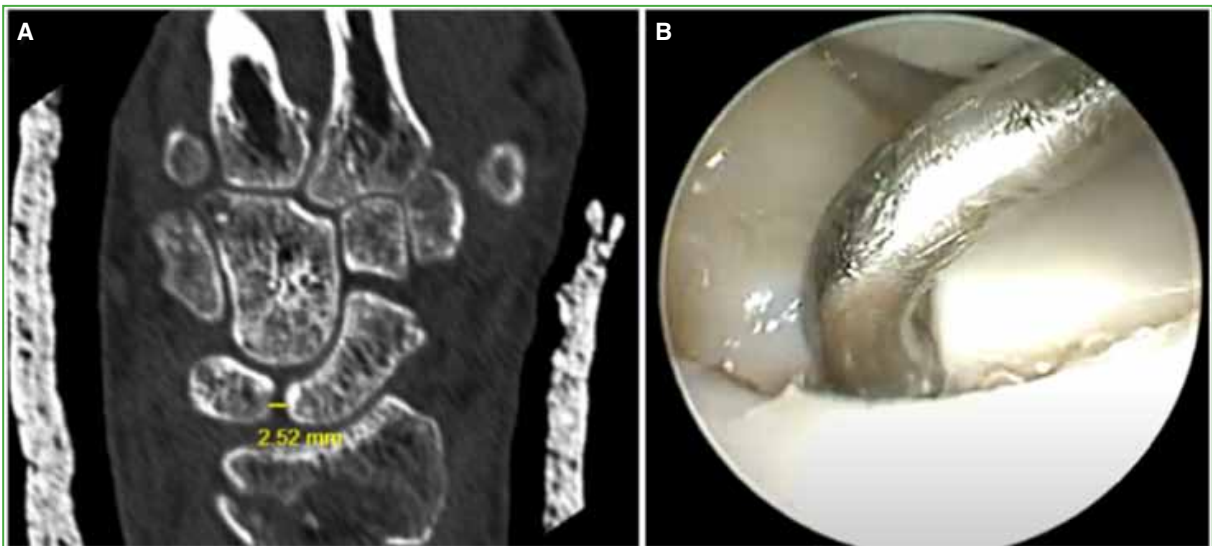
Lunotriquetral ligament injury was assessed based on the presence of fracture or avulsion at the lateral or medial aspects of these bones, respectively. Scapholunate ligament injury was diagnosed if the narrowest distance between the scaphoid and lunate exceeded 2.0 mm on coronal CT slices, and the scapholunate angle measured  $>60^\circ$  on sagittal slices (Figure 3).<sup>11</sup>

Additionally, carpal fractures and osteochondral lesions were evaluated (Table 2).

The validity of CT as a diagnostic tool for the different injuries was determined by analyzing its sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) for each lesion, using the Easy R® software (version 4.2.1).



**Figure 2.** TFCC injury. **A.** Computed tomography of the wrist, coronal section. Radial lunate facet fracture and scaphoid fracture. **B.** Wrist computed tomography, coronal section. Fracture of ulnar styloid. **C.** Distal radioulnar subluxation and radial lunate facet fracture. **D.** Arthroscopic view through portal 3-4-R. Injury at the level of the triangular fibrocartilage in its dorsal portion.



**Figure 3.** Scapholunate ligament injury. **A.** Computed tomography of the wrist, coronal section. Scapholunate distance > 2 mm. **B.** Arthroscopy. Introduction of the probe through the scapholunate ligament observing the scapholunate ligament injury.

**Table 2.** Tomographic and arthroscopic evaluation of associated lesions.

| Injury                          | Tomography   | Arthroscopy   |
|---------------------------------|--|---|
| TFCC injury                     | Fracture of the lunate facet                                     | Evaluation according to Palmer's classification   |
|                                 | Distal radioulnar dislocation or subluxation                     |   |
|                                 | Fracture of the styloid process                                  |   |
| Scapholunate lesion             | Scapholunate distance >2 mm in coronal slice                     | Evaluation according to Geissler's classification   |
|                                 | Scapholunate angle >60°.   |   |
| Lunotriquetral lesion           | Avulsion of the semilunate or triquetral in its articular facet. | Macroscopic visualization of the ligament and avulsion of the articular facet of the lunate or triquetral bone. |
| Associated carpal bone fracture | Fracture lines involving carpal bone                             | Direct visualization of fracture lines involving carpal bone.   |
| Osteochondral injury            | Bone surface defect  | Direct visualization of the osteocartilaginous defect of the articular surface of the carpal bones.             |

TFCC = triangular fibrocartilage complex.

## Surgical Technique

All patients underwent the same surgical procedure. They were positioned in the dorsal decubitus position under a plexus anesthetic block, with a hemostatic cuff inflated to 250 mmHg. The first stage involved open reduction and internal fixation via the Henry volar approach, modified by Orbay, using an anatomical volar locking plate for the distal radius.<sup>12</sup> The limb was then positioned in a traction tower, with the shoulder at 90° of abduction, the elbow at 90° of flexion, and the forearm in a neutral position. Standard arthroscopic portals were used (3-4R, 6R, radial and ulnar midcarpal), and diagnostic and therapeutic arthroscopy was performed. If SLL injuries were identified, the Geissler classification was applied.<sup>13</sup> TFCC injuries were classified and treated according to Palmer's concepts and, in cases of type Ib injuries, treatment followed Atzei's criteria, distinguishing between stable and unstable Ib lesions.<sup>14,15</sup> Immobilization with a plaster cast was maintained for 2 to 4 weeks, depending on the severity of the injury.

## RESULTS

In this series, 50% of the patients were women and 49% were men, with an average age of 46.9 years. Regarding fracture type frequency according to the AO classification, 100 fractures were classified as 2R3C (68%), while 23 were 2R3A and 23 were 2R3B (16% each).

The diagnostic accuracy of CT with multiplanar reconstruction was assessed by comparing its findings with those from intraoperative arthroscopy.

**TFCC injury:** Arthroscopy confirmed this injury in 115 patients. On CT evaluation, 128 patients were diagnosed with TFCC lesions, while 18 were not. Of the 128 positive cases on CT, 99 were true positives and 29 were false positives. Among the 18 negative CT cases, only 2 were true negatives, while 16 were false negatives. From these data, the sensitivity was 84% (CI 76–96%), specificity was 65% (CI 8–21%), PPV was 77% (CI 68–84%), and NPV was 10% (CI 1–32%).

**Scapholunate ligament (SLL) injury:** Arthroscopy identified 71 cases of SLL injury. CT detected 72 cases with ligament injuries and 74 without. Of the 72 CT-positive cases, 44 were true positives, while 28 were false positives. Among the 74 CT-negative cases, 47 were true negatives and 27 were false negatives. The sensitivity was 61% (CI 49–73%), specificity was 62% (CI 50–73%), PPV was 60% (CI 47–71%), and NPV was 63% (CI 51–74%).

**Osteochondral injury:** Nine patients were diagnosed with this injury by arthroscopy, while CT identified 23 cases. Of these, 5 were true positives and 18 were false positives. Among the 123 CT-negative cases, 4 were false negatives, and 119 were true negatives. Sensitivity was 55% (CI 21–86%), specificity was 87% (CI 80–92%), PPV was 22% (CI 7.5–43%), and NPV was 97% (CI 92–99%).

**Lunotriquetral injury:** Arthroscopy detected only 2 cases of this type of injury, making it insufficient to evaluate the diagnostic accuracy of CT.

**Carpal bone fractures:** Arthroscopy identified 5 carpal bone fractures, whereas CT detected 16 cases. Additionally, 7 patients had radiocarpal ligament injuries diagnosed arthroscopically, which were not assessed by CT. The results are detailed in Table 3.

In this series, only 9 patients had no carpal injury associated with the fracture, indicating a high overall incidence of carpal injuries, at 92% (Table 4).

**Table 3.** Outcomes.

| Injury | Arthroscopy            | CT                                    | Sensitivity        | Specificity         | PPV                 | NPV                |
|--------|------------------------|---------------------------------------|--------------------|---------------------|---------------------|--------------------|
| TFCC   | With injury:<br>115    | With injury: 128<br>99 TP<br>29 FP    | 84%<br>(CI 76-96%) | 65%<br>(CI 0.8-21%) | 60%<br>(CI 47-71%)  | 10%<br>(CI 1-32%)  |
|        | Without injury:<br>31  | Without injury: 18<br>2 TN<br>16 FN   |                    |                     |                     |                    |
| SLL    | With injury:<br>71     | With injury: 72<br>44 TP<br>28 FP     | 61%<br>(CI 49-73%) | 62%<br>(CI 50-73%)  | 60%<br>(CI 47-71%)  | 63%<br>(IC 51-74%) |
|        | Without injury:<br>75  | Without injury: 74<br>47 TN<br>27 FN  |                    |                     |                     |                    |
| OCI    | Injury: 9              | With injury: 23<br>5 TP<br>18 FP      | 55%<br>(CI 21-86%) | 87%<br>(CI 80-92%)  | 22%<br>(CI 7.5-43%) | 97%<br>(IC 92-99%) |
|        | Without injury:<br>135 | Without injury: 123<br>119 TN<br>4 FN |                    |                     |                     |                    |

CT = computed tomography; PPV = positive predictive value; NPV = negative predictive value; CI = confidence interval; TFCC = triangular fibrocartilage complex; SLL = scapholunate ligament; OCI = osteochondral injury; TP = true positive; FP = false positive; TN = true negative; FN = false negative.

**Table 4.** Incidence of associated injuries

| Injury                            | Patients | Incidence |
|-----------------------------------|----------|-----------|
| Triangular fibrocartilage complex | 115      | 78.7%     |
| Scapholunate ligament             | 70       | 48%       |
| Osteochondral injury              | 9        | 6%        |
| Radiocarpal ligament              | 7        | 4.8%      |
| Carpal bone fracture              | 5        | 3.5%      |
| Lunotriquetral lesion             | 2        | 1.36%     |

## DISCUSSION

A large number of publications establish a close relationship between DRF and associated injuries, which have a predictive value for short- and long-term functional outcomes.

The complex anatomy of the carpus makes it difficult to diagnose associated injuries using plain radiographs. Failure to detect them can lead to complications such as carpal instability and biomechanical alterations, which may result in persistent pain and functional impairment.<sup>16</sup>

The use of arthroscopic assistance in the treatment of DRF has highlighted the high incidence of associated intercarpal injuries, including the TFCC and radiocarpal and intercarpal ligaments. The importance of repairing unstable injuries and identifying acute lesions, which may be treated with postoperative immobilization, has been emphasized. Injuries to the interosseous carpal ligaments and TFCC that are accessible via arthroscopy have been extensively evaluated.

A high incidence of associated ligament injuries has been reported. Linscheid et al. were pioneers in describing scapholunate instability, which remains the most common type of associated carpal instability.<sup>17</sup> Several authors have observed SLL injuries in 53.7% of cases, TFCC injuries in 82%, lunotriquetral ligament injuries in 27.1%, and osteochondral lesions in 32% of DRF cases treated with open reduction and internal fixation. Additionally, extrinsic carpal ligament injuries were described in 74%.<sup>18-21</sup> In our series, similar results were obtained for TFCC (78.7%) and SLL (48%) injuries, whereas the incidence of radiocarpal and chondral injuries was considerably lower, at 4.8% and 6%, respectively.

Richards et al. reported the low accuracy of radiographs as a diagnostic tool, noting that in 60% of cases where a ligament tear was confirmed arthroscopically, the scapholunate distance appeared normal on preoperative radiographs.<sup>20</sup> Although MRI and MR angiography have greater sensitivity for detecting ligament injuries than radiographs, they do not precisely define the extent of ligament damage, the quality of the affected tissue, or the presence of associated chondral lesions—information that is crucial for surgical planning and technique selection.<sup>22</sup>

The aforementioned studies correlate arthroscopic and radiographic findings. However, Suzuki was the first to evaluate the correlation between arthroscopy and CT. In a series of 88 wrists, they compared arthroscopic findings of the scapholunate interval with preoperative CT measurements and concluded that measuring the scapholunate distance on the central coronal CT slice was reproducible, with high intra- and interobserver agreement, for diagnosing low- and high-grade SLL lesions confirmed by arthroscopy.<sup>9</sup> The present study found that an increased scapholunate distance on coronal CT had a positive predictive value (PPV) of 60%, meaning that 3 out of 5 patients with this imaging finding actually had the lesion.

Radiocarpal and lunotriquetral ligament injuries had a low incidence in this series, rendering specificity and sensitivity values insignificant.

Regarding the frequency and distribution of injuries, Heo et al. evaluated a series of 223 patients with DRF and found that 20.6% had associated carpal fractures, with the triquetrum being the most frequently affected bone.<sup>23</sup> Other studies report that scaphoid fractures have the highest incidence, ranging from 0.75% to 6.5%, which aligns with the 4.1% observed in our series.<sup>24,25</sup>

Similar to the previously mentioned series, the incidence of carpal fractures in this study was 13% (19 patients). Among them, 14 cases were diagnosed solely by CT, 3 by arthroscopy, and only 2 were identified by both methods. This demonstrates the superior diagnostic accuracy of CT compared to arthroscopic visualization, which may be attributed to the lack of routine use of specific portals for viewing different regions of the carpus.

## CONCLUSIONS

The prevalence of lesions associated with DRF has been reported to be high, with up to 80% of TFCC and 50% of SLL injuries. While our findings are consistent with these values, no significant correlation was found between CT imaging and arthroscopic findings. The authors consider arthroscopy to remain the gold standard for diagnosing intercarpal lesions, with its primary advantage being the ability to treat these injuries during the same surgical procedure. However, disadvantages include increased surgical time, additional costs, and the need for an experienced surgeon. The importance of CT for evaluating fractures and joint injuries is emphasized; however, it should only be considered a preliminary tool for suspected intercarpal injuries. We recommend MRI or arthroscopy as more reliable diagnostic methods.

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

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# Supracondylar Humerus Fracture Treatment in Children: A Comparison Between Supine and Prone Positions

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## ABSTRACT

**Introduction:** Supracondylar humeral fractures are common injuries in pediatric patients, accounting for approximately 60-70% of all elbow fractures in this population. The aim of this study was to describe the clinical and radiological outcomes of osteodesis for supracondylar humeral fractures in pediatric patients and to evaluate the impact of patient positioning (prone vs. supine). **Materials and Methods:** A retrospective study was conducted, including all patients under 16 years of age with Grade II and III Gartland supracondylar humeral fractures who underwent humerus reduction and osteodesis between 2002 and 2022, with a minimum follow-up of 6 months. **Results:** The study included 265 patients, of whom 127 underwent surgery in the supine position and 138 in the prone position. The most significant finding of our study was that osteodesis achieves excellent clinical and radiological outcomes, and the patient's position does not have a significant impact on the surgery. **Conclusions:** Reduction and osteodesis of the humerus provide excellent clinical and radiological outcomes for the treatment of supracondylar fractures. The patient's position (prone or supine) does not appear to affect the consolidation rate or limb function.

**Keywords:** Distal humeral fractures; supracondylar humerus fracture; prone position; supine position.

**Level of Evidence:** III

## Tratamiento de las fracturas supracondíleas de húmero en niños. Comparación entre decúbito supino y prono

## RESUMEN

**Introducción:** Las fracturas supracondíleas de húmero son lesiones comunes en pacientes pediátricos, representan aproximadamente el 60-70% de todas las fracturas de codo en esta población. El propósito de este estudio fue describir los resultados clínico-radiológicos del tratamiento con osteodesis de fracturas supracondíleas de húmero en pacientes pediátricos y evaluar el impacto de la posición (decúbito prono o supino). **Materiales y Métodos:** Se realizó un estudio retrospectivo que incluyó a todos los pacientes <16 años con diagnóstico de fractura supracondílea de húmero grado II y III de Gartland, que fueron sometidos a reducción y osteodesis de húmero, entre 2002 y 2022, con un seguimiento mínimo de 6 meses. **Resultados:** La serie estaba formada por 265 pacientes, 127 fueron operados en decúbito supino y 138, en decúbito prono. El hallazgo más importante de nuestro estudio fue que la osteodesis permite alcanzar excelentes resultados clínicos y radiológicos, y que la posición del paciente no tiene un impacto significativo en la cirugía. **Conclusiones:** La reducción y osteodesis de húmero logra excelentes resultados clínico-radiológicos para el tratamiento de las fracturas supracondíleas. La posición del paciente (decúbito ventral o prono) no parece tener un impacto en la tasa de consolidación ni en la función del miembro.

**Palabras clave:** Fracturas humerales distales; fractura supracondílea del húmero distal; posición prona; posición supina.

**Nivel de Evidencia:** III

## INTRODUCTION

Supracondylar humerus fractures are common injuries in pediatric patients, accounting for approximately 60-70% of all elbow fractures in this population.<sup>1</sup> They occur mainly in school-age children, with a peak incidence around six years of age.<sup>1</sup> The most common mechanism of injury is a fall onto an outstretched hand

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with the elbow in full extension,<sup>2-4</sup> leading to a fracture proximal to the condyles and dorsal displacement of the distal fragment.<sup>5,6</sup> This pattern is observed in 98% of cases.<sup>7</sup> Proper treatment is crucial to restore elbow function and prevent long-term complications such as cubitus varus, neuropraxia, vascular injuries, or compartment syndrome.<sup>8</sup>

Over the years, various surgical techniques have been developed for managing these fractures. One of the most common is osteosynthesis, which involves fracture reduction and fixation using K-wires to promote bone healing and restore anatomical alignment of the elbow.<sup>9</sup> Traditionally, surgery has been performed with patients in the supine or dorsal decubitus position.<sup>10</sup> However, in recent years, different authors have described performing the procedure in the prone or ventral decubitus position.

The supine position has traditionally been preferred because it allows good visualization and access to the surgical site, provides stability during osteosynthesis, and facilitates better control of fracture reduction.<sup>11</sup>

Conversely, the prone position offers greater surgeon comfort and is associated with a lower incidence of neurological complications.<sup>12</sup> However, its main drawback is the patient positioning process, which may increase operative time and require a more experienced anesthesiologist.<sup>13</sup>

Despite the widespread use of both techniques, there is limited scientific evidence directly comparing osteosynthesis in the prone versus supine position for treating supracondylar humerus fractures in pediatric patients.<sup>14</sup>

Therefore, this study aimed to describe the clinical and radiological outcomes of osteosynthesis for supracondylar humerus fractures in pediatric patients and evaluate the impact of patient positioning (prone or supine) on these outcomes.

## MATERIALS AND METHODS

A retrospective study was conducted, including all patients under 16 years of age diagnosed with a supracondylar humerus fracture (Gartland grade II or III)<sup>15</sup> who underwent fracture reduction and osteosynthesis between 2002 and 2022, with a minimum follow-up of six months.

Patients with open fractures, other ipsilateral upper limb injuries, polytrauma, pathological fractures, or incomplete clinical records were excluded.

### Analyzed Variables

Clinical history and institutional records were reviewed to collect data on age, sex, and laterality. Fractures were classified according to the Gartland criteria<sup>15</sup> using anteroposterior and lateral radiographs of the elbow.

Data were recorded on patient positioning, type of reduction (open or closed), and K-wire configuration (crossed vs. laterally divergent) during definitive osteosynthesis. The surgeon determined patient positioning at the time of the procedure. Range of motion was measured with a goniometer at the six-month postoperative follow-up.

Anteroposterior and lateral elbow radiographs were analyzed. The Baumann angle (formed by a line along the humeral axis and another crossing the epiphyseal plate of the capitellum, normal range: 64°-81°) (Figure 1)<sup>16</sup> and the carrying angle of the elbow (formed between the radially deviated forearm axis and the anatomical humeral axis, normal values: 14° in girls, 11° in boys) (Figure 2) were measured. Both angles were used to assess postoperative reduction adequacy.

Fracture consolidation was defined as radiological union in at least three of the four cortices, along with clinical examination confirming mechanical stability of the affected limb and absence of patient-reported symptoms.<sup>17</sup>

The Flynn criteria were applied for clinical and functional assessment, evaluating both functional capacity (range of motion) and cosmetic outcome (loss of the normal carrying angle on radiographs).<sup>18</sup>

Surgical complications were also documented, including superficial and deep infections (defined as signs of localized inflammation at the K-wire entry site), loss of initial reduction >5° on follow-up radiographs based on Baumann and carrying angle values, heterotopic ossification, malunion, chronic pain, and complex regional pain syndrome.



**Figure 1.** Anteroposterior radiograph of the right elbow. Measurement of Baumann angle.



**Figure 2.** Anteroposterior radiograph of the right elbow. Measurement of the elbow carrying angle.

All procedures were performed by two surgeons from the same pediatric orthopedic team at a high-complexity private hospital.

In prone-positioned patients, the shoulder was abducted  $90^\circ$  with the elbow flexed at  $90^\circ$ , leaving the distal humerus free. In supine-positioned patients, fracture reduction was achieved by applying traction to the proximal humerus and counter-traction to the forearm, elevating the distal fragment from posterior to anterior. Once adequate reduction was confirmed via fluoroscopy, the fracture was stabilized with either crossed or divergent K-wires at the surgeon's discretion.

Postoperatively, patients were immobilized with a long arm cast until the third week, when K-wires were removed. A closed long arm cast was then applied for an additional three weeks. Thereafter, active and passive range-of-motion exercises were initiated and explained to the patient and caregivers.

## Statistical Analysis

Quantitative variables are expressed as means and standard deviation or median and interquartile range, depending on distribution. Qualitative variables are presented as frequencies and percentages. Continuous data were compared using Student's t-test, while categorical variables were analyzed using the  $\chi^2$  test (or Fisher's exact test). A p-value <0.05 was considered statistically significant.

All data were recorded in an Excel spreadsheet (Microsoft, Redmond, USA), and statistical analyses were performed using GraphPad Prism 9.0.

## RESULTS

During the study period, 273 osteodeses for supracondylar humerus fractures were performed at our institution. Three open fractures, one pathological fracture, and four polytraumatized patients were excluded.

The final series included 265 patients: 127 operated on in the supine position and 138 in the prone position. The overall follow-up period was  $9.2 \pm 2.6$  months. Table 1 provides a global description of the patients and surgical positioning, as well as a comparative analysis between those operated on in the supine and prone positions.

**Table 1.** Global characteristics and according to surgical technique

| Variables                | Global      | Supine        | Prone         | p       |
|--------------------------|-------------|---------------|---------------|---------|
| No. of patients          | 265         | 127           | 138           |         |
| Age, years (mean, SD)    | $6 \pm 0.9$ | $6.5 \pm 1.4$ | $5.9 \pm 1.6$ | 0.44    |
| Sex (n, %)               |             |               |               | 0.50    |
| Male                     | 153 (57.7)  | 76 (60)       | 77 (56)       |         |
| Female                   | 112 (42.3)  | 51 (40)       | 61 (44)       |         |
| Side (n, %)              |             |               |               | 0.61    |
| Left                     | 171 (64.5)  | 80 (63)       | 91 (66)       |         |
| Right                    | 94 (35.4)   | 47 (37)       | 47 (34)       |         |
| Gartland (n, %)          |             |               |               | 0.74    |
| Type II                  | 78 (29.4)   | 44 (35)       | 34 (25)       |         |
| Type III                 | 187 (70.6)  | 83 (65)       | 104 (75)      |         |
| Reduction (n, %)         |             |               |               | 0.13    |
| Closed                   | 253 (95.5)  | 123 (98)      | 128 (93)      |         |
| Open                     | 12 (4.5)    | 4 (2)         | 10 (7)        |         |
| Pin configuration (n, %) |             |               |               | <0.0001 |
| Two lateral              | 129 (48.7)  | 118 (93)      | 11 (8)        |         |
| Two crossed              | 136 (51.3)  | 9 (7)         | 127 (92)      |         |

There was a statistically significant difference regarding K-wire placement. The proportion of lateral K-wires was significantly higher in the supine group (92.9%) compared to the prone group (8.0%) ( $p < 0.0001$ ).

In the supine group, Gartland type III fractures were the most frequent (83 cases; 65.3%), while the remaining 44 cases (34.6%) were type II. None of the patients had vascular injuries at the time of the fracture. There were four nerve injuries: two anterior interosseous nerve palsies, one posterior interosseous nerve palsy, and one ulnar neuropraxia. In the prone group, 104 patients (75%) had a type III fracture, and 34 (25%) had a type II fracture, with no vascular or nerve injuries reported.

The results according to patient positioning are detailed in Table 2. A statistically significant difference was found in the Flynn criteria in the supine group ( $p < 0.001$ ).

The mean Baumann angle was  $17.11^\circ$ , and the mean carrying angle was  $15.75^\circ$ . A global flexion deficit of  $4.05^\circ$  and an extension deficit of  $0.59^\circ$  were observed, both statistically significant ( $p < 0.001$ ). According to the Flynn criteria, 7% of patients had a fair outcome, 14% had a good outcome, and 79% achieved excellent outcomes (Table 2).

**Table 2.** Global and comparative outcomes according to patient position.

| Variables                       | Global<br>(265 patients)   | Supine<br>(127 patients) | Prone<br>(138 patients) | p      |
|---------------------------------|----------------------------|--------------------------|-------------------------|--------|
| <b>Complications</b> (n, %)     | 17 (6.3)                   | 6 (4.8)                  | 11 (8.0)                | 0.21   |
| Superficial infections          | 8 (3)                      | 2 (1.6)                  | 6 (4.3)                 |        |
| Deep infections                 | 1 (0.3)                    | 1 (0.8)                  | 0 (0.0)                 |        |
| Loss of initial reduction       | 7 (2.7)                    | 3 (2.4)                  | 4 (2.9)                 |        |
| Heterotopic calcification       | 1 (0.3)                    | 0 (0)                    | 1 (0.7)                 |        |
| <b>Baumann angle</b> (mean)     | $17.1^\circ \pm 2.3^\circ$ | $17.5^\circ$             | $16.72^\circ$           | 0.12   |
| <b>Carrying angle</b> (mean)    | $15.8^\circ \pm 1.8^\circ$ | $16.2^\circ$             | $15.3^\circ$            | 0.07   |
| <b>Flexion deficit</b> (mean)   | $4.1^\circ \pm 1.7^\circ$  | $3.4^\circ$              | $4.7^\circ$             | <0.001 |
| <b>Extension deficit</b> (mean) | $0.6^\circ$                | $0.5^\circ$              | $0.68^\circ$            | <0.001 |
| <b>Flynn criteria</b> (n, %)    |                            |                          |                         | <0.001 |
| Fair                            | 18 (7)                     | 5 (3.9)                  | 13 (9.4)                |        |
| Good                            | 38 (14)                    | 10 (7.9)                 | 28 (20.2)               |        |
| Excellent                       | 209 (79)                   | 112 (88)                 | 97 (70.3)               |        |

There were 17 complications: 8 superficial infections requiring antibiotics, 1 deep infection requiring surgical debridement, 7 cases of loss of initial reduction requiring reoperation, and 1 case of heterotopic ossification.

Complete fracture healing was observed in all patients. The prone position was associated with a higher complication rate than the supine position (8.7% vs. 4.7%), although this difference was not statistically significant ( $p = 0.21$ ).

## DISCUSSION

The most important finding of our study was that osteodesis achieves excellent clinical and radiological outcomes and that patient positioning does not significantly impact surgical success.

To evaluate functional and aesthetic outcomes, we used the Flynn classification,<sup>18</sup> as we consider it the most rigorous. In our study, 79% of patients achieved excellent outcomes. These findings are consistent with those of Mazda et al.,<sup>19</sup> who reported a 91.6% success rate in 116 patients treated with reduction and osteodesis. Based on these results, we believe that the quality of the reduction is far more critical for achieving good outcomes than the patient's positioning.

We agree with Fowler and Marsh<sup>20</sup> that the prone position offers several advantages over the conventional supine technique. The primary benefit is avoiding excessive hyperflexion ( $>90^\circ$ ) of the elbow. When the patient is positioned prone, reduction is smoother, aided by gravity due to the weight of the forearm. Additionally, maneuvering the upper limb in the prone position improves intraoperative fluoroscopic visualization. In the supine position, maintaining the reduction while inserting K-wires and positioning the C-arm for anteroposterior imaging is challenging, and extreme external rotation of the arm may result in loss of reduction.<sup>21</sup> Conversely, in the prone position, slight forearm extension allows for a proper anteroposterior view of the elbow. Furthermore, without moving the limb, simply rotating the fluoroscopic C-arm provides an optimal lateral view of the joint.

In our study, the mean Baumann angle in the supine group was  $17.5^\circ$ , while in the prone group, it was  $16.72^\circ$ . The carrying angle was  $16.2^\circ$  in the supine group and  $15.3^\circ$  in the prone group. These results align with those reported by Venkatadass et al.,<sup>22</sup> who found a Baumann angle of  $18.14^\circ$  in the supine group and  $18.46^\circ$  in the prone group.

Mapes and Hennrikus<sup>23</sup> observed that elbow flexion beyond  $90^\circ$  reduces radial artery flow and increases intracompartmental pressure in the forearm, potentially leading to elevated pressure in the deep volar compartment and ischemia at the fracture site.<sup>24</sup> In the prone position, the elbow does not need to be flexed beyond  $90^\circ$ , thereby reducing the risk of neurovascular complications.<sup>20</sup> Consequently, in addition to avoiding postoperative immobilization in hyperflexion, we recommend minimizing prolonged hyperflexion during the surgical procedure. In our study, no neurovascular complications of this nature were observed, suggesting that both prone and supine positions provide safe exposure and treatment.

The prone position also reduces the risk of ulnar nerve injury, both during reduction maneuvers and during K-wire placement, as excessive elbow flexion narrows the ulnar tunnel.<sup>25</sup> Additionally, in children, the ulnar nerve is highly mobile and can easily dislocate when the elbow is hyperflexed, as required in the supine technique.<sup>25</sup>

The main limitation of our study is its retrospective design.

## CONCLUSIONS

Reduction and osteodesis of the humerus provide excellent clinical and radiological outcomes in the treatment of supracondylar fractures. Patient positioning (supine or prone) does not appear to impact the consolidation rate or functional outcomes, although in our series, the prone position was associated with nearly twice the complication rate.

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

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# Radiation Exposure in Orthopaedics in Argentina

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## ABSTRACT

**Introduction:** Many orthopedic surgical procedures require the use of fluoroscopic imaging, exposing surgeons to ionizing radiation. This study aims to assess the practices, frequency of intraoperative imaging use, level of knowledge, and adherence to radiological protection measures among orthopedic surgeons in Argentina. **Materials and Methods:** This was an analytical, observational, cross-sectional study based on an online survey conducted among orthopedic surgeons in Argentina between September 2020 and October 2021. The survey included 18 questions collecting sociodemographic, professional, and occupational data related to the use of intraoperative fluoroscopy, radiation protection measures, and knowledge of radiation exposure risks. **Results:** A total of 919 responses were collected. Nearly half of the participants (48.7%) reported using fluoroscopy more than once per week. However, 73.9% were unaware of their actual exposure time, 60.5% did not know whether protective equipment was regularly replaced, and only 10% reported using a dosimeter. The most commonly used protective device was the lead apron, yet only one-third of respondents used thyroid protection. Training in ionizing radiation was deemed insufficient, with 97% of respondents expressing interest in receiving formal education on the topic. **Conclusions:** There is a need to raise awareness among orthopedic surgeons regarding radiation exposure. Most surgical procedures lack adequate radiological protection, and there are no mandatory training programs, standardized protocols, or monitoring systems in place.

**Keywords:** Ionizing radiation; exposure; radiation protection; fluoroscopy; orthopedic surgery; occupational hazard.

**Level of Evidence:** IV

## Exposición a la radiación en Ortopedia y Traumatología, en la Argentina

## RESUMEN

**Introducción:** Múltiples procedimientos en cirugía ortopédica implican el uso de imágenes radioscópicas, lo que plantea un riesgo mayor de exposición a radiación ionizante para los cirujanos. Este estudio tiene como objetivo identificar las prácticas, la frecuencia de uso de imágenes intraoperatorias, el nivel de conocimiento y el empleo de elementos de protección radiológica de los médicos especialistas en ortopedia y traumatología de la Argentina. **Materiales y Métodos:** Estudio analítico observacional transversal. Se realizó en base a una encuesta en línea a traumatólogos de nuestro país, entre septiembre de 2020 y octubre de 2021. Mediante 18 preguntas se recabaron datos sociodemográficos, profesionales y laborales relacionados con el uso de la radioscopia intraoperatoria, las medidas de protección y el respectivo conocimiento. **Resultados:** Se recibieron 919 respuestas a la encuesta. La mitad de los participantes (48.7%) utiliza radioscopia más de una vez por semana. El 73.9% desconoce el tiempo real de exposición, la mayoría (60.5%) ignora si se renuevan los elementos de protección, y solo el 10% usa dosímetro. El elemento de protección más utilizado es el chaleco de plomo; sin embargo, solo un tercio emplea protección tiroidea. La formación académica en radiaciones ionizantes es insuficiente y al 97% de los encuestados le interesaría recibirla. **Conclusiones:** Existe una necesidad de concientización sobre la radiación por parte del cirujano ortopédico. La protección radiológica en la mayoría de los procedimientos quirúrgicos es inadecuada, no existen programas formativos obligatorios, protocolos de uso ni el respectivo control.

**Palabras clave:** Radiación ionizante; radioexposición; radioprotección; radioscopia; cirugía ortopédica; riesgo laboral.

**Nivel de Evidencia:** IV

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## INTRODUCTION

The use of fluoroscopy has increased significantly in trauma surgery. This technology offers advantages such as reduced surgical times and the possibility of developing less invasive techniques, which contribute to decreased morbidity in patients.<sup>1-3</sup> However, it also increases radiation exposure for surgical teams, with adverse effects that may not become evident until decades later.<sup>1-4</sup> It is critical to understand that fluoroscopy employs ionizing radiation, which carries potentially harmful health effects, including genetic damage, an increased risk of cancer, and impairment of the hematopoietic system.<sup>2,4-7</sup>

In Argentina, as in other countries, regulations on radiation protection in healthcare are established by agencies such as the Nuclear Regulatory Authority, based on international guidelines from the *International Commission on Radiological Protection (ICRP)*<sup>5</sup> and the World Health Organization. According to these regulations, the dose limit for the general public is 1 mSv per year from natural and artificial sources, including X-rays, CT scans, and other radiological procedures. For occupational exposure, the maximum permissible limits are 20 mSv per year for whole-body exposure, 20 mSv for the lens, 150 mSv for the thyroid, and 500 mSv for the hands.<sup>1,2,5,8</sup>

Various studies have assessed the radiation dose received by surgical personnel (both medical and non-medical) at different body sites and during specific procedures to estimate exposure and the associated cancer risk.<sup>4,6-10</sup> Mastrangelo et al.<sup>9</sup> conducted a study in an Italian healthcare center between 1976 and 2000 and reported that orthopedic surgeons using fluoroscopy were five times more likely to develop cancer than healthcare workers not exposed to radiation. Additionally, the incidence of cancer in general—including skin, colon, lung, lymphoma, and chondrosarcoma—was higher. In 2009, Chou et al.<sup>11</sup> surveyed female orthopedic surgeons who were members of the American Academy of Orthopaedic Surgeons (AAOS) and reported that the prevalence of cancer was 85% higher than in the general population, with similar characteristics in terms of sex, age, and race.<sup>10,11</sup>

In Argentina, some studies have been conducted, such as the one by Vanoli et al.<sup>12</sup> which focused exclusively on wrist fracture fixation procedures, and the one by Bazán et al, on spine fractures.<sup>13</sup> The Research Committee of the Asociación Argentina de Ortopedia y Traumatología also conducted a survey on the use of dosimeters in accredited services.<sup>14</sup> However, to our knowledge, no national reports have been published that comprehensively analyze radiation exposure in orthopedic practice, including protective measures and the level of knowledge on the subject.

The aim of this study was to analyze the results of a survey identifying practices involving radiation exposure in the field of orthopedics and traumatology in Argentina, considering the frequency of fluoroscopy use, the level of knowledge, and the utilization of radiological protection elements.

## MATERIALS AND METHODS

Through the Asociación Argentina de Ortopedia y Traumatología, an online survey was conducted using the SurveyMonkey® platform between September 2020 and October 2021. The survey was sent via email to all orthopedic surgeons registered in the association's database (including professionals with varying years of experience as well as residents and fellows) and was also disseminated through social media for voluntary completion.

The survey consisted of 18 questions, including mandatory and optional closed-ended questions, some with a single-response option and others allowing multiple responses ([Annex](#)).

Demographic data (sex, age, and region of practice) and occupational data (type of practice, subspecialty, and years of experience) were collected. Regarding fluoroscopy, participants were asked about its frequency of use, the type and frequency of radiological protection employed, the equipment used, and dose measurement. The survey also inquired about knowledge of the allowable dose limit, use of dosimeters, training received, and awareness of radiation exposure risks. The study complied with the Declaration of Helsinki, ensuring the anonymity of participants and healthcare institutions.

### Statistical Analysis

The collected responses were entered into an Excel® (Microsoft®) spreadsheet. A descriptive analysis of the variables was performed, with results expressed as frequency and percentage based on the number of responses obtained for each question.

## RESULTS

A total of 919 orthopedic surgeons responded to the survey. Some questions were optional, and the number of responses ranged from 913 to 919.

### Demographic Data

87.9% (808 respondents) were men, and 11.7% (107) were women (four respondents omitted their gender). A total of 71.3% were under 50 years of age (Table 1).

Regarding length of practice, most respondents were specialists (86.5%), and 70% had more than five years of experience. In terms of employment, 43.1% (n = 396) reported working exclusively in the private sector. Geographically, 42.2% practiced in the AMBA region (Buenos Aires Metropolitan Area), followed by the Pampa region (31.9%). Concerning subspecialization, 36.5% worked in orthopedic trauma, followed by hip and knee (26.1%) (Table 1).

**Table 1.** Demographic data of the patients

|  | Total (n = 919) |
|--|-----------------|
| <b>Gender*</b>   |                 |
| Male   | 808 (87.9%)     |
| <b>Age</b>   |                 |
| <40  | 337 (36.7%)     |
| 40-49  | 318 (34.6%)     |
| 50-59  | 167 (18.2%)     |
| 60 or more   | 97 (10.6%)      |
| <b>Specialization**</b>  |                 |
| Specialist, more than 5 years  | 643 (70.0%)     |
| Specialist, less than 5 years  | 135 (14.7%)     |
| Fellow   | 23 (2.5%)       |
| Resident   | 115 (12.5%)     |
| <b>Type of institution</b>   |                 |
| Private and public   | 393 (42.8%)     |
| Private  | 396 (43.1%)     |
| Public   | 130 (14.1%)     |
| <b>Surgical field#</b>   |                 |
| Hip and knee   | 240 (26.1%)     |
| Spine  | 58 (6.3%)       |
| Shoulder and elbow   | 40 (4.4%)       |
| Hand   | 74 (8.1%)       |
| Leg and foot   | 105 (11.4%)     |
| Trauma/Orthopedic trauma   | 335 (36.5%)     |
| Pediatric Traumatology   | 54 (5.9%)       |
| Oncologic traumatology   | 11 (1.2%)       |
| <b>Region where you work##</b>   |                 |
| Buenos Aires Metropolitan Area   | 388 (42.2%)     |
| Cuyo (San Juan, San Luis, Mendoza)   | 52 (5.7%)       |
| Northeast (Formosa, Misiones, Chaco, Corrientes)                             | 27 (2.9%)       |
| Northwest (Jujuy, Salta, Tucumán, Catamarca, Santiago del Estero, La Rioja)  | 80 (8.7%)       |
| Pampas (Entre Ríos, Santa Fe, Córdoba, Buenos Aires, La Pampa)               | 293 (31.9%)     |
| Patagonia (Neuquén, Río Negro, Chubut, Santa Cruz, Tierra del Fuego)         | 76 (8.3%)       |
| <b>Do you belong to any association/society? Check the one(s) that apply</b> |                 |
| AAOT   | 849 (92.4%)     |
| Specialty Association/Society  | 468 (50.9%)     |
| Regional Association/Society   | 326 (35.5%)     |
| None   | 29 (3.2%)       |

\*4 not answered; \*\*3 not answered; #2 not answered; ##3 not answered.

## Use of Fluoroscopy

Of the 919 responses, the most frequently used equipment during surgery was the C-arm (97.9%). Regarding frequency of use, almost half (48.7%) used fluoroscopy more than once a week, and 94.6% used pulsed fluoroscopy. Additionally, the majority (73.9%, n = 679) indicated that they did not monitor the actual time of radiation exposure. Those who reported never using fluoroscopy (2.4%) belonged to various subspecialties (Table 2).

**Table 2.** Use of fluoroscopy

|  | Total (n = 919) |
|--|-----------------|
| <b>What type of intraoperative equipment do you use? Check the applicable one(s)</b> |                 |
| C-arm (open)   | 900 (97.9%)     |
| O-arm (closed)   | 5 (0.5%)        |
| Mini C-arm   | 13 (1.4%)       |
| Intraoperative tomography  | 2 (0.2%)        |
| Intraoperative navigation  | 16 (1.7%)       |
| <b>Do you use fluoroscopy in your usual surgical practice?*</b>                      |                 |
| More than once a week  | 448 (48.7%)     |
| 3 or 4 times per month   | 227 (24.7%)     |
| 1 or 2 times per month   | 146 (15.9%)     |
| Less than 6 times per year   | 75 (8%)         |
| Never  | 22 (2.4%)       |
| <b>How do you use the image intensifier?***</b>                                      |                 |
| Continuously   | 40 (4.4%)       |
| In pulsed form   | 869 (94.6%)     |
| <b>Do you control the actual exposure time?#</b>                                     |                 |
| No   | 679 (73.9%)     |
| Yes  | 233 (25.4%)     |

\*1 not answered; \*\*10 not answered; #7 not answered.

## Protection

The question on protective elements allowed multiple responses, enabling some options to be combined. A total of 88.3% of respondents (n = 809) used a lead vest or apron (710 wore a one-piece vest, and 99 used a two-piece vest); 38.6% used thyroid protection; 3.4% used leaded glasses; and 0.1% used leaded gloves (Table 3, Figure 1).

Regarding the frequency of use, 11.9% (n = 109) reported not using any protective equipment, while 37.2% always used it, and 11.8% used it half the time. Specifically, concerning lead vests, 94.8% of respondents indicated that the vest belonged to the institution where they worked, while in 22 cases, it was the surgeon's personal property. When asked about vest renewal, 60.5% were unaware of it, and 23.1% stated that it was not renewed (Table 3).

**Table 3.** Use of protective elements and data corresponding to leaded aprons

|  | Total (n = 919) |
|--|-----------------|
| <b>In surgeries with fluoroscopy, you use (check all that apply)</b> |                 |
| One-piece leaded apron   | 710 (77.3%)     |
| Two-piece leaded apron   | 99 (10.8%)      |
| Thyroid protection (collar)  | 355 (38.6%)     |
| Leaded goggles or glasses  | 31 (3.4%)       |
| Leaded gloves  | 1 (0.1%)        |
| Distance more than 2 m from the emitter                              | 109 (11.9%)     |
| Dosimeter  | 93 (10.1%)      |
| <b>You use protection equipment*</b>                                 |                 |
| Always   | 342 (37.2%)     |
| 75% of surgeries   | 249 (27.1%)     |
| 50% of surgeries   | 108 (11.8%)     |
| Less than 50%  | 107 (11.6%)     |
| Never  | 109 (11.9%)     |
| <b>The lead vest belongs to**</b>                                    |                 |
| The institution  | 871 (94.8%)     |
| The surgeon  | 22 (2.4%)       |
| <b>The lead vest is renewed#</b>                                     |                 |
| Once a year  | 17 (1.8%)       |
| Every 2 years  | 57 (6.2%)       |
| Every 3 years  | 64 (7.0%)       |
| I do not know  | 556 (60.5%)     |
| It is not renewed  | 212 (23.1%)     |

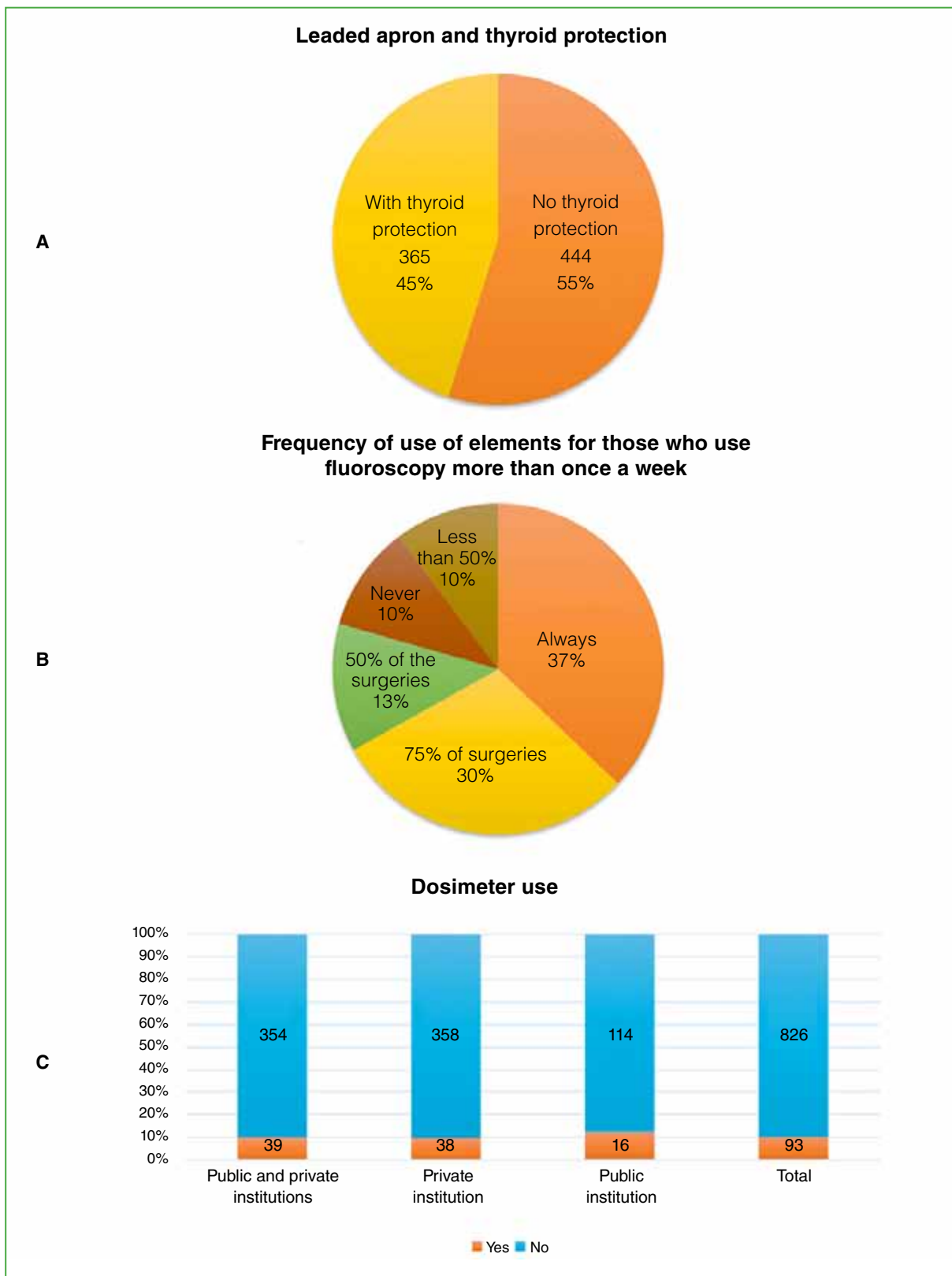
\*4 not answered; \*\*26 not answered; #13 not answered.

Among those maintaining a distance greater than two meters from the radiation source, 53% reported not using any protective equipment.

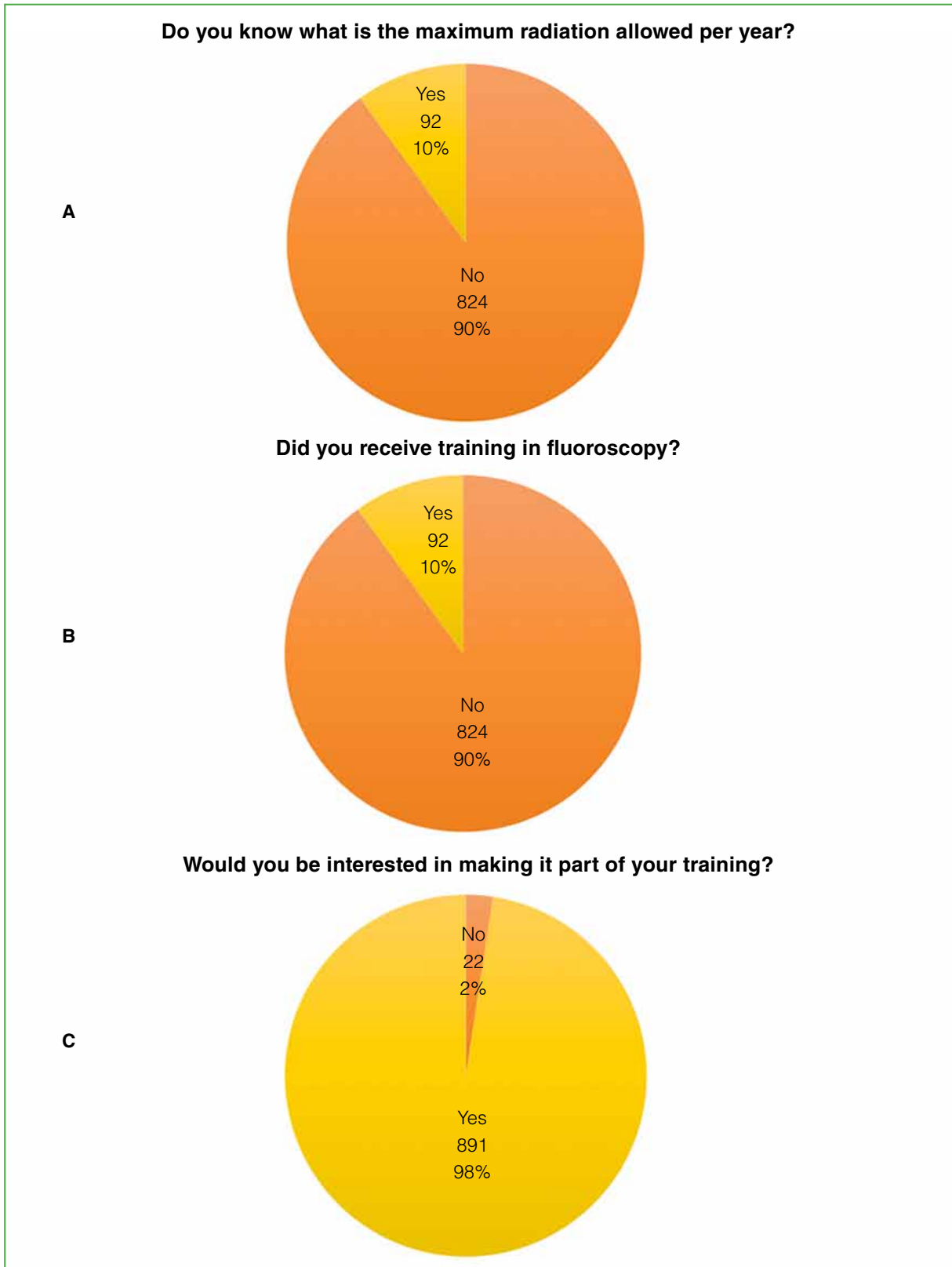
Only 10.1% of participants used dosimeters to measure their radiation exposure, with similar percentages across work environments (private 9.6%, public 12.3%, mixed 9.9%) (Figure 1).

### Education and Knowledge

Of the 916 responses received (three omitted), 89.7% (n = 824) stated that they were unaware of the maximum permissible radiation exposure per year, and only 17.2% had received specific training on the use of fluoroscopy and protective measures. Additionally, 97.6% of respondents expressed interest in incorporating such training into their professional education (Figure 2).



**Figure 1.** **A.** Use of leaded vest/apron (1 or 2 pieces) with or without thyroid protection. **B.** Frequency of use of radiological protection elements in those who use fluoroscopy more than once a week. **C.** Use of dosimeter according to the work environment.



**Figure 2.** **A.** Knowledge of radiation limits. **B.** Received training in fluoroscopy. **C.** Would be interested in making it part of their training.

### Subspecialties

Among different subspecialties, those who used fluoroscopy frequently (more than once a week) were hand surgeons (63%), trauma surgeons (62%), and leg and foot specialists (56%). Comparatively, those who had received training in fluoroscopy use were mostly foot and ankle surgeons (25.7%, n = 105), whereas in trauma, only 15% had received instruction (Figure 3).

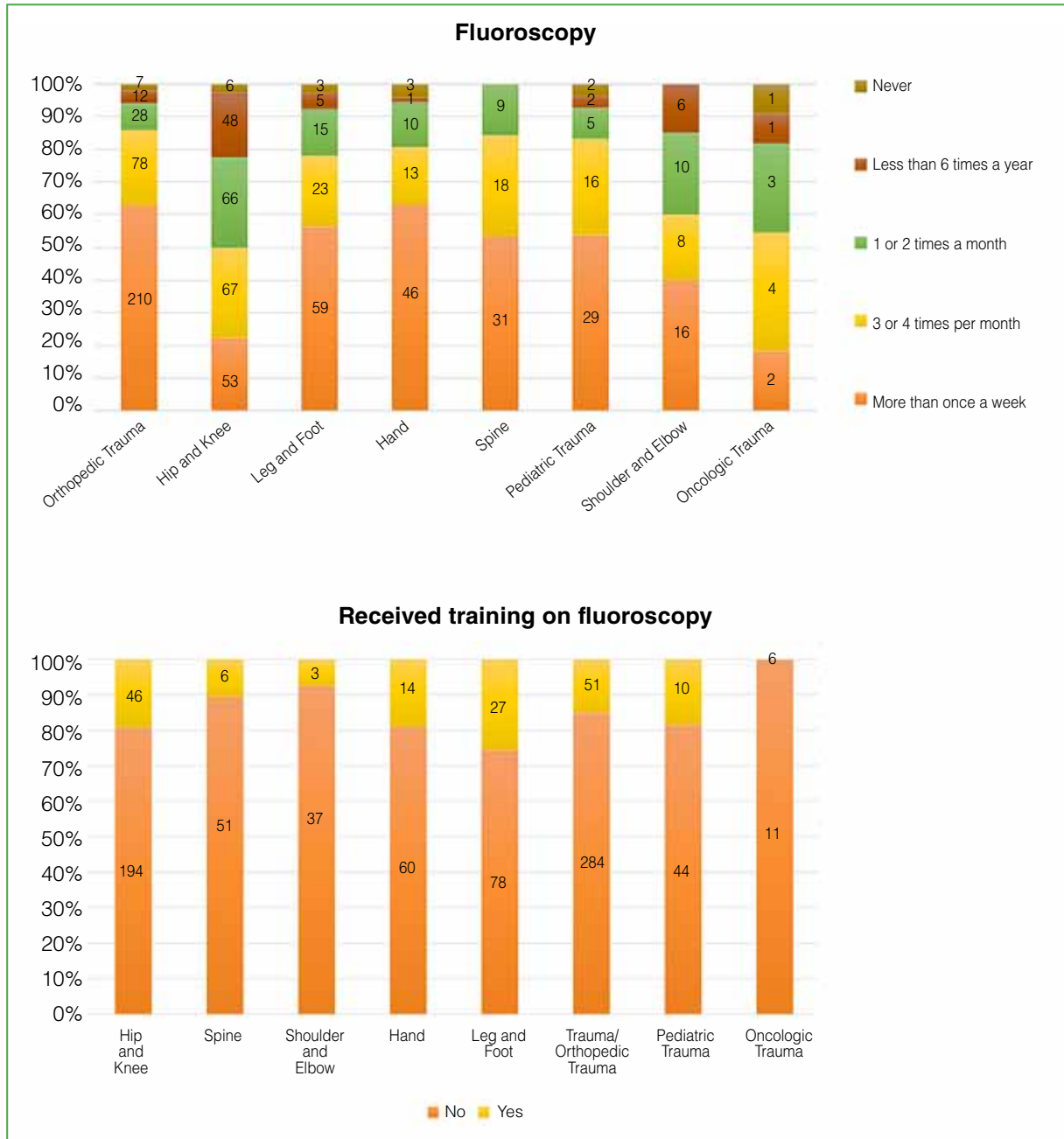


Figure 3. A. Frequency of use of fluoroscopy according to subspecialty. B. Fluoroscopy training according to subspecialty.

## DISCUSSION

Orthopedic surgeons are increasingly exposed to ionizing radiation during various procedures. Multiple studies have shown that they have a higher risk of developing cancer compared to healthcare workers who are not exposed to radiation.<sup>7,9-11</sup> The literature also emphasizes the importance of implementing key radiation protection measures, summarized by the acronym ALARA (As Low As Reasonably Achievable).<sup>3,8</sup> However, adherence to these measures remains inconsistent.<sup>6-8,15</sup>

A major issue is the absence of universally applied guidelines to minimize exposure, not only for surgeons but also for medical and non-medical personnel present in the operating room, as well as for patients.<sup>3</sup> Radiation exposure varies significantly by subspecialty and procedure type. Spine and trauma surgeries involve the highest levels of exposure due to frequent intraoperative fluoroscopy use, particularly in procedures such as vertebroplasties and kyphoplasty, followed by pelvic surgery, hip surgery, and osteosynthesis with intramedullary devices.<sup>2,3,8,15,16</sup> In our survey, hand and trauma surgeons reported the highest fluoroscopy use, consistent with existing literature.

The tissues most sensitive to radiation exposure include red bone marrow, the colon, lungs, stomach, and breasts.<sup>1,4,7</sup> However, surgeons' hands are typically the most exposed anatomical region due to their proximity to the radiation source.<sup>4,6-8,17</sup> Additionally, although the thyroid gland and eyes receive lower doses, they are highly sensitive to radiation.<sup>2,5-7,17</sup> Proper shielding of these regions is crucial; however, many surgeons often neglect these areas compared to other organs, such as the thorax, abdomen, and gonads, as noted by Kaplan et al.<sup>7</sup> and Vanoli et al.<sup>12</sup>

Thyroid protectors and vests are the most common protective elements. It is recommended that they have a minimum lead thickness of 0.25 mm (which reduces exposure by more than 90%) or 0.50 mm (which reduces exposure by up to 99%). Ideally, they should provide circumferential coverage, including the thyroid gland.<sup>1,3,4,7</sup> Despite their availability, their use remains inconsistent.<sup>2,7,8,17</sup> Thyroid protectors are often integrated into vests, but when used separately, their usage rates range from 24% to 30%, with some studies reporting rates as low as 4%.<sup>2,6-8</sup> In our survey, 88% of respondents reported using lead vests, but fewer than 40% used thyroid protection.

Radiation exposure is a known risk factor for conditions such as adenomas, thyroiditis, hypothyroidism, and malignant neoplasms—85% of papillary carcinomas are radiation-induced.<sup>6,7,9</sup>

Furthermore, the effectiveness of protective equipment heavily depends on individual compliance. Previous studies have indicated that many surgeons do not adhere to radiation safety recommendations.<sup>7,15</sup> In our survey, 11.9% of respondents did not use any protection, 11.8% used it occasionally, and only 37.2% used it consistently, highlighting a lack of awareness or knowledge about the importance of radiation safety and the potential consequences of inadequate protection.

A fundamental aspect to consider is that the protective function of these elements is compromised by inadequate storage and maintenance. Kaplan et al.<sup>7</sup> emphasize the importance of performing annual quality controls.<sup>3,4</sup> However, in our survey, 60.5% of respondents did not know whether the lead vests at their institution were renewed, and 23% stated that they were not renewed. Notably, 94.8% of the participants indicated that the vests belonged to the institution.

Eye protection is generally inadequate, with usage ranging from 2.5% to 5%, likely due to a lack of awareness regarding the risk of cataracts from ionizing radiation exposure.<sup>3-6</sup> The pathogenesis involves opacification of the crystalline lens, specifically in its posterior portion.<sup>1,3,6,7</sup> Burns et al.<sup>16</sup> reported a 90% reduction in exposure with the use of leaded glasses in pelvic and hip surgeries.<sup>7,16</sup> In our survey, only 3.4% of respondents reported using eye protection, reflecting this lack of awareness.

Lead gloves are effective only if they are not directly exposed to the radiation beam. When automatic exposure control is activated, radiation levels increase when gloves are detected.<sup>2,7,17-19</sup> They often create a false sense of security; therefore, direct exposure should be avoided. In our study, lead glove usage was rare, reported by only 0.1% of respondents.

Radiation dose monitoring is an essential practice that should be applied to all personnel exposed in the operating room. However, only 10% of respondents reported using dosimeters in both public and private healthcare settings, indicating a lack of adequate control and monitoring.<sup>1,14,18,20</sup>

All personnel exposed to radiation in the operating room should wear individual dosimeters, and their data should be collected and analyzed by the facility's radiation safety department.<sup>1,14,18,20</sup> However, only 10% of respondents in our study reported using them. Joeris et al. found that approximately half of orthopedic surgeons had never used a dosimeter, and among those who had, only half received information about their radiation exposure levels.<sup>21</sup> Al Mohammad et al.<sup>20</sup> reported that only 5.5% of surgeons used dosimeters.

Similarly, there is a general lack of knowledge regarding radiation exposure limits. Eighty-nine percent of respondents were unaware of the existence of occupational exposure limits, and 73.9% did not monitor their radiation exposure time. This finding is consistent with international reports suggesting a widespread lack of awareness regarding the occupational exposure limits established by the ICRP.<sup>3,7</sup>

There are two types of C-arm fluoroscopes: the standard and the mini C-arm. While the latter is recognized for its versatility and potential to reduce surgeon exposure, improper use can increase radiation exposure, particularly to the hands.<sup>3,4,7</sup> In our survey, the standard C-arm was the most commonly used device (97.9%), and 94.6% of respondents reported using the pulsed mode. The way the equipment is used is a crucial factor: continuous fluoroscopy, capturing 30 to 35 images per second, significantly increases radiation exposure compared to pulsed mode, which generates only 1 to 5 images per second.<sup>4,7,18,19</sup>

Finally, only 17.2% of respondents had received specific training in radiation protection during their education, underscoring the urgent need to incorporate this knowledge into training programs (97% expressed interest in receiving such training). Previous studies have highlighted the lack of radiation safety training among orthopedic surgeons.<sup>4,7,21</sup> Pires et al.<sup>22</sup> and Kaplan et al.<sup>7</sup> have noted the absence of a standardized radiation safety curriculum during medical training. Saroki et al. found that 91.2% of orthopedic surgeons believed they needed additional training on radiation exposure.<sup>23</sup>

This study has certain limitations, such as the lack of actual radiation exposure quantification, preventing us from determining whether surgeons and residents exceed the ICRP-recommended limits. Additionally, the sample was not homogeneous in terms of subspecialties, with a higher representation of trauma, hand, and foot surgeons, which may limit comparisons across specialties. Despite these limitations, this is the first study in Argentina to investigate occupational radiation exposure among orthopedic surgeons, providing valuable data to improve surgical practices.

The question remains: how much radiation are orthopedic surgeons, operating room staff, and patients actually exposed to during various procedures?

## CONCLUSIONS

Our survey aimed to collect key information on radiological protection practices among orthopedic surgeons in Argentina. The findings highlight the need to implement measures to reduce radiation exposure. The results reveal widespread deficiencies in knowledge regarding radiation risks, doses received, exposure limits, and radiation safety techniques, both among specialists and residents. Radiation monitoring should be mandatory for all occupationally exposed personnel; however, in orthopedic surgery, its use remains unregulated. Although current exposure levels may be within established limits, any exposure poses long-term risks. Further research is needed in this area.

It is essential to incorporate radiation safety training programs into residency curricula and continuing post-graduate education to ensure safer and more responsible surgical practices.

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# Effectiveness of 0.35% Diluted Povidone-Iodine Irrigation on Bacterial Cultures: An In Vitro Study

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## ABSTRACT

**Introduction:** Hip and knee arthroplasties are increasingly performed due to their excellent outcomes in pain relief and quality of life improvement. However, they are not free from complications, with periprosthetic infection being one of the most challenging. This study aimed to evaluate the effectiveness of 0.35% diluted povidone-iodine irrigation against various microorganisms as a prophylactic measure against periprosthetic infections. **Materials and Methods:** A prospective study was conducted using *in vitro* irrigation of 0.35% diluted povidone-iodine on bacterial cultures. Gram-positive cocci (*Staphylococcus aureus*, coagulase-negative *Staphylococcus*, and *Enterococcus faecalis*) and gram-negative bacilli (*Pseudomonas aeruginosa*, *Acinetobacter* sp., and *Klebsiella pneumoniae*) were studied to simulate intraoperative contamination. The bacterial inoculum was quantified using the McFarland scale, reflecting concentrations similar to those expected in *in vivo* periprosthetic infections. **Results:** Growth inhibition of *Staphylococcus* sp. (*S. aureus* and coagulase-negative *Staphylococcus*) was observed in the presence of diluted povidone-iodine. However, there was no significant reduction in the colony-forming units of gram-negative bacilli treated with povidone-iodine. **Conclusions:** Povidone-iodine diluted to 0.35% significantly inhibits the growth of *Staphylococcus* sp. However, gram-negative bacilli and *Enterococcus* sp. (*E. faecalis*) exhibited substantial colony growth, highlighting the limited efficacy of this dilution against these pathogens *in vitro*.

**Keywords:** Periprosthetic infection; McFarland scale; povidone-iodine; gram-negative microorganisms.

**Level of Evidence:** IV

## Efectividad de la irrigación de povidona yodada diluida al 0,35% en cultivos bacterianos. Estudio *in vitro*

## RESUMEN

**Introducción:** Las artroplastias de cadera y rodilla siguen en aumento debido a sus excelentes resultados en cuanto al alivio del dolor y la mejoría de la calidad de vida; sin embargo, no están exentas de complicaciones y una de las más desafiantes es la infección periprotésica. El objetivo de este estudio fue evaluar la efectividad de la irrigación de povidona yodada diluida contra distintos microorganismos como profilaxis contra infecciones periprotésicas. **Materiales y Métodos:** Se realizó un estudio prospectivo que consistió en la irrigación de povidona yodada diluida al 0,35% a cultivos bacterianos *in vitro*. Se estudiaron cocos grampositivos (*Staphylococcus aureus*, *Staphylococcus* coagulasa negativo y *Enterococcus faecalis*) y bacilos gramnegativos (*Pseudomonas aeruginosa*, *Acinetobacter* sp., *Klebsiella pneumoniae*), simulando una contaminación intraquirúrgica. Usando la escala de McFarland se cuantificó el inóculo bacteriano infectante, de manera similar a las concentraciones esperadas en infecciones periprotésicas *in vivo*. **Resultados:** Se evidenció inhibición del crecimiento de *Staphylococcus* sp. (*S. aureus* y *Staphylococcus* coagulasa negativo) en presencia de povidona yodada diluida. Sin embargo, no se observó un descenso significativo en la cantidad de unidades formadoras de colonias de bacilos gramnegativos tratados con povidona yodada. **Conclusiones:** La povidona yodada diluida al 0,35% inhibe significativamente el crecimiento de *Staphylococcus* sp. Sin embargo, los bacilos gramnegativos y *Enterococcus* sp. (*E. faecalis*) muestran un gran crecimiento de colonias, lo que pone de manifiesto la baja efectividad de la dilución contra estos patógenos *in vitro*.

**Palabras clave:** Infección periprotésica; escala de McFarland; povidona yodada; microorganismos gramnegativos.

**Nivel de Evidencia:** IV

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## INTRODUCTION

As hip and knee arthroplasties continue to evolve and grow steadily, there has been an exponential increase in complications, such as periprosthetic joint infections (PJI).<sup>1</sup> Efforts to reduce the risk of infection have focused on numerous patient-related factors, including bacterial skin decolonization, optimization of nutritional status, metabolic diseases, obesity, and smoking. Additionally, surgical factors such as prophylactic antibiotics, operating room environment, and surgical duration play a crucial role. Among these measures, surgical site irrigation is highly cost-effective in preventing PJI, as it minimizes bacterial contamination. This is often performed using saline alone or with the addition of chlorhexidine or povidone-iodine (PI). Thorough irrigation is essential to reduce the risk of infection in arthroplasty procedures.<sup>2</sup> While various irrigation methods have been described,<sup>3</sup> the World Health Organization Clinical Practice Guidelines recommend the use of PI for wound irrigation during surgical procedures.<sup>4-6</sup>

The Second Philadelphia International Consensus on Musculoskeletal Infections (2018) recommended diluted PI irrigation for PJI prophylaxis;<sup>7</sup> however, there are no clear guidelines regarding the optimal type, volume, or irrigation protocol for PJI management.

PI is highly soluble in water, allowing its gradual release in an aqueous medium with a broad spectrum of antimicrobial activity against bacteria, protozoa, fungi, and viruses. It achieves this through the iodination of lipids and the oxidation of cytoplasmic and membrane components. Additionally, PI inhibits the formation of staphylococcal biofilms, and no acquired resistance has been reported. However, it has been found to cause histological damage in its pure form due to cytotoxicity. Therefore, a dilution of 17.5 cc of PI in 500 cc of saline (0.35%) is recommended as an antiseptic agent for tissue irrigation.<sup>8,9</sup>

The objective of this study was to evaluate the effectiveness of 0.35% diluted PI irrigation in reducing bacterial growth and preventing complications related to PJI, thereby decreasing the economic costs associated with managing this complication.

## MATERIALS AND METHODS

A prospective *in vitro* study was conducted to evaluate the bactericidal effect of 0.35% diluted PI against selected bacteria. The study was carried out in the bacteriology unit of Hospital Central de San Isidro “Melchor Á. Posse,” using tryptic soy agar as the culture medium.

The microorganisms analyzed included:

- Gram-positive bacteria: Coagulase-negative *Staphylococcus*, *S. aureus*, *E. faecalis*.
- Gram-negative bacteria: *Pseudomonas aeruginosa*, *Acinetobacter* sp., *Klebsiella pneumoniae*.
- *In vitro* bacteria obtained from clinical samples and cultured for 24 hours at 37 °C.

The selection of these microorganisms was based on the local institutional epidemiology of Hospital Central de San Isidro “Melchor Á. Posse,” as they are the most prevalent in PJI cases.

The McFarland scale<sup>10</sup> was used as a reference for the number of colony-forming units (CFU) seeded and cultured, in order to subsequently make *in vitro* suspensions of the microorganisms, with 0.5 McFarland corresponding to approximately  $1 \times 10^8$  colony-forming units per milliliter (CFU/ml). Serial dilutions were then performed to achieve lower bacterial concentrations ( $1 \times 10^4$  and  $1 \times 10^2$  CFU/ml), representing intraoperative contamination levels.

Each bacterial strain was cultured at concentrations of  $1 \times 10^8$ ,  $1 \times 10^4$ , and  $1 \times 10^2$  CFU/ml on tryptic soy agar and incubated in Petri dishes at 37 °C for 4 hours (estimated duration of a joint arthroplasty surgery).

For each bacterial concentration, three additional Petri dishes were prepared to assess the effectiveness of irrigation. The effect of the 0.35% diluted PI was evaluated by irrigating the plates post-incubation (Figure 1) for 3 minutes (Figure 2).

The plates were then washed with sterile saline to remove excess antiseptic, halting its activity, and incubated at 37 °C for 24 hours for subsequent analysis. In parallel, 2 control groups were included; the first was the growth control, plates without any added solution and the second, a wash control, in which the plates were rinsed with sterile saline for the same duration as the PI.



**Figure 1.** Irrigation of Petri dishes with 0.35% povidone-iodine.



**Figure 2.** Timed control of povidone-iodine application to Petri dishes.

After 24 hours of incubation, the plates were analyzed, and CFU/ml counts were recorded for each dilution and bacterial strain.

## RESULTS

A significant reduction in CFU/ml was observed in *Staphylococcus* sp. cultures treated with 0.35% diluted PI compared to both the growth control and the saline-treated group. However, no reduction in CFU/ml was noted for the gram-negative bacilli or *Enterococcus* sp. in any of the growth controls (Tables 1-3)

**Table 1.** *Pseudomonas aeruginosa* culture at 24 hours.

| Bacteriological CFU concentration of <i>P. aeruginosa</i> | Povidone-iodine diluted at 0.35%. | Washing control (saline) | Growth control (without irrigation) |
|---|-----------------------------------|--------------------------|-------------------------------------|
| 1 x 10 <sup>8</sup>                                       | Develops                          | Develops                 | Develops                            |
| 1 x 10 <sup>4</sup>                                       | Develops                          | Develops                 | Develops                            |
| 1 x 10 <sup>2</sup>                                       | Develops                          | Develops                 | Develops                            |

CFU = colony forming units.

**Table 2.** Culture of *Acinetobacter* sp. at 24 hours.

| Bacteriological CFU concentration of <i>Acinetobacter</i> sp. | Povidone-iodine diluted at 0.35%. | Washing control (saline) | Growth control (without irrigation) |
|---|-----------------------------------|--------------------------|-------------------------------------|
| 1 x 10 <sup>8</sup>   | Develops                          | Develops                 | Develops                            |
| 1 x 10 <sup>4</sup>   | Develops                          | Develops                 | Develops                            |
| 1 x 10 <sup>2</sup>   | Develops                          | Develops                 | Develops                            |

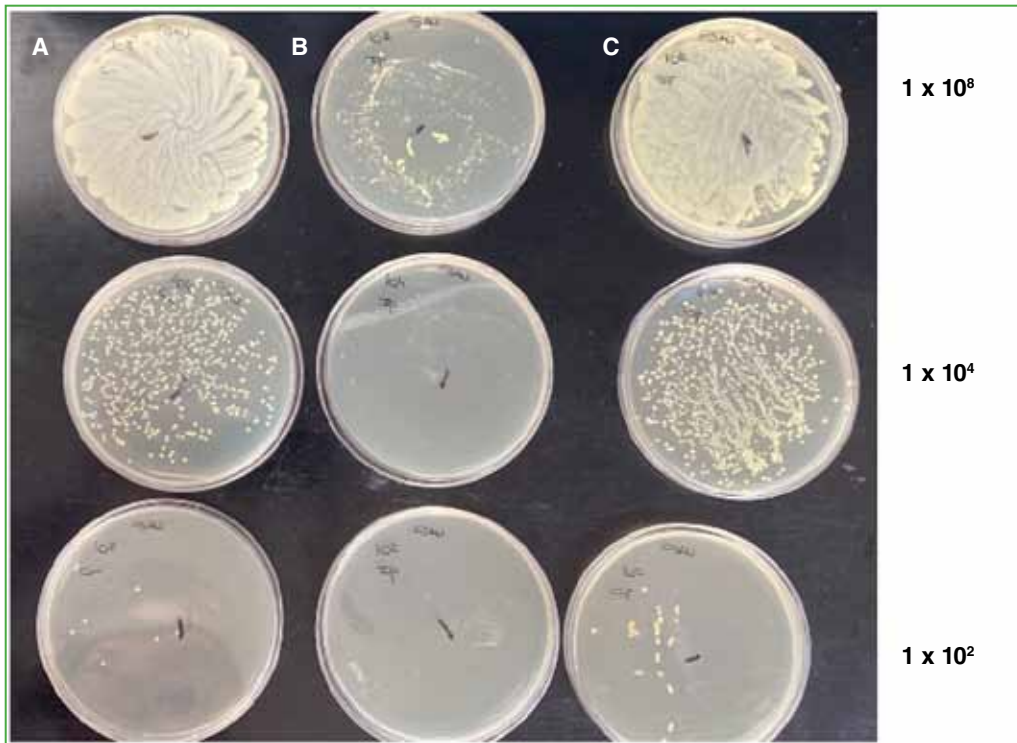
CFU = colony forming units.

**Table 3.** Culture of *Klebsiella pneumoniae* at 24 hours.

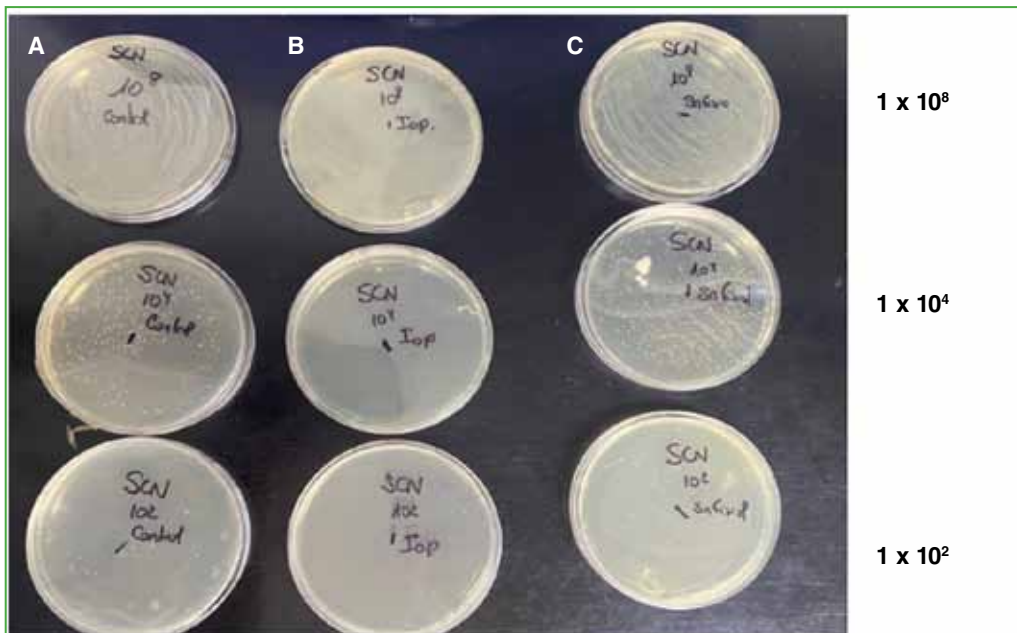
| Bacteriological CFU concentration of <i>K. pneumoniae</i> | Povidone-iodine diluted at 0.35%. | Washing control (saline) | Growth control (without irrigation) |
|---|-----------------------------------|--------------------------|-------------------------------------|
| 1 x 10 <sup>8</sup>                                       | Develops                          | Develops                 | Develops                            |
| 1 x 10 <sup>4</sup>                                       | Develops                          | Develops                 | Develops                            |
| 1 x 10 <sup>2</sup>                                       | Develops                          | Develops                 | Develops                            |

CFU = colony forming units.

Specifically, growth inhibition of gram-positive cocci (Figures 3 and 4) (coagulase-negative *Staphylococcus* and *S. aureus*) was detected in the presence of the antiseptic (Tables 4 and 5). In contrast, gram-negative bacilli strains (*P. aeruginosa*, *K. pneumoniae* and *Acinetobacter* sp.) (Figures 5-7) and a culture of *E. faecalis* (Figure 8, Table 6), developed bacterial growth in 100% of the samples (Tables 1-3) across all experimental conditions, including PI-treated cultures, saline-treated controls, and the untreated control. These findings indicate differential susceptibility to diluted PI, with greater sensitivity observed in *Staphylococcus* sp. compared to gram-negative bacilli and *Enterococcus* sp.



**Figure 3.** *In vitro* cultures of *S. aureus*. Column **A**, Control cultures without irrigation, showing extensive colony growth. Column **B**, Cultures treated with povidone-iodine, showing clear inhibition of CFU growth. Column **C**, Cultures exposed to saline irrigation, with a reduction in CFU count but preserved colony-forming capacity.



**Figure 4.** *In vitro* cultures of coagulase-negative *Staphylococcus*. Column **A**, control cultures without irrigation. Column **B**, Cultures treated with povidone-iodine, showing clear inhibition of CFU growth. Column **C**, Cultures exposed to saline irrigation, with a reduction in CFU count but preserved replication capacity.

**Table 4.** *Staphylococcus aureus* culture at 24 hours

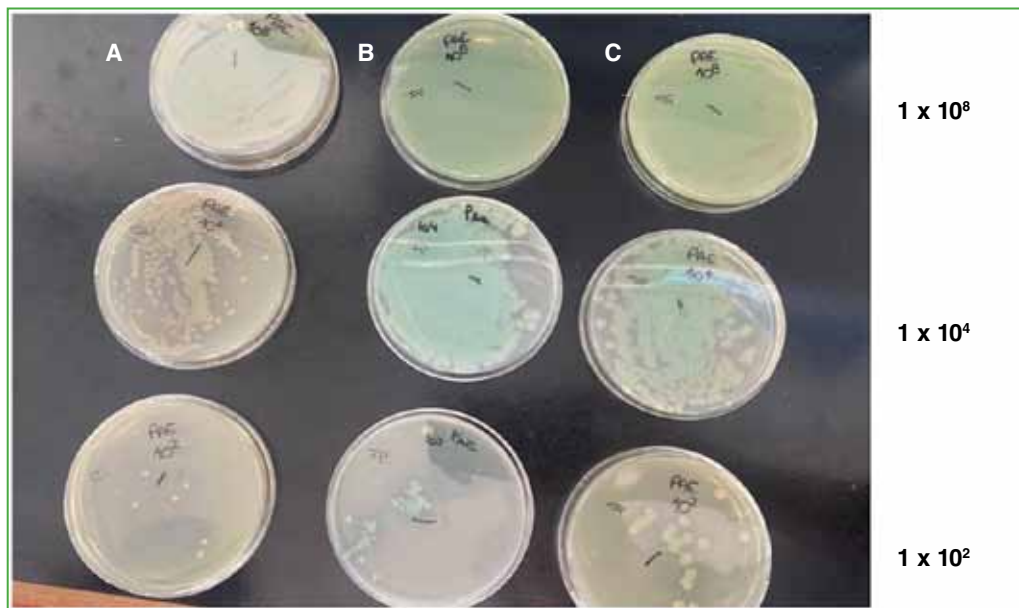
| Bacteriological CFU concentration of <i>S. aureus</i> | Povidone-iodine diluted at 0.35%. | Washing control (physiological solution) | Growth control (without irrigation) |
|---|-----------------------------------|--|-------------------------------------|
| $1 \times 10^8$                                       | Does not develop                  | Develops                                 | Develops                            |
| $1 \times 10^4$                                       | Does not develop                  | Develops                                 | Develops                            |
| $1 \times 10^2$                                       | Does not develop                  | Develops                                 | Develops                            |

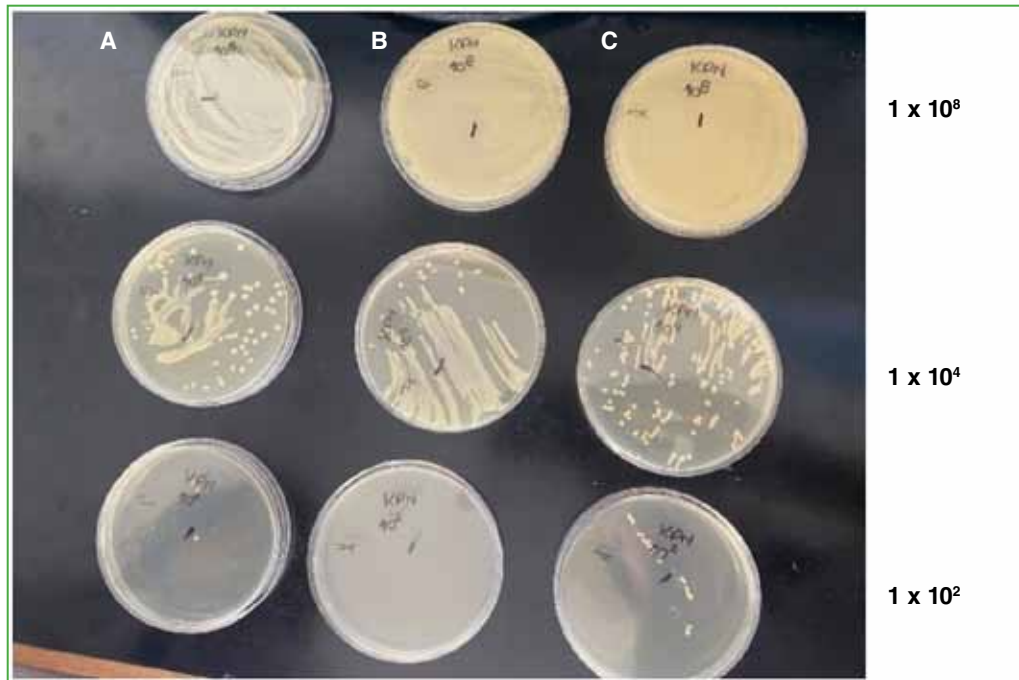
CFU = colony forming units.

**Table 5.** Coagulase negative *Staphylococcus* culture at 24 hours

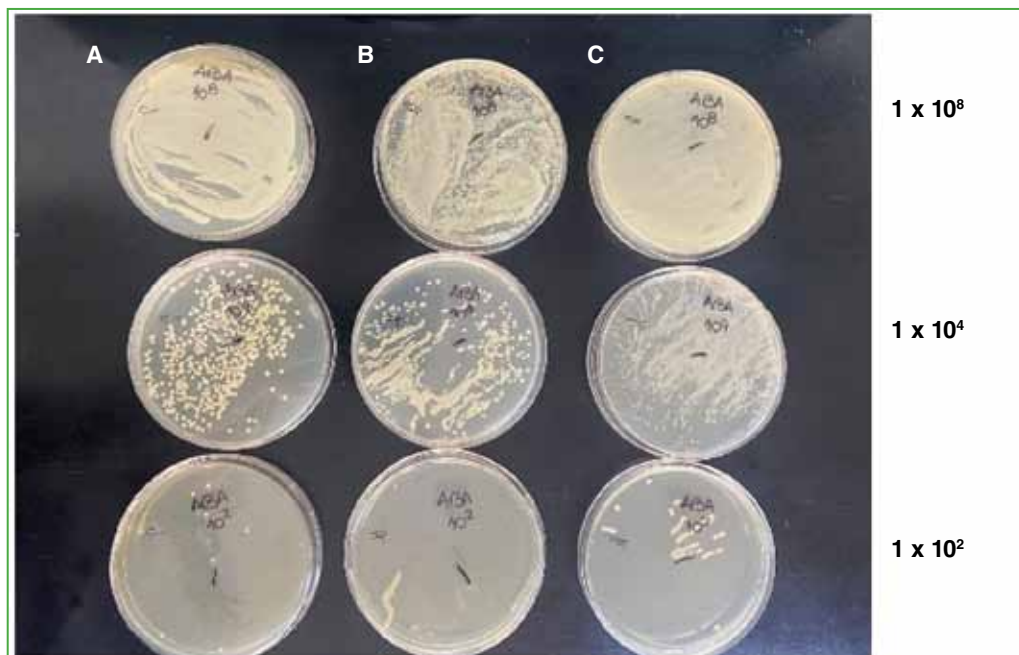
| Bacteriological CFU concentration of coagulase negative <i>Staphylococcus</i> | Povidone-iodine diluted at 0.35%. | Washing control (saline) | Growth control (without irrigation) |
|---|-----------------------------------|--------------------------|-------------------------------------|
| $1 \times 10^8$   | Does not develop                  | Develops                 | Develops                            |
| $1 \times 10^4$   | Does not develop                  | Develops                 | Develops                            |
| $1 \times 10^2$   | Does not develop                  | Develops                 | Develops                            |

UFC = unidades formadoras de colonias.

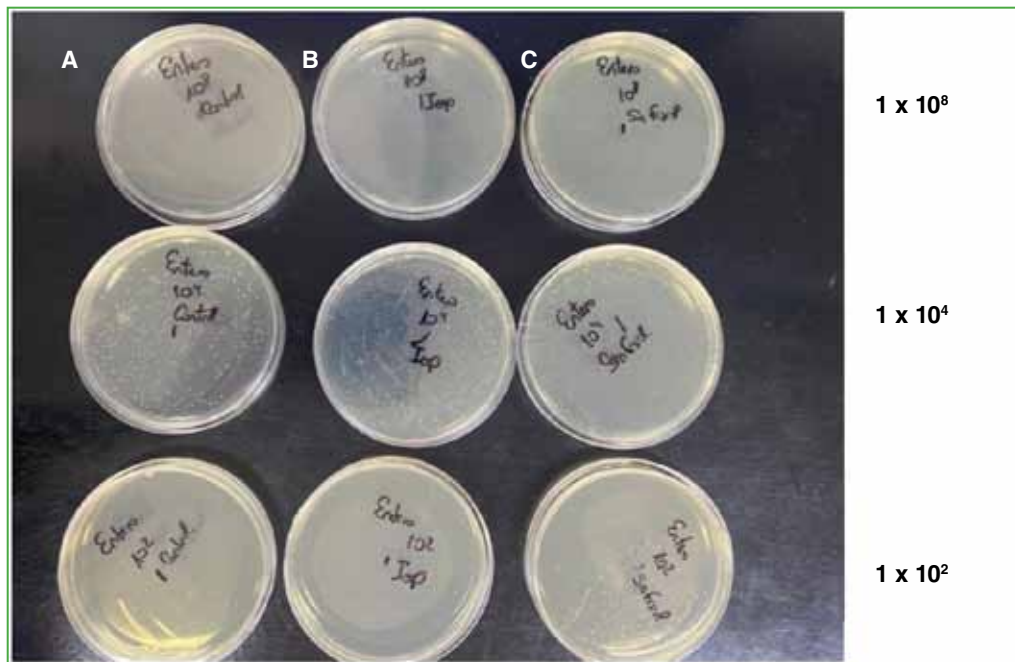
**Figure 5.** *In vitro* cultures of *Pseudomonas aeruginosa*. Column A, control cultures without irrigation. Column B, cultures exposed to povidone-iodine. Column C, Cultures irrigated with saline. CFU formation remains evident in all conditions.



**Figure 6.** *In vitro* cultures of *Klebsiella pneumoniae*. Column A, control cultures without irrigation. Column B, cultures exposed to povidone-iodine. Column C, cultures irrigated with saline. A reduction in CFUs is observed; however, colonies retain their replication capacity across all conditions.



**Figure 7.** *In vitro* cultures of *Acinetobacter baumannii*. Column A, control cultures without irrigation. Column B, cultures exposed to povidone-iodine. Column C, cultures irrigated with saline. CFU formation remains evident in all controls.



**Figure 8.** *In vitro* cultures of *Enterococcus faecalis*. Column A, control cultures without irrigation. Column B, cultures irrigated with povidone-iodine, showing partial inhibition of CFU growth. Column C, Cultures exposed to saline irrigation, showing a slight CFU reduction.

**Table 6.** *Enterococcus faecalis* culture at 24 hours

| Bacteriological CFU concentration of <i>E. faecalis</i> | Povidone-iodine diluted at 0.35%. | Washing control (saline) | Growth control (without irrigation) |
|---|-----------------------------------|--------------------------|-------------------------------------|
| $1 \times 10^8$   | Develops                          | Develops                 | Develops                            |
| $1 \times 10^4$   | Develops                          | Develops                 | Develops                            |
| $1 \times 10^2$   | Does not develop                  | Develops                 | Develops                            |

CFU = colony forming units.

## DISCUSSION

The effectiveness of PI against polymicrobial flora *in vitro* has been documented in several studies, highlighting its efficacy against a range of bacteria, including *S. epidermidis*, *H. influenzae*, *Burkholderia cepacia*, and *Escherichia coli*.<sup>11</sup>

According to Cichos et al., PI irrigation has been shown to eradicate common bacteria associated with prosthetic joint infections, such as methicillin-resistant *S. aureus* (MRSA), methicillin-sensitive *S. aureus* (MSSA), *S. epidermidis*, *H. influenzae*, *P. aeruginosa*, and *E. coli*, on a variety of orthopedic materials, including stainless steel screws, titanium discs, and polyethylene washers in *in vitro* studies.<sup>12</sup>

In 2010, Brown et al. demonstrated a decrease in the rate of PJI with the use of 0.35% diluted PI. They reported 18 cases (0.97%) of infection within the first 90 days before the use of the antiseptic and only one (0.15%) after its implementation. As a result, its use began to expand to other institutions.<sup>13</sup>

However, despite its antimicrobial efficacy, PI also poses potential risks to patient health. According to studies by Driesman et al. and Von Keudell et al., this antiseptic, in its undiluted form, can be highly toxic and cause tissue damage, potentially delaying the healing process. Therefore, it is crucial to address this issue and implement measures to mitigate its adverse effects. Its potential toxicity raises significant concerns for patient safety. Dilution to 0.35% with saline emerges as a key strategy to reduce these risks while preserving the antimicrobial benefits, minimizing its negative impact on wound healing and overall patient health.<sup>14,15</sup>

Several studies have shown that PI diluted with saline helps reduce its toxicity while maintaining antimicrobial effectiveness. This practice is particularly relevant in primary arthroplasty surgeries, where minimizing the risk of postoperative infection is critical. By diluting PI, a balance can be achieved between antimicrobial efficacy and patient safety, significantly reducing complications associated with antiseptic toxicity. Furthermore, dilution may help preserve surrounding tissue and promote faster and more effective wound healing.<sup>16</sup>

In our study, PI demonstrated efficacy as an antimicrobial agent against gram-positive bacteria (*S. aureus*, coagulase-negative *Staphylococcus*) for the prevention of prosthetic joint infections. However, its effectiveness was found to be limited against gram-negative bacilli and *Enterococcus* sp., as bacterial growth was observed following exposure to PI.

A strength of this research is that *in vitro* studies were conducted to recreate and simulate the typical duration of a joint prosthesis surgery, mimicking theoretical intraoperative contamination and subsequent irrigation with diluted PI.

This study also has limitations: the small number of strains and species analyzed, as well as the lack of a thorough assessment of gram-negative bacilli resistance to PI dilution. Prospective multicenter studies are needed to determine whether the observed lack of susceptibility is an institutional finding or a more generalized phenomenon. Another limitation is the absence of other antiseptic solutions as a control group.

## CONCLUSIONS

0.35% PI is an effective intraoperative irrigation solution for inhibiting *Staphylococcus* sp. bacterial growth. However, its efficacy against gram-negative bacilli was shown to be limited, making it an unreliable option for reducing the overall risk of PJI. This is an emerging area of research, and further studies are needed to elucidate the resistance mechanisms of gram-negative bacteria to this antiseptic agent and to improve our understanding of the role of intraoperative irrigation in PJI prevention.

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

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# Spondylodiscitis in Infants Under 6 Months with Negative Blood Culture: Case Report and Literature Review

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## ABSTRACT

In spondylitis, the infection is usually introduced hematogenously into the vertebral body. If it spreads to the intervertebral space, it is termed spondylodiscitis. In recent years, the incidence of pyogenic infections has increased. One of the main challenges in diagnosing spondylodiscitis is the delay due to nonspecific symptoms, particularly in infants under 1 year of age. Laboratory tests are also inconclusive, as parameters often remain normal or only slightly elevated. We present the case of a 4-month-old infant with spondylodiscitis and a negative blood culture, who was followed for 18 months. The condition resolved with conservative treatment using antibiotics and a thoracolumbosacral orthosis (TLSO) brace.

**Keywords:** Spondylodiscitis; spine; infant; negative culture.

**Level of Evidence:** IV

## Espondilodiscitis en lactantes <6 meses con hemocultivo negativo. Reporte de un caso y revisión bibliográfica

## RESUMEN

En la espondilitis, la inoculación generalmente es hematógena hacia el cuerpo vertebral. Si la infección se propaga al espacio intervertebral, se denomina espondilodiscitis. Hoy en día, el número de infecciones piógenas ha aumentado. Uno de los principales problemas con la espondilodiscitis es el retraso en el diagnóstico debido a los síntomas no específicos, especialmente en niños <1 año. Los análisis de laboratorio tampoco ofrecen certeza en el diagnóstico, ya que, en muchos casos, los parámetros son normales o solo están ligeramente elevados. Presentamos el caso de una paciente de 4 meses con espondilodiscitis y cultivo negativo, controlada durante 18 meses, cuyo cuadro se resolvió, de manera conservadora, con antibióticos y un corsé toraco-lumbo-sacro.

**Palabras clave:** Espondilodiscitis; columna espinal; lactante; cultivo negativo.

**Nivel de Evidencia:** IV

## INTRODUCTION

The incidence of spondylodiscitis is approximately 1 in 250,000 live births.<sup>1,2</sup> The age distribution of pediatric spondylodiscitis follows a triphasic pattern: the first peak occurs between 6 months and 4 years of age (79%), a second, smaller peak during adolescence (20%), and only an exceptional group before 6 months of age (1%).<sup>3</sup> In the past, tuberculous spondylodiscitis was the most common form. Today, the number of pyogenic infections has increased, particularly those caused by bacteria from the *Staphylococcus*, *Streptococcus*, and *Kingella* genera.<sup>3</sup>

One of the main challenges in spondylodiscitis is the delay in diagnosis due to nonspecific symptoms and the fact that radiographic changes take 2 to 3 weeks to appear.<sup>4</sup> Diagnosing spondylodiscitis in children under 1 year of age is particularly difficult, as these patients are unable to cooperate during physical examination.<sup>4</sup>

Laboratory tests also fail to provide diagnostic certainty, and both blood cultures and cultures of biopsy material are frequently negative, with reported negativity rates ranging from 56% to 100%, depending on the series.<sup>5</sup>

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The aim of this article is to raise awareness of this rare disease in very young patients and to establish a standardized approach to its investigation and treatment.

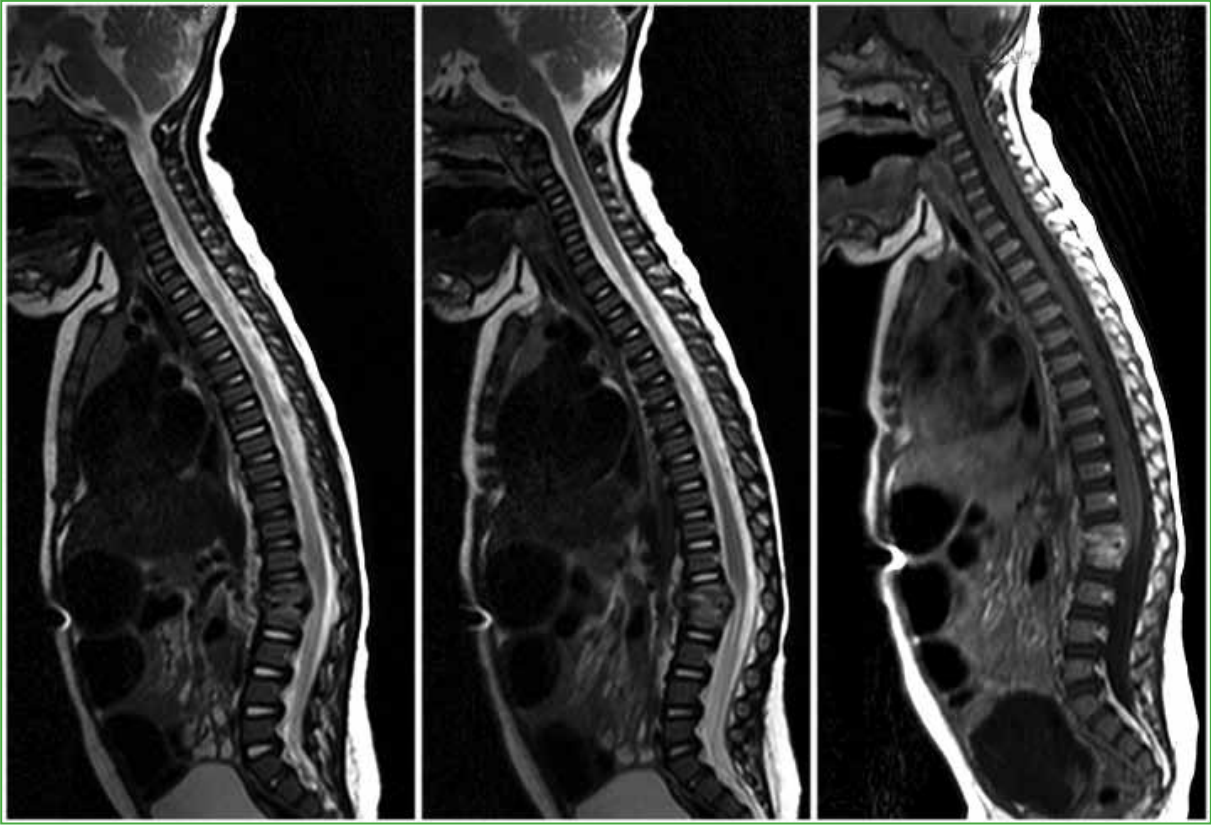
## CLINICAL CASE

A 4-month-old, breastfed infant with no significant medical history was brought to the Emergency Department due to anuria for more than 12 hours, associated with 72 hours of constipation. The mother reported that symptoms had begun 20 days prior with an episode of diarrhea, which resolved within 48 hours. However, since then, she had noticed a change in the child's behavior, including refusal to breastfeed.

On physical examination, the patient was afebrile, clinically stable, and hemodynamically compensated. Marked pain was evident upon palpation of the thoracolumbar and perivertebral region, causing the infant to cry. Initial laboratory tests showed a white blood cell count of 16,800, an erythrocyte sedimentation rate of 75 mm/h, and a C-reactive protein level of 0.7 mg/dL. Radiographs and an MRI were performed 48 hours after admission, revealing findings consistent with spondylodiscitis at the L1-L2 level (Figures 1 and 2).



**Figure 1.** Anteroposterior and lateral dorsal-lumbosacral spine radiographs. Signs compatible with spondylodiscitis are observed in the L1-L2 space, with kyphosis of T12-L2 of 27°.

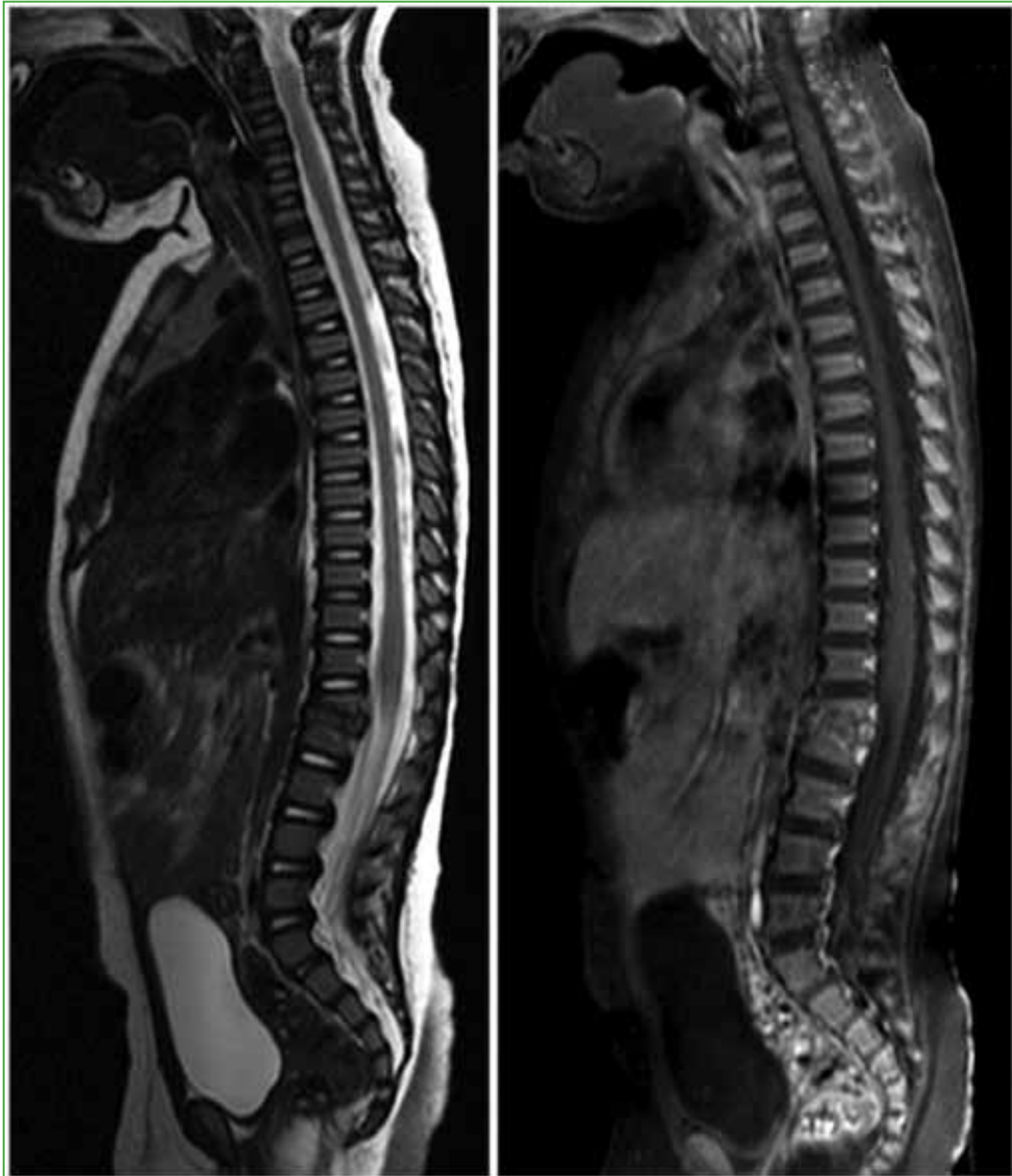


**Figure 2.** Spine MRI. The L1-L2 intervertebral disc shows decreased T2 signal and reduced height. After injection of gadolinium, intense enhancement of the aforementioned vertebral bodies is observed, with small anterolateral paravertebral inflammatory collections up to 6 mm in maximum thickness.

Blood cultures were obtained, and empirical antibiotic therapy was initiated with intravenous ceftriaxone (80 mg/kg/day, every 24 hours) and vancomycin (60 mg/kg/day, every 8 hours) for 21 days. During hospitalization, the infant's condition gradually improved, with a decrease in spontaneous crying. A follow-up MRI was performed after 11 days (Figure 3).

After three weeks, a thoracolumbosacral brace was recommended, and antibiotic therapy was switched to oral cefuroxime axetil syrup (125 mg/5 mL): 2.5 mL every 12 hours, along with trimethoprim-sulfamethoxazole syrup (40 mg trimethoprim plus 200 mg sulfamethoxazole per 5 mL): 5.5 mL every 12 hours.

Given the favorable clinical evolution and negative blood cultures, antibiotic treatment was discontinued at five months. At present, 18 months after symptom onset, the child is engaging in age-appropriate activities without lumbar pain (Figure 4).



**Figure 3.** Spine MRI 11 days after diagnosis. A reduction of inflammatory changes in L1-L2 is observed, with a decrease in the collections previously detected.



**Figure 4.** Anteroposterior and lateral dorsal-lumbosacral spine radiographs. Mild sequelae of spondylodiscitis of L1-L2 with wedging at L1, without significant angular deformity and kyphosis of T12-L2 of  $1^{\circ}$ .

## DISCUSSION

Spondylodiscitis typically occurs in children older than 6 months, with no gender preference.<sup>6</sup> The nonspecific nature of symptoms, laboratory findings, and late detection on radiographic studies often lead to initial misdiagnosis, with reported rates as high as 50%.<sup>6,7</sup> In neonates, symptoms and signs may be ambiguous, including drowsiness, fever, and vomiting. In cases of delayed diagnosis, the disease course may be protracted. If left untreated, children in this age group may develop irreversible spinal deformities.<sup>8</sup>

In our case, the parents sought medical attention three weeks after the first symptoms (diarrhea) appeared, and the diagnosis was delayed by an additional two days following the initial emergency department visit.

Laboratory tests may not always show elevated inflammatory markers.<sup>9</sup> C-reactive protein is almost always elevated in cases of pyogenic spondylodiscitis, which can help distinguish it from tuberculous spondylodiscitis, where inflammatory markers may remain within the normal range.<sup>10</sup> In our patient's initial laboratory tests, the white blood cell count was 16,800, the erythrocyte sedimentation rate was 75 mm/h, and the C-reactive protein level was 0.7 mg/dL. These values raised doubts about the diagnosis, prompting further investigation into the disease's etiology.

MRI enables early diagnosis of spondylodiscitis.<sup>11</sup> Moic et al. reported that MRI has a sensitivity of 96%, specificity of 92%, and overall diagnostic accuracy of 94%.<sup>11</sup> In contrast, conventional radiographs have a sensitivity of 82% and a specificity of 75%. Additionally, MRI allows for differential diagnoses, such as spinal tumors and erosive osteochondrosis.<sup>12</sup>

Unlike in adults, there are no established guidelines for the treatment of pediatric spondylodiscitis. Some authors question the necessity of antimicrobial therapy in all cases of primary spondylodiscitis, as spontaneous resolution has been observed in some instances.<sup>13</sup> Generally, while awaiting laboratory test results, empirical broad-spectrum intravenous antibiotics—including coverage against *S. aureus*—are recommended for an initial period of 3 to 4 days.<sup>14</sup> It is important to highlight *Kingella kingae* as a reemerging pathogen responsible for osteoarticular infections.<sup>15</sup> This gram-negative coccobacillus belongs to the HACEK group and is part of the normal oropharyngeal microbiota, with a carriage rate of 10% in children under 4 years of age. Its incidence is lower in infants under 6 months, likely due to maternal antibody protection.<sup>16</sup> The fastidious nature of *K. kingae* means it does not grow easily in traditional culture media, but the use of automated systems significantly improves its detection.<sup>16</sup> More than 80% of *K. kingae* spondylodiscitis cases occur between 6 months and 4 years of age, with 70% affecting the L4-L5 intervertebral space.<sup>17</sup>

Intravenous antibiotics are typically continued for several days, and if the patient's condition improves, treatment is transitioned to oral antibiotics for a total duration of 6 to 8 weeks.

The indication for more invasive procedures, such as biopsy or needle aspiration, remains unclear. Reported identification rates for the causative organism range from 0% to 63% for needle aspiration and open biopsy.<sup>18</sup> However, due to surgical and anesthetic risks, these procedures are not routinely performed and are generally reserved for cases that do not respond to empirical antibiotic therapy. In our patient, clinical improvement was observed after 72 hours of antibiotic treatment, making bone aspiration unnecessary.

As suggested by Menelaus et al., we believe that spinal immobilization is crucial for achieving favorable long-term outcomes.<sup>15</sup> Immobilization not only facilitates infection resolution but also helps maintain spinal alignment, preventing the development of more severe deformities. Treatment discontinuation is warranted once the patient is pain-free and laboratory parameters have normalized.<sup>19</sup>

Our patient was prescribed orthopedic management with a thoracolumbosacral brace three weeks after initiating antibiotic therapy to correct dorsal spine kyphosis. She wore the brace for 10 months, achieving good outcomes. At the last follow-up, 18 months after symptom onset, no thoracolumbar junction deformity was present.

## CONCLUSIONS

Despite its rarity in infants, infectious spondylodiscitis should be considered in the pediatric population. In most cases, the disease follows a mild course and may resolve spontaneously or with a combination of spinal immobilization and antibiotic therapy. However, distinguishing between mild and severe cases can be challenging due to the nonspecific nature of clinical signs. Magnetic resonance imaging is the gold standard for diagnosing spondylodiscitis in children under 6 months of age.

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

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# Neonatal Vertebral Osteomyelitis: Case Report and Literature Review

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## ABSTRACT

**Introduction:** Neonatal vertebral osteomyelitis is a severe and extremely rare condition that is challenging to treat and rarely requires open surgery during the acute phase. We present a case of a 25-day-old neonate who was admitted to the Neonatal Intensive Care Unit due to a respiratory infection with poor progression and no response to conventional treatment. The patient subsequently developed lower cervical and upper thoracic spondylodiscitis, with progressive deterioration and worsening general condition. Open surgical debridement and anterior reconstruction were performed, along with prolonged sequential antibiotic therapy (intravenous to oral). In selected cases, neonatal vertebral osteomyelitis may require open surgical treatment for the resolution of acute infection. However, this approach does not eliminate the risk of residual deformities.

**Keywords:** Neonatal; vertebral osteomyelitis; pyogenic spondylodiscitis; infant.

**Level of Evidence:** IV

## Osteomielitis vertebral neonatal. Presentación de un caso y revisión bibliográfica

## RESUMEN

La osteomielitis vertebral neonatal es una enfermedad grave, muy infrecuente, de tratamiento difícil, que excepcionalmente requiere de cirugía a cielo abierto en la etapa aguda. Se presenta el caso de un recién nacido de 25 días que ingresó en la Unidad de Cuidados Intensivos Neonatales por una infección respiratoria con mala evolución, sin respuesta al tratamiento convencional y que desarrolló una espondilodiscitis cervical inferior y torácica alta con empeoramiento progresivo y mal estado general. Requirió una limpieza quirúrgica a cielo abierto y reconstrucción por vía anterior, además de antibioticoterapia secuencial (por vía intravenosa-oral) prolongada. En casos seleccionados, las osteomielitis vertebrales neonatales pueden requerir un tratamiento a cielo abierto para curar la infección aguda. Esto no protege, sin embargo, de la posibilidad de deformidades como secuelas.

**Palabras clave:** Neonatal; lactante; osteomielitis vertebral; espondilodiscitis cervical.

**Nivel de Evidencia:** IV

## INTRODUCTION

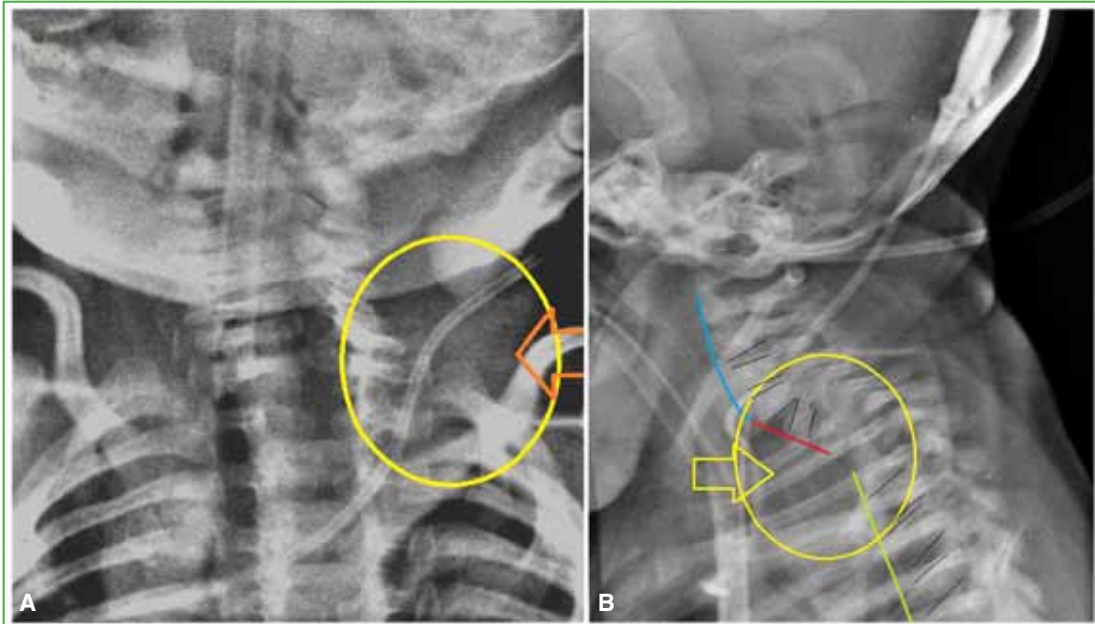
Neonatal spondylodiscitis, or neonatal vertebral osteomyelitis, is a severe and rare condition. Its treatment is technically and ethically challenging, with a high incidence of sequelae and complications.<sup>1</sup> It is exceptionally rare for surgical treatment to be required in the acute stage, particularly at the cervical or cervico-thoracic level.<sup>2,3</sup> This report presents and describes a case of neonatal cervico-thoracic spondylodiscitis treated surgically during the acute stage. The diagnostic and therapeutic options at such a young age are discussed, and relevant literature is reviewed.

## CLINICAL CASE

A 25-day-old male neonate with no significant prenatal or perinatal history was admitted for febrile symptoms related to a respiratory infection, for which conventional antibiotic treatment was initiated. During his stay in the Neonatal Intensive Care Unit, he progressively deteriorated, presenting with dyspnea, sepsis, and a palpable left supraclavicular soft-tissue mass. Plain radiographs revealed this mass (Figure 1A), along with alignment abnormalities in the cervico-thoracic spine (Figure 1B).

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**Figure 1.** A. Anteroposterior thorax radiograph. Note the supraclavicular soft tissue mass (yellow circle, red arrow). B. Lateral cervical spine radiograph. Note the break in the alignment of the cervico-thoracic passage (red and green lines, circle and yellow arrow).

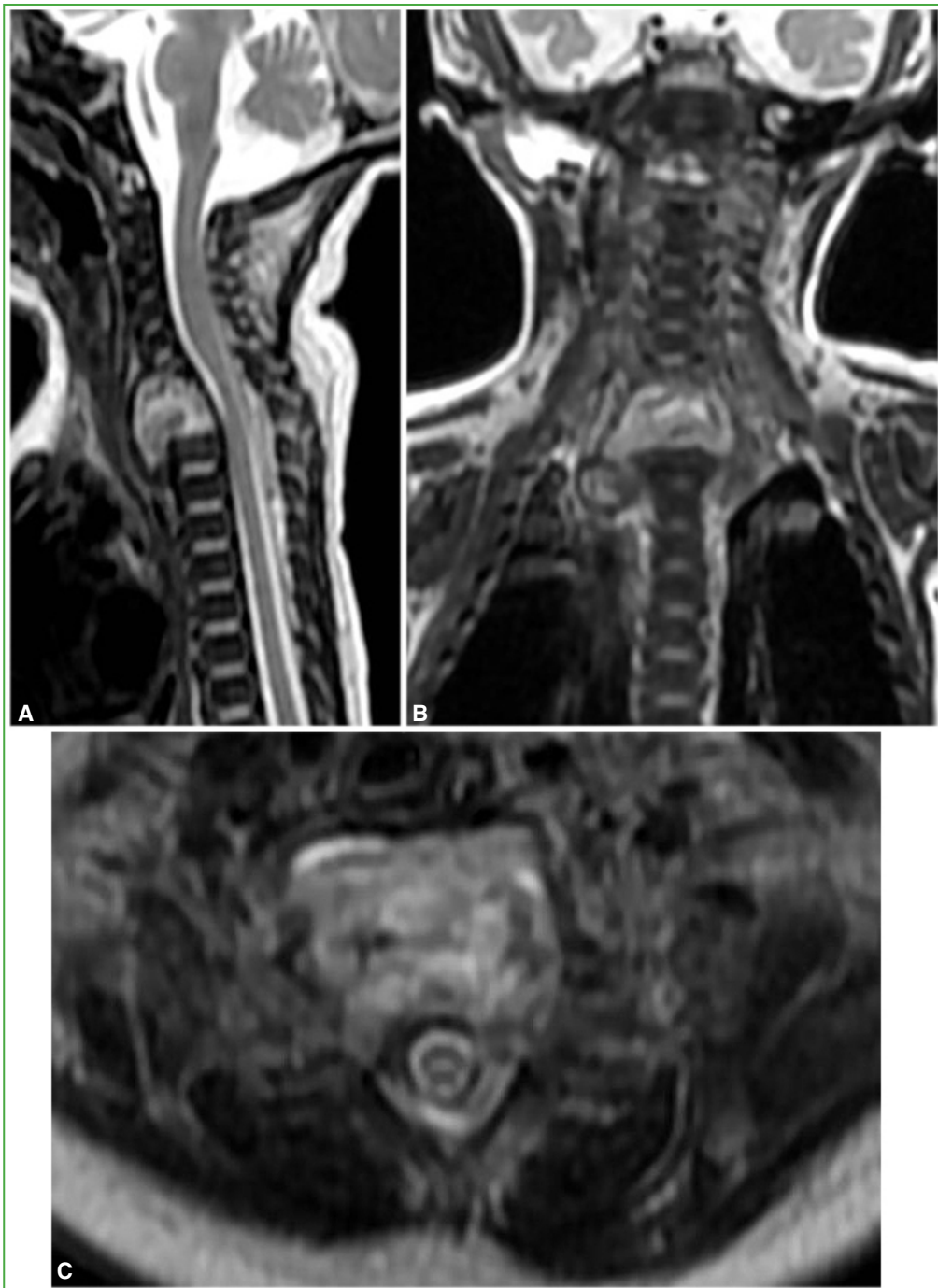
The patient required intubation, and aspiration of the supraclavicular mass revealed methicillin-sensitive *Staphylococcus aureus*. Additionally, *Klebsiella pneumoniae* was identified in secretions from the endotracheal tube.

Despite treatment, the respiratory condition continued to worsen. Helical computed tomography with reconstruction (Figure 2) showed a significant retropharyngeal and retrotracheal abscess, accompanied by osteolysis of the lower cervical vertebral bodies and infectious lesions in the lower cervical and upper thoracic spine.



**Figure 2.** Computed tomography of the neck. A. Sagittal view; note the destruction/disappearance of vertebral bodies and the soft tissue mass of the abscess (yellow arrow). B. Coronal section.

Magnetic resonance imaging (MRI) further confirmed the abscess and infectious destruction of the vertebral bodies of T1, C7, and partial destruction of C6 (Figure 3).



**Figure 3.** Magnetic resonance imaging of the neck. The abscess and the disappearance/destruction of vertebral bodies can be appreciated with greater fidelity. **A.** Sagittal view. **B.** Coronal view. **C.** Axial view.

The clinical scenario was diagnosed as severe neonatal vertebral osteomyelitis in the context of sepsis, with progressive respiratory deterioration unresponsive to antibiotic therapy. Surgical intervention was therefore indicated to address the infectious focus. An extended left anterolateral cervical approach was selected, given the elasticity of neonatal tissues, allowing adequate distal access with appropriate retraction. In case of difficulties, the surgical plan included possible resection of the left lateral portion of the sternal manubrium and the medial extremity of the left clavicle, but this was ultimately unnecessary. The procedure was performed at eight weeks of age, achieving ample visualization of the operative area for successful debridement, which resulted in a significant cavity.

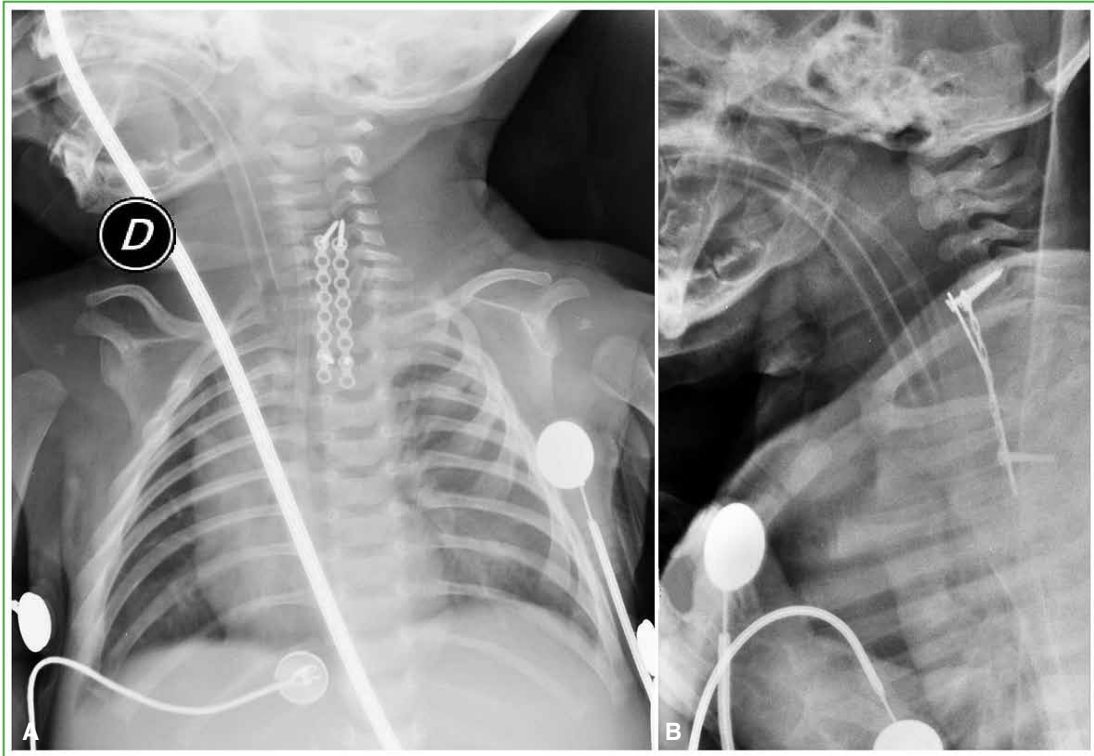
Intraoperative continuous multimodal neurophysiological monitoring was employed. Initially, motor evoked potentials were abnormal, while sensory evoked potentials remained unaffected (Figure 4).



**Figure 4.** Intraoperative positioning. Note the use of neurophysiological monitoring.

However, the monitoring limited the use of a fibula graft for stabilization; instead, a rib graft was used for structural support, supplemented with bone chips and two titanium mini-plates for additional stability. Postoperative imaging, including C-arm fluoroscopy and radiographs, confirmed satisfactory results (Figure 5).

Following surgery, the patient was fitted with a soft cervical collar, which was replaced on the third postoperative day with a custom-made cervico-thoracic orthosis featuring a soft frontal cephalic component (Figure 6).



**Figure 5.** Anteroposterior (A) and lateral (B) radiographs of the cervico-thoracic spine in the immediate postoperative period in the Neonatal Intensive Care Unit. Note the adequate placement of the osteosynthesis elements.



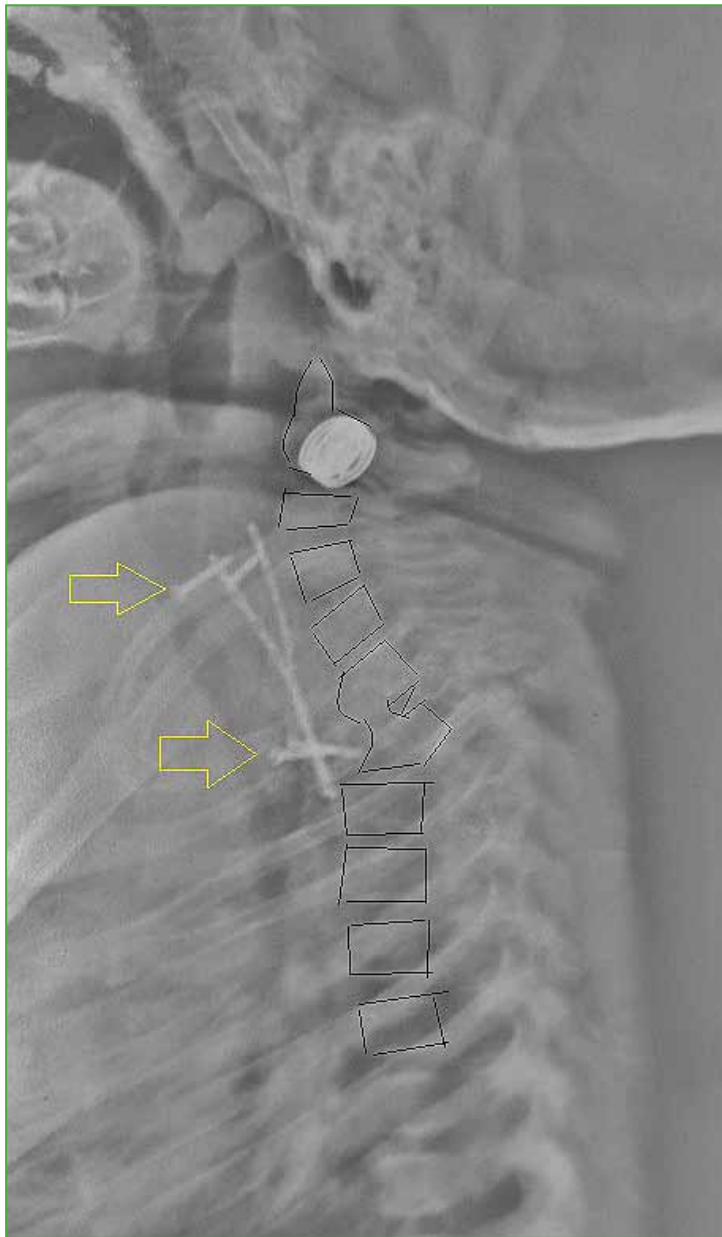
**Figure 6.** Patient fitted with custom-made, soft cervico-thoracic orthosis prior to discharge.

During surgery, meropenem and vancomycin were initiated after obtaining culture samples. These cultures grew methicillin-resistant *Staphylococcus aureus* (MRSA) sensitive to vancomycin. Consequently, vancomycin was continued alongside parenteral amikacin for four weeks, followed by oral trimethoprim-sulfamethoxazole and rifampin for eight weeks.

Three months postoperatively, the patient exhibited normal weight gain, psychomotor development, and no visible spinal deformities. Follow-up imaging was normal, and the orthosis was used consistently.

Eight months post-surgery, radiographic evaluation revealed disassembly of the osteosynthesis without significant kyphosis. The patient remained asymptomatic, with normal development and no neurological deficits, despite continued use of the orthosis (Figure 7).

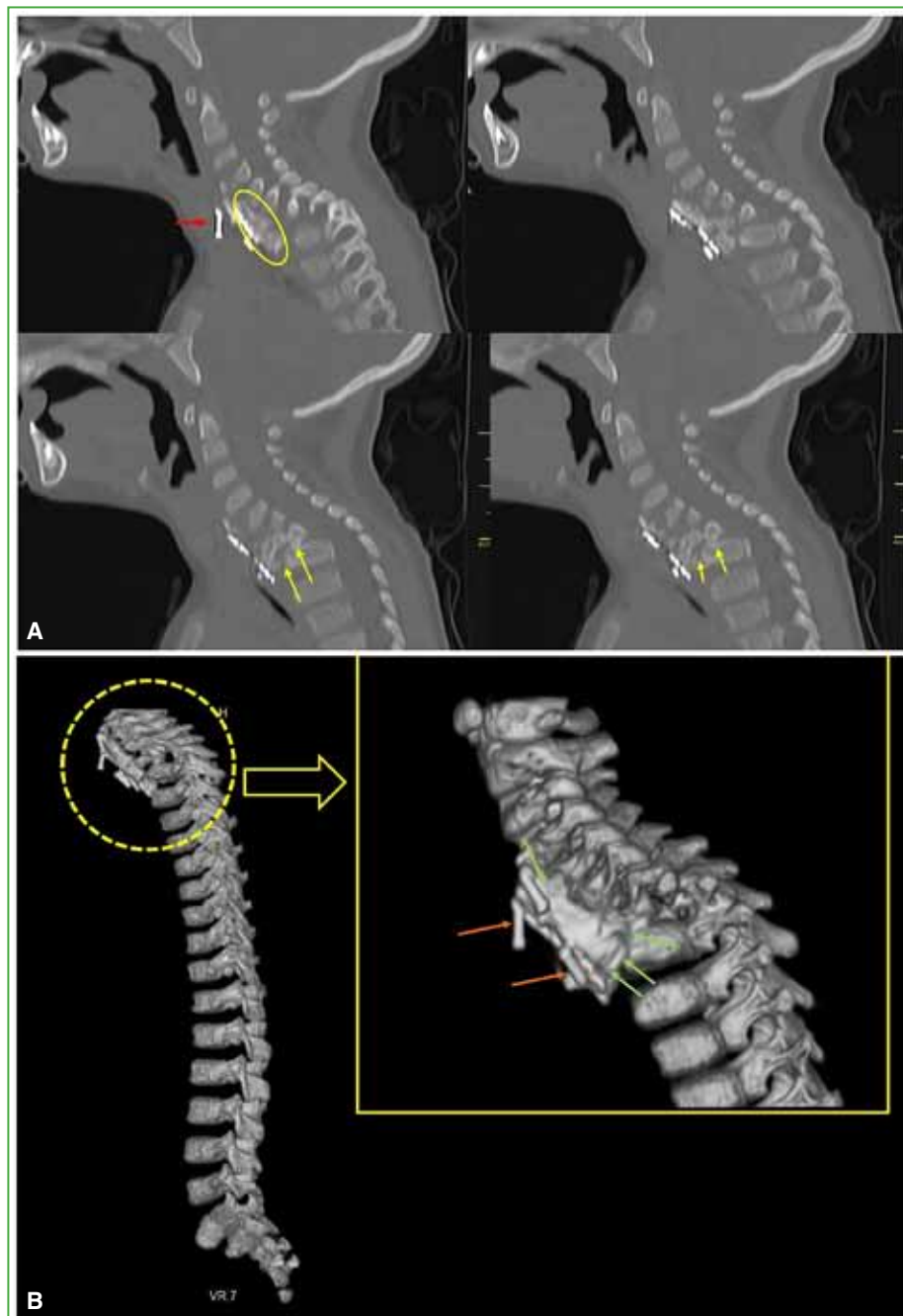
The patient achieved independent walking at one year and three months of age.



**Figure 7.** Lateral radiograph of the cervico-thoracic spine 8 months after surgery. Note the partial disassembly of the osteosynthesis (yellow arrows), with slight kyphosis of the focus.

At one year and ten months postoperatively (two years of age), the patient maintained normal development with no evidence of neurological impairment or visible deformities. A follow-up computed tomography scan (Figure 8) showed intersomatic fusion with robust anterior bony bridging. However, segmental kyphosis was noted, associated with mild compensatory hyperlordosis. Instrumentation disassembly remained unchanged, with no related complications or symptoms such as dysphagia, cough, cervical pain, or dysphonia.

To prevent progression of the kyphosis during remaining growth, a revision and complementary surgery was scheduled.



**Figure 8.** Control CT scan of the cervico-thoracic spine at 1 year and 10 months after surgery. **A.** Note intersomatic fusion (yellow arrows), significant anterior bony bridging (yellow oval), instrumentation disassembly (red arrow), and segmental kyphosis. **B.** 3D reconstruction. In the inset, the important fusion mass stabilizing the region can be seen.

## DISCUSSION

The prevalence of neonatal spondylodiscitis is extremely low; in referral centers, it accounts for only 7 out of every 1000 admissions to the Neonatal Intensive Care Unit.<sup>4</sup> The incidence is approximately 0.40% in live newborns.<sup>5</sup> Although preterm infants are typically at higher risk, it has also been described in healthy newborns, usually occurring between 2 and 4 weeks of life,<sup>6</sup> as in our case.

Forty-five years ago, Ogden<sup>7</sup> described the pathogenesis of neonatal vertebral osteomyelitis: in newborns, small capillaries pass through the vertebral growth plates, facilitating the spread of infection and contamination of both the disc and the vertebral body. The cortical bone of neonates and infants is thin, weak, and lax, predominantly composed of immature bone tissue. While this allows for the release of pressure caused by the accumulation of infectious material, it also promotes rapid dissemination to the subperiosteal region. Consequently, large sequestra do not typically form because extensive cortical infarction, if present, is quickly resorbed due to the significant vascularization in neonates.<sup>6</sup> However, necrosis of the vertebral endplates may occur due to capillary obstruction caused by septic emboli, potentially leading to the formation of large subperiosteal abscesses.

Retropharyngeal abscesses have been reported in neonates and infants, sometimes presenting as soft tissue masses in the neck,<sup>8</sup> as in our case. On CT scans, additional associated lesions are often identified,<sup>9</sup> which may be complicated by nearby spondylodiscitis, potentially causing neurological deficits.<sup>8</sup>

The clinical presentation of spondylodiscitis in neonates and infants often includes high fever, signs of sepsis, irritability or pain—especially during mobilization or breastfeeding—and developmental delay.<sup>10</sup> In preterm, low-birth-weight neonates with prolonged Neonatal Intensive Care Unit stays, sepsis, and irritability or pain during trunk movements, pyogenic vertebral osteomyelitis should be suspected.<sup>4,10-13</sup>

The severity of both acute and chronic injury caused by this condition has been aptly described by Pershin and Mushkin as “a ticking time bomb.”<sup>1</sup>

Although ultrasound and conventional radiography may aid in the diagnosis, spinal MRI is the diagnostic method of choice due to its superior sensitivity and specificity. MRI enables evaluation and differentiation of bone and disc destruction and delineation of paravertebral abscesses.<sup>12</sup> In our case, the use of CT before MRI was due to institutional availability; however, it proved very useful in identifying the lesion and evaluating bone destruction (Figure 2).

There are few published reports on the treatment of neonatal spondylodiscitis in the acute stage, with various approaches described: antibiotic therapy combined with immobilization using orthoses;<sup>14,15</sup> abscess evacuation via aspiration followed by orthopedic treatment;<sup>16-18</sup> drainage and open debridement;<sup>2</sup> or surgical treatment in the chronic phase after infection resolution, typically involving double approaches or repeated posterior fusions with anterior approaches.<sup>1,18,19</sup> Most of the published cases involve older infants or children aged 1–2 years. Our case is noteworthy because the patient underwent surgery during the acute stage at just 8 weeks of age. Drainage with cleansing and debridement, along with anterior reconstruction, enabled rapid healing and improvement. Sequential treatment with intravenous antibiotics, followed by a switch to oral antibiotics—a proven approach in this patient group—ensured complete resolution.<sup>20</sup>

Instrumentation of the cervical and upper thoracic spine in young children is generally associated with complications, especially in younger patients.<sup>21</sup> While successful outcomes have been reported in the upper thoracic spine in children under 2 years of age,<sup>22</sup> reports of successful instrumentation in children younger than 1 year are rare,<sup>3</sup> and we found no reports of anterior-approach implants in neonates. In our case, the use of an anterior implant added intraoperative stability (Figure 5). Although partial disassembly occurred postoperatively (Figure 7), the plates ensured the grafts remained in place until consolidation of the lesion (Figure 8).

The most common complication of this condition, aside from neurological deficits, is the dissolution of the vertebral bodies, leading to kyphosis. This deformity is often angular and can resemble congenital kyphosis due to vertebral body aplasia. Reconstructive surgeries, usually involving double approaches, are often required.<sup>1,23</sup> While there are limited long-term studies following growth completion, the severity of this deformity and the young age of affected patients—who have significant growth potential—make it comparable to the progression of pediatric Pott’s kyphosis.<sup>24</sup> Similar criteria can guide decisions regarding additional procedures. In our case,

the residual deformity poses a risk of progression, with potential neurological deterioration due to its location (the cervico-thoracic junction and high thoracic spine).<sup>25</sup> Additionally, the marked growth deficit in the anterior segment of the affected region (secondary to vertebral body and physis destruction) led us to schedule a second intervention (Figure 8).

## CONCLUSION

Neonatal vertebral osteomyelitis, in selected cases, may require open surgery to resolve acute infection. However, such interventions do not eliminate the risk of deformity as a sequela, necessitating long-term follow-up until growth is complete.

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# Reconstruction of Congenital Pseudarthrosis of the Radius Using a Vascularized Tibial Periosteum Transplant: A Case Report

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## ABSTRACT

Congenital pseudarthrosis of the radius is a rare condition, commonly associated with neurofibromatosis or fibrous dysplasia. We present the first reported case of using a vascularized periosteal flap for the treatment of congenital pseudarthrosis of the radius. The patient was a 14-month-old boy with neurofibromatosis type 1, presenting with severe shortening of the forearm, radial deviation of the wrist, and limitation of pronation-supination (60°-80°). Radiographs revealed pseudarthrosis in the distal third of the right radius. Surgical treatment involved debridement, bone fixation with a Kirschner wire, and placement of a vascularized periosteal flap harvested from the contralateral tibia to cover the pseudarthrosis site. Radiographic evidence of callus formation was observed two weeks postoperatively, accompanied by full wrist flexion-extension and improved pronation-supination (90°-90°). At five weeks, the patient resumed activities without orthotic protection. The use of vascularized tibial periosteum represents an innovative approach for treating congenital pseudarthrosis of the radius, demonstrating rapid bone healing and early return to activity, with no morbidity at the donor site.

**Keywords:** Vascularized periosteum; congenital pseudarthrosis; reconstruction; flaps; neurofibromatosis.

**Level of Evidence:** IV

## Reconstrucción de una pseudoartrosis congénita de radio mediante un trasplante de periostio vascularizado de tibia: reporte de un caso

## RESUMEN

La pseudoartrosis congénita de radio es un cuadro raro, comúnmente asociado a neurofibromatosis o displasia fibrosa. Presentamos el primer caso de un colgajo de periostio vascularizado utilizado para tratar la pseudoartrosis congénita de radio. Se trata de un varón de 14 meses de edad con neurofibromatosis tipo 1, acortamiento severo del antebrazo y desviación radial de la muñeca. La prono-supinación estaba limitada (60°-80°). En las radiografías, se observó una pseudoartrosis del tercio distal del radio derecho. El tratamiento quirúrgico consistió en desbridamiento, fijación ósea con una aguja de Kirschner y la colocación de un colgajo de periostio vascularizado de tibia de la pierna contralateral cubriendo el sitio pseudoartrosico. A las 2 semanas de la operación, se observó la formación de callo en la radiografía, con flexo-extensión completa de la muñeca y prono-supinación de 90°-90°. A las 5 semanas, reanudó sus actividades sin protección ortésica. El uso de periostio vascularizado de tibia es una opción innovadora para tratar la pseudoartrosis congénita de radio, ya que la consolidación ósea y el retorno a las actividades son rápidos, sin morbilidad asociada en el sitio donante.

**Palabras clave:** Periostio vascularizado; pseudoartrosis congénita; reconstrucción; colgajos; neurofibromatosis.

**Nivel de Evidencia:** IV

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## INTRODUCTION

Congenital pseudarthrosis of the radius is a very rare condition, commonly associated with neurofibromatosis or fibrous dysplasia.<sup>1,2</sup> The local bone repair process is defective, similar to what occurs in congenital pseudarthrosis of the tibia. This is likely due to the presence of an abnormal periosteum, which leads to the formation of a fibrous hamartoma at the pseudarthrosis site following a fracture of a previously dysplastic bone.

Several therapeutic options have been described, including conventional bone grafting, vascularized bone grafts, bone shortening, and single-bone forearm procedures.<sup>3</sup>

According to the literature, vascularized fibula grafting is currently the preferred treatment for this specific disorder.<sup>2-5</sup> The use of vascularized periosteal flaps to treat complex pseudarthroses in children has recently gained popularity<sup>6,7</sup> and has proven highly effective, even in challenging cases such as congenital pseudarthrosis of the tibia.<sup>8,9</sup>

We present the first reported case of a vascularized periosteal flap used for the treatment of congenital pseudarthrosis of the radius.

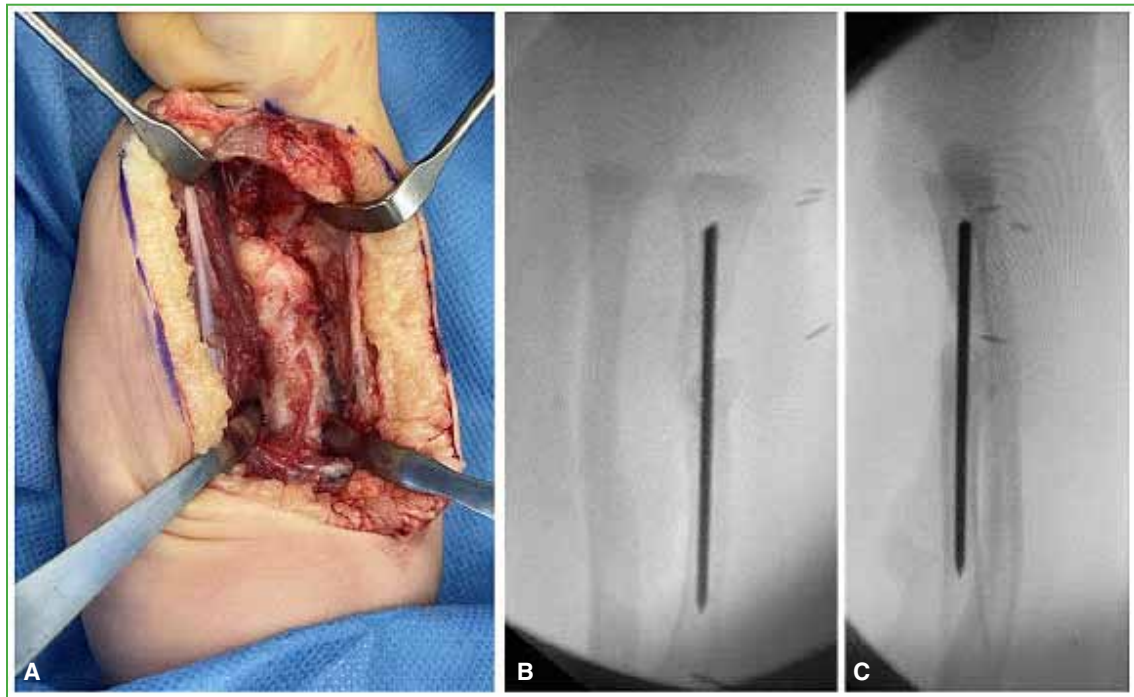
## CLINICAL CASE

A 14-month-old male with neurofibromatosis type 1 presented with severe forearm shortening and radial deviation deformity of the right wrist (Figure 1). On physical examination, passive pronation-supination of the forearm was limited to 60-80°, with no flexion-extension deficit. Radiographs revealed an area of atrophic pseudarthrosis with angulation of the distal third of the radius, with an ulnar and volar apex.



**Figure 1.** Deformity of the right forearm. Dorsal (A) and volar (B) clinical images. Forearm radiographs, anteroposterior (C) and lateral (D).

Surgery was performed through a volar longitudinal approach to the forearm and included debridement of the pseudarthrosis site, extensive resection of the anomalous native radial periosteum, and diaphyseal osteotomy of the middle third of the radius for realignment in both the coronal and sagittal axes. Finally, bone fixation was achieved using a 2-mm retrograde K-wire (Figure 2).



**Figure 2.** A. Abnormal radial periosteum (fibrous hamartoma). B and C. Anteroposterior and lateral radiographic images, respectively, of K-wire placement.

Subsequently, a vascularized periosteal flap was harvested from the contralateral tibia following the technique described by Soldado et al.<sup>8</sup> (Figure 3). The flap was positioned to cover the radial periosteum, the pseudarthrosis site, and the osteotomy site, leaving a skin island for postoperative flap monitoring. Anastomosis of the tibial vessels to the radial vessels was performed. There were no immediate or late postoperative complications.



**Figure 3.** A. Donor area. Vascularized periosteal flap of contralateral tibia. B and C. Recipient site on the right forearm with skin island for monitoring.

Control radiographs taken three weeks after surgery showed solid callus formation, defined as the presence of bone bridges in at least two projections (Figure 4). To assess healing, we used the Radiographic Union Score for Radius, a simple and standardized method described for distal radius fractures.<sup>10</sup> A radial shortening of 5 mm was observed. Passive forearm exercises were prescribed. Due to the COVID-19 outbreak, K-wire removal was delayed until six months postoperatively.

At the last follow-up, the patient had 90° of forearm supination, 90° of pronation, and full wrist flexion-extension. The child resumed all daily and school activities without the need for orthotic protection.



**Figure 4.** Postoperative radiographic controls. **A.** At 3 weeks. **B.** At 8 weeks.

## DISCUSSION

Several surgical techniques have been described for the treatment of congenital radial pseudarthrosis. Standard bone grafting is generally not recommended due to its high failure rate.<sup>11</sup> The single-bone forearm procedure is rarely indicated for this condition. While it is a simpler procedure compared to microsurgical options, it sacrifices forearm rotation and may still be associated with pseudarthrosis, as abnormal bone remains at the union site.<sup>12</sup>

Biological procedures have been proposed to improve consolidation rates. Bone resection and free vascularized fibula grafting have shown excellent outcomes in congenital forearm pseudarthrosis.<sup>13,14</sup>

Allieu was the first to use the vascularized fibula technique in 1981.<sup>4</sup> He recommended early treatment to maximize the growth potential and remodeling capacity in pediatric patients.<sup>13</sup> The youngest reported patient to undergo this procedure was one year old.<sup>14</sup>

According to Barrera-Ochoa et al., the use of vascularized periosteal flaps for treating complex osseous pseudarthrosis has gained popularity in recent years across a variety of clinical scenarios.<sup>6,15-18</sup>

Vascularized free periosteal flaps, harvested from the fibula or tibia, have been used for the treatment and prevention of osseous pseudarthrosis in children, with excellent outcomes. Studies suggest that the tibial vascularized periosteal flap, based on the anterior tibial vessels, is easier to harvest and has greater osteogenic capacity compared to the fibular vascularized periosteal flap.<sup>8,9,19</sup> Using this technique, we performed the first vascularized periosteal flap procedure for congenital forearm pseudarthrosis and achieved rapid consolidation. The advantage of using a tibial vascularized periosteal flap over a fibular one is the avoidance of potential donor site complications associated with fibular removal, which are not negligible.<sup>20</sup> To date, no local morbidity has been reported after tibial vascularized periosteal flap harvesting. Another advantage is the early return of the child to daily activities, as this technique leads to rapid consolidation. Indeed, our patient was allowed mobility three weeks after surgery.

A major limitation of our study is that it is a single-case report with short-term follow-up. A larger study including additional cases treated with this technique, along with a comparison to the vascularized fibular periosteal flap and long-term follow-up, would be valuable.

## CONCLUSIONS

The tibial vascularized periosteal flap proved to be highly effective and rapid in achieving consolidation in a patient with congenital pseudarthrosis of the radius. Successful reconstruction was achieved using this novel technique.

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

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# Modified Lemaire Lateral Extraarticular Tenodesis in Skeletally Immature Patients: Technical Note

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## ABSTRACT

In recent years, the incidence of anterior cruciate ligament (ACL) injuries in skeletally immature athletes has increased exponentially. Although numerous techniques have been developed to stabilize the knee while minimizing the risk of physeal injury, ACL reconstruction in young patients remains associated with a high graft failure rate. The anterolateral ligament has recently gained considerable attention due to its role in anterolateral rotational stability. The objective of this article is to describe the surgical technique used by the authors to perform a combined ACL reconstruction and anterolateral tenodesis in patients with open physes who are at high risk of ACL re-tear.

**Keywords:** Modified Lemaire tenodesis; pediatric; anterolateral ligament; anterior cruciate ligament.

**Level of Evidence:** V

## Tenodesis extrarticular lateral de Lemaire modificada en pacientes esqueléticamente inmaduros.

### Nota técnica

## RESUMEN

La incidencia de lesiones del ligamento cruzado anterior en deportistas esqueléticamente inmaduros ha aumentado, de manera exponencial, en los últimos años. Si bien se han desarrollado numerosas técnicas que permiten estabilizar la rodilla minimizando el riesgo de lesión fisaria, la reconstrucción del ligamento cruzado anterior en pacientes jóvenes sigue vinculada a una alta tasa de fracaso del injerto. El ligamento anterolateral ha despertado un considerable interés recientemente debido a su papel en la estabilidad rotatoria anterolateral. El objetivo de este artículo es describir la técnica quirúrgica utilizada por los autores para realizar una reconstrucción combinada del ligamento cruzado anterior y tenodesis anterolateral en pacientes con fisis abiertas que presentan un riesgo elevado de re-rotura del ligamento cruzado anterior.

**Palabras clave:** Tenodesis de Lemaire; niños; ligamento anterolateral; ligamento cruzado anterior.

**Nivel de Evidencia:** V

## INTRODUCTION

The incidence of anterior cruciate ligament (ACL) injuries in skeletally immature athletes has increased exponentially in recent years.<sup>1,2</sup> Current literature favors early surgical management in children when the injury is complete and the knee is clinically unstable. Although numerous techniques have been developed to stabilize the knee while minimizing the risk of physeal injury, ACL reconstruction in young patients is still associated with a high rate of graft failure.<sup>3</sup> The anterolateral ligament (ALL) has recently attracted considerable interest due to its role in anterolateral rotational stability.<sup>4,5</sup> This has led surgeons to consider lateral extra-articular tenodesis (LET) and ALL reconstruction techniques as adjuncts to ACL reconstruction.

In biomechanical studies, both procedures have been shown to significantly reduce internal tibial rotation and anterolateral rotational instability. When combined with ACL reconstruction, they restore anterior tibial translation to levels comparable to those seen in healthy, native knees.<sup>6</sup>

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Clinical studies have demonstrated significant advantages, including lower graft rupture rates, improved knee stability, and higher rates of return to sports.<sup>7</sup>

Due to the proximity of the femoral insertion of the ALL, techniques commonly used in adults may pose a risk to the lateral physis of the distal femur in pediatric and adolescent patients.

The aim of this article is to describe the surgical technique used by the authors to perform a combined ACL and ALL reconstruction (LET) in patients with open physes who present a high risk of ACL re-tear.

## SURGICAL TECHNIQUE

### Indications

The authors' current indications for ACL reconstruction combined with LET in patients with open physes are: 1) Revision of a failed ACL reconstruction; 2) a high-grade pivot shift on clinical examination; 3) generalized ligamentous hyperlaxity; 4) high-performance athletes engaged in sports requiring pivoting movements.

### Description of the Procedure

The patient is placed in the supine position under spinal anesthesia, with a hemostatic cuff applied. A single dose of 1 g of cefazolin is administered preoperatively. Aseptic and antiseptic preparation is performed, and surgical drapes are placed according to standard technique. After exsanguinating the affected limb with an Esmarch bandage, a hemostatic cuff is inflated to 250 mmHg.

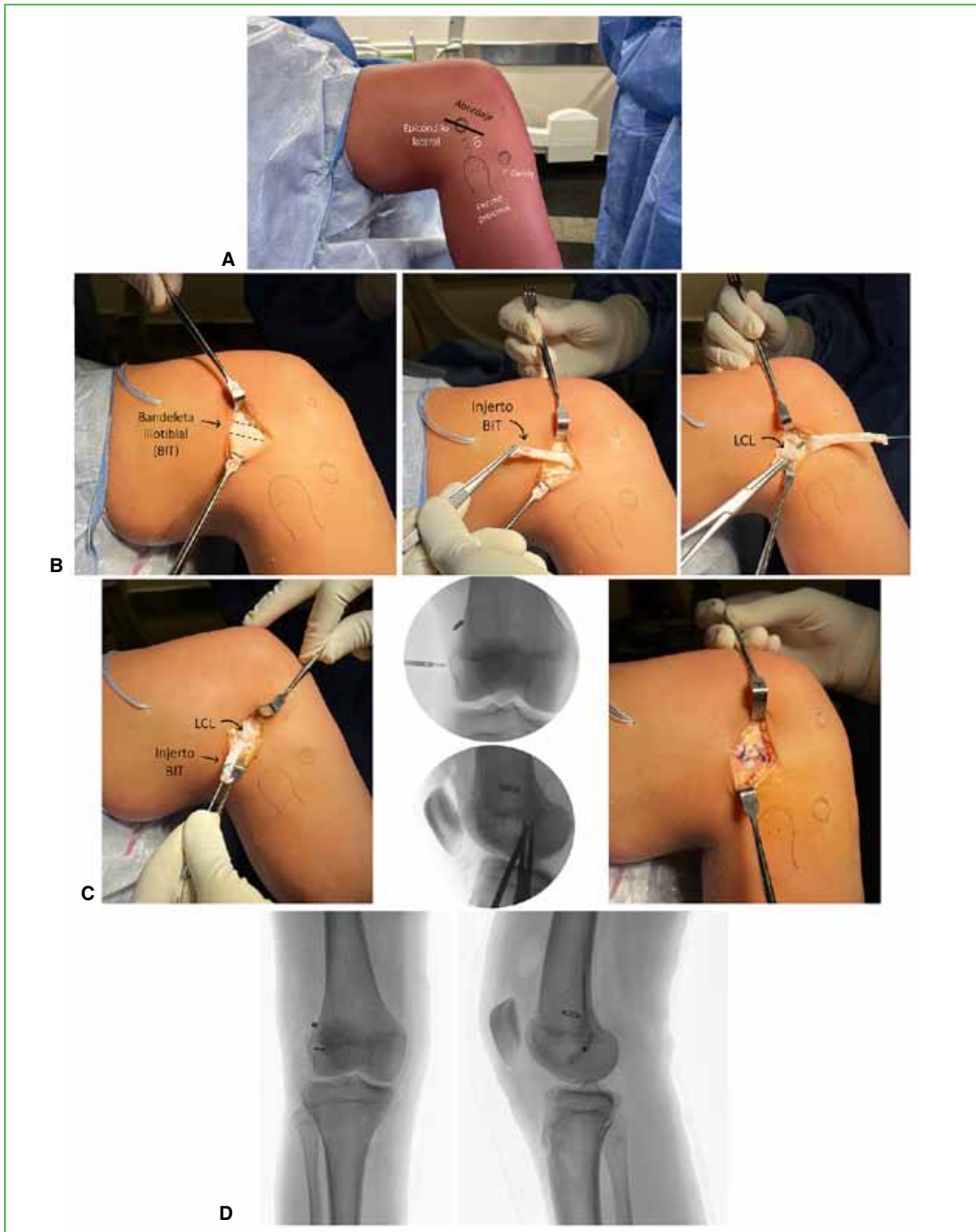
Following ACL reconstruction, the knee is positioned in approximately 80° of flexion, and a longitudinal incision of about 5 cm is made, 1 cm posterior to the lateral femoral epicondyle, starting 2 cm proximal to Gerdy's tubercle. If greater visualization is required, particularly in patients with abundant subcutaneous tissue, the incision can be extended proximally. The anterior and posterior borders of the iliotibial band (ITB) are dissected and identified. A strip of ITB measuring 6–8 cm in length and 1 cm in width is harvested from its posterior half, ensuring that the distal insertion at Gerdy's tubercle remains intact. A No. 1 Vicryl™ suture (Ethicon Inc., NJ, USA) is placed at the free end of the graft. The lateral collateral ligament (LCL) is identified by palpation with the leg in a figure-four position. Two small capsular incisions are made anterior and posterior to the proximal portion of the LCL, and a dissection is carried out from anterior to posterior to create a passage for the graft. It is crucial to remain extracapsular and avoid damaging the popliteus muscle or the LCL. The ITB graft is then passed under the LCL from distal to proximal using double utility forceps. The femoral fixation point is determined at the level of the lateral epicondyle, below the physis, using fluoroscopic guidance (Figure) A 3.5 mm or 2.8 mm titanium or bioabsorbable anchor is placed, depending on the patient's size. When inserting the anchor, care must be taken to avoid invading the physis or damaging the femoral attachment of the ACL, as the suspensory button anchor is in close proximity. With the knee flexed at 90° and the foot in neutral rotation to prevent overconstriction of the lateral compartment, the graft is held taut and secured with the anchor sutures. The wound is irrigated, hemostasis is confirmed, and the wound is closed in layers. The ITB is repaired with interrupted No. 1 Vicryl™ sutures up to the level of the transverse retinacular ligament.

### Postoperative Management

All patients follow the same rehabilitation program used after ACL reconstruction. This includes the use of a knee immobilizer and crutches for 10–14 days, with immediate partial weight-bearing (50% of body weight) and an allowed range of motion from 0° to 90° immediately after surgery. After the first two weeks, weight-bearing and range of motion are increased as tolerated. Rehabilitation focuses on maintaining full extension and promoting early quadriceps activation.

Cycling exercises are introduced approximately four weeks after surgery, along with a progressive strengthening program. Straight-line jogging and agility training begin at four months postoperatively, progressing to sport-specific training and jumping exercises.

At six months, patients undergo a functional return-to-sport assessment, which includes evaluations of range of motion, strength, thigh circumference, balance, and functional performance. Any identified deficiencies are addressed. Return to sport is gradual and typically begins between 10 and 12 months, depending on the results of the functional assessment.



**Figure.** Surgical technique. **A.** Anatomical parameters. **B.** Surgical approach, graft harvest and dissection of the lateral collateral ligament (LCL). **C.** Graft passage, fluoroscopy-guided femoral fixation and iliotibial band (ITB) closure. **D.** Immediate postoperative radiograph.

## DISCUSSION

This article describes the technique used by the authors to perform combined ACL and ALL reconstruction in patients with open physes who are at high risk of ACL re-tear. The surgical technique involves placing an iliotibial band graft as an anterolateral tenodesis, with a femoral fixation point guided by intraoperative fluoroscopy to avoid injuring the distal femoral physis or interfering with the ACL tunnel. The advantages and disadvantages of this procedure are summarized in [Table 1](#).

**Table 1.** Advantages and disadvantages of the combined anterior cruciate ligament and LET technique in skeletally immature high-risk patients.

| Advantages   | Disadvantages  |
|--|--|
| Preserves the femoral and tibial physis.                         | Increases surgical time  |
| Provides additional rotational stabilization                     | Requires an additional incision  |
| Decreases the tear rate of the anterior cruciate ligament graft. | Overtightening of the tenodesis can lead to overconstriction of the knee and restriction of rotational motion. |
|  | Intraoperative fluoroscopy required  |

LET = lateral extra-articular tenodesis.

The ALL is located in the lateral region of the knee, anterior to the LCL. Recent anatomical and biomechanical studies have highlighted the role of this extra-articular anterolateral structure and its synergistic relationship with the ACL in maintaining rotational stability of the knee. Although the specific indications for these procedures remain a topic of debate, recent studies suggest that this surgery significantly reduces the risk of ACL reconstruction failure.<sup>8,9</sup> In a randomized controlled trial, failure rates at two years were reported as 11% for primary ACL reconstructions using a hamstring autograft (semitendinosus/gracilis) and 4.5% for ACL reconstructions combined with LET (modified Lemaire technique), with no significant differences in patient-reported subjective outcomes.<sup>9</sup>

The addition of lateral extra-articular procedures has also been shown to be effective in pediatric patients, although the available literature on this population remains limited. A recent systematic review<sup>10</sup> analyzed 381 pediatric patients (mean age 11.73 years, range 5.6–16) with a mean follow-up of 50.1 months. The overall graft failure rate was 4.65% (range 0–13.6%), which is comparable to that reported for ACL plus LET reconstruction in adults. The return-to-sport rate was high (95.11%), with good functional scores (Lysholm mean 94.51 and Pedi-IKDC 93.39).

Although multiple studies have been conducted on the anatomy of the LCL, some controversy remains regarding its anatomical insertions. A pediatric cadaveric study<sup>11</sup> demonstrated that the popliteal insertion and the origin of the LCL are consistently distal to the distal femoral physis, suggesting that tunnels or drill holes should be positioned within the epiphysis. Due to the smaller size of pediatric knees, the proximity of the femoral tunnel for ACL reconstruction, and the undulating shape of the distal femoral physis, caution is necessary when securing the graft to the epiphysis. Our current preference is to use a 2.8 mm or 3.5 mm harpoon, which eliminates the need for a tunnel that could interfere with the ACL tunnel. The same study<sup>11</sup> also found that the iliotibial band insertion at Gerdy's tubercle had an inconsistent relationship with the physis, being proximal to the physis in six specimens and distal in three. For this reason, we currently prefer to leave the iliotibial band insertion intact and avoid additional tibial fixation.

It remains unclear whether performing LET in skeletally immature patients increases the risk of growth disturbances due to the forces exerted on the growth plate. In the same study by the SANTI group,<sup>10</sup> 1.9% of patients developed a coronal plane deformity, and 0.8% had a limb length discrepancy. The authors of this article are currently evaluating a series of 48 patients aged 13 to 18 years who underwent the described surgical procedure, with 61% being skeletally immature. None of these cases have shown angular deformities or limb length discrepancies.

In summary, this article presents a surgical technique for combined ACL reconstruction and anterolateral tenodesis in pediatric patients with open physes. We emphasize the importance of intraoperative fluoroscopy and precise anatomical knowledge of the distal femoral physis and ALL insertions to prevent complications related to physeal injury (Table 2). While preliminary results in this high-risk population are promising, further studies are needed to validate clinical outcomes and assess potential complications in this patient group.

**Table 2.** Important aspects to avoid complications.

Insufficient graft length (<6 cm) may hinder femoral fixation.

To avoid damage to the physis, epiphyseal femoral fixation should be performed under fluoroscopic control.

Consider the anatomy of the distal femoral physis (wavy shape) at the time of femoral fixation.

Fixation with a 3.5 mm anchor allows fixation of the graft in the epiphysis without the need for tunneling.

Avoid confluence of the anchor with the femoral tunnel of the anterior cruciate ligament.

If the tibia is in external rotation during LET tension and fixation, it may result in overconstriction of internal rotation of the knee.

If the tibia is in internal rotation, it may result in laxity of the graft and impede the protective effects of the LET.

LET = lateral extra-articular tenodesis.

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

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# Case Resolution

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Case presentation on page 3.

## Stress Fracture as a Differential Diagnosis for Bone Sarcomas

### ABSTRACT

Stress fractures require a thorough evaluation to differentiate them from neoplastic processes. This evaluation includes medical history, physical examination, and diagnostic studies. A diagnostic algorithm is proposed.

**Keywords:** Stress fracture; biopsy; bone sarcoma.

**Level of Evidence:** IV

### Fractura por estrés como diagnóstico diferencial de sarcomas óseos

### RESUMEN

Las fracturas por estrés requieren una evaluación exhaustiva para distinguirlas de procesos neoplásicos. Esta incluye la anamnesis, el examen físico y los estudios complementarios. Se propone un algoritmo diagnóstico.

**Palabras clave:** Fractura por estrés; biopsia; sarcoma óseo.

**Nivel de Evidencia:** IV

**DIAGNOSIS:** Stress fracture of the left femoral diaphysis.

### DISCUSSION

Based on the findings in the imaging studies described above, a core needle biopsy of the lesion was performed under CT guidance (Figure 4).

The histopathological analysis revealed compact bone with marked signs of remodeling, without evidence of cellular atypia (Figure 5).

After ruling out a neoplastic process and confirming a stress fracture, partial weight-bearing was maintained, and a consultation with Endocrinology was requested to evaluate possible metabolic causes. Laboratory tests and bone densitometry were performed, and metabolic disorders were ruled out.

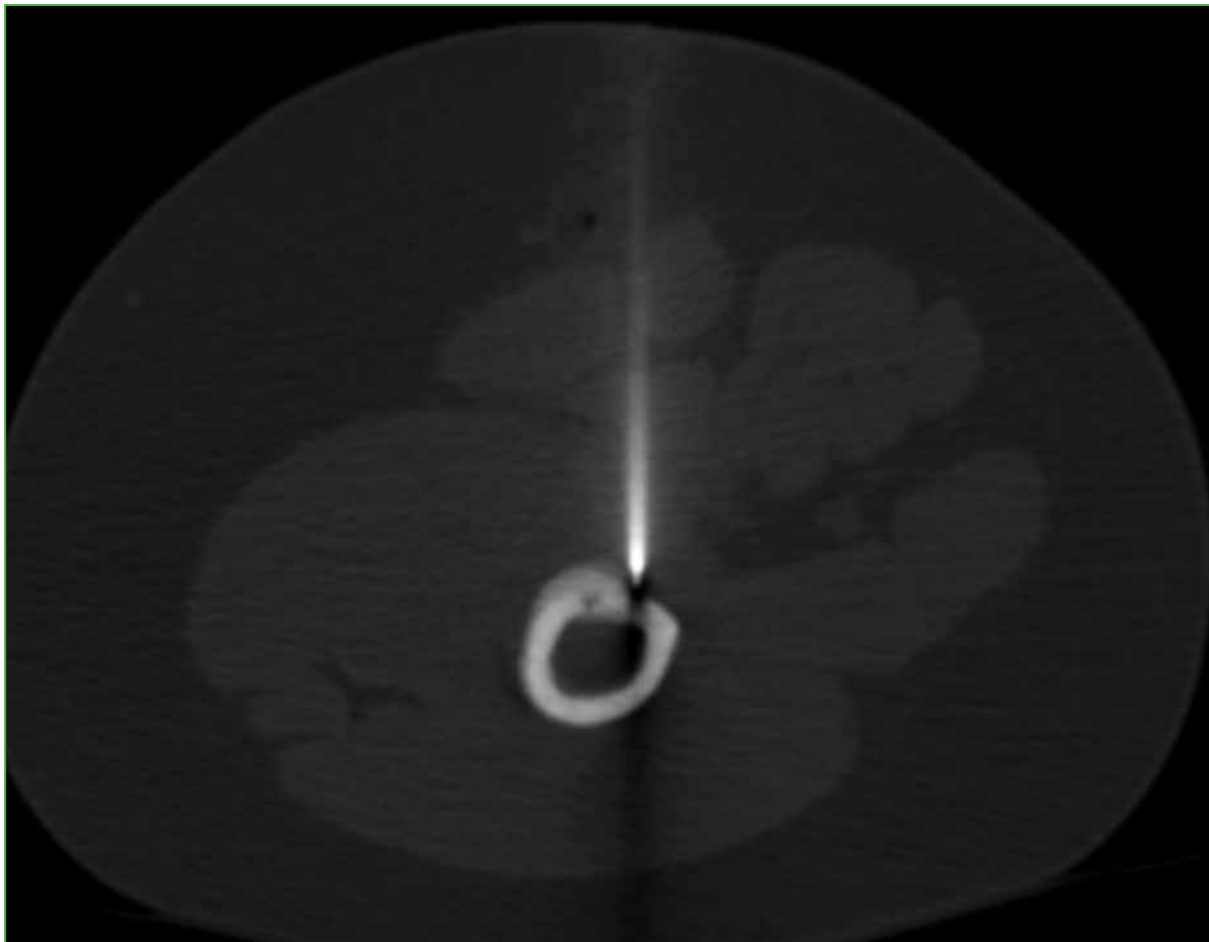
After four weeks of partial weight-bearing, the patient reported no pain, allowing for full weight-bearing. Follow-up radiographs showed no changes compared to previous imaging. At six-month and one-year follow-ups, the patient remained asymptomatic and was able to perform daily activities and sports without restrictions.

A stress fracture results from cyclic and repetitive mechanical overload that prevents adequate bone remodeling in a metabolically healthy bone. Repeated loading below the bone's maximum resistance threshold leads to microfractures without sufficient time for repair.<sup>1,2</sup> It is crucial to differentiate stress fractures from pathological fractures, where tumor tissue replaces healthy bone and alters its strength, and from insufficiency fractures, where bone architecture is weakened, leading to reduced bone quality.<sup>1-3</sup> In both cases, fractures can occur with

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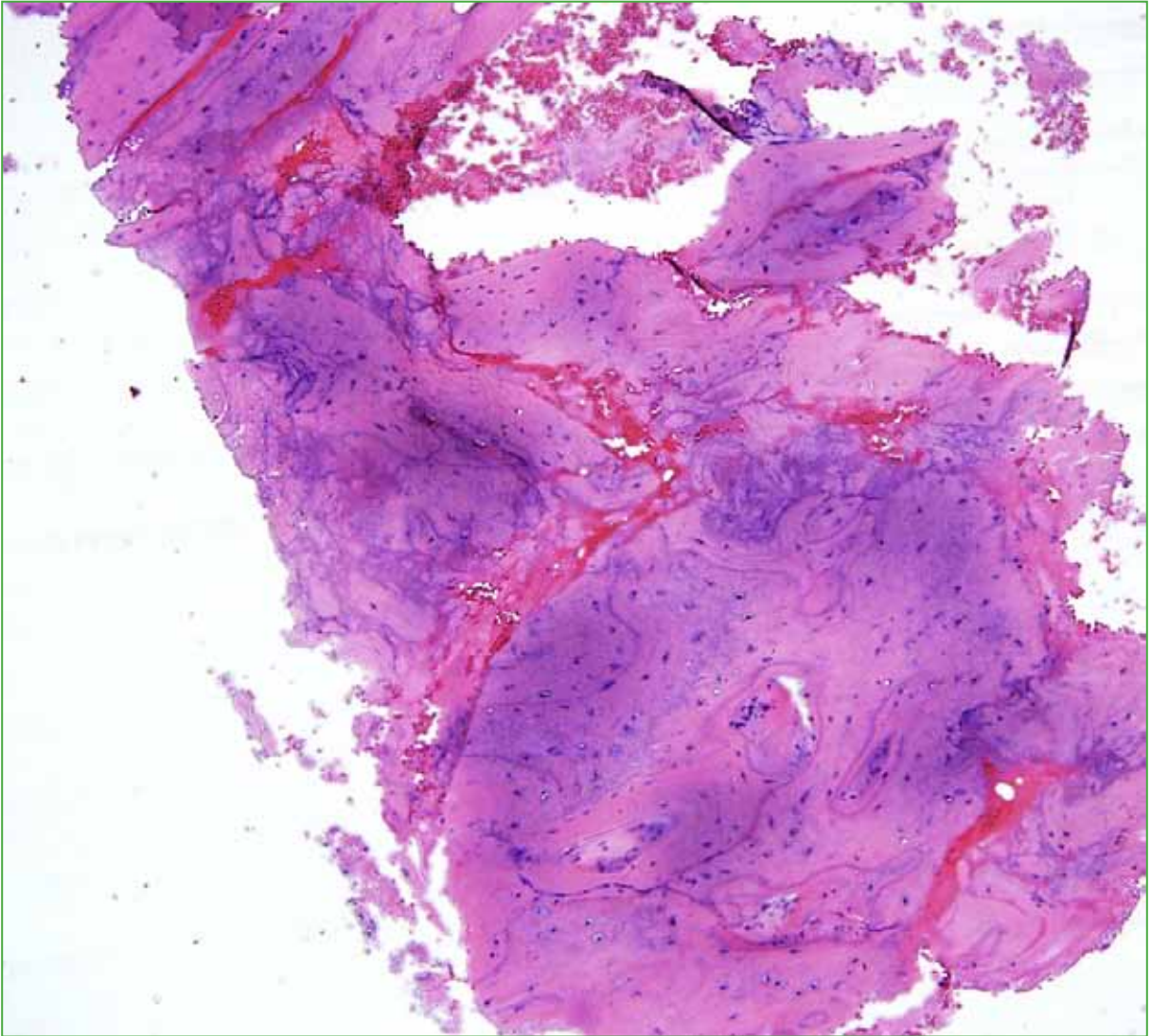
physiological loads or very low-energy trauma. The classic triad of a stress fracture includes a new activity or a modification in activity, increased intensity, and repetitive loading, leading to symptom onset—criteria that our patient meets.<sup>3</sup>



**Figure 4.** Computed tomography of the left femur, axial view. The site of the bone biopsy is observed in the area of cortical thickening.

The location of stress fractures depends on the type of activity performed and specific anatomical characteristics. The femoral diaphysis is considered a low-risk site for stress fractures, and metabolic factors should always be evaluated (Table 1).<sup>1</sup>

Diagnosis is based on medical history, physical examination, and complementary studies, including imaging and, if necessary, histopathological analysis. Regarding medical history, it is essential to evaluate symptom duration, the type and intensity of physical activity, changes in activity frequency, pain characteristics, load tolerance, and the presence of nocturnal pain. Initially, pain occurs only during activity, but as the mechanical stress progresses, it may persist at rest and even become nocturnal. Additionally, metabolic, hormonal, and nutritional factors should be assessed, as they may influence bone metabolism.<sup>4</sup>



**Figure 5.** Pathological anatomy specimen. Bone tissue with signs of remodeling is observed, without atypical cells or cellular pleomorphisms. These signs are interpreted as fracture repair. Hematoxylin-eosin stain, magnification in x10 field.

Physical examination is often nonspecific. Patients typically present with localized tenderness and pain, with painful full-range or limited mobility. In chronic cases, there may be localized swelling, increased temperature, or a palpable mass.

Treatment includes reducing mechanical load, pain management, physiotherapy to optimize biomechanics, and evaluation of phosphocalcic metabolism. The time required for bone healing depends on fracture location and severity, requiring clinical and imaging follow-up.

To prevent recurrence, biomechanical and environmental factors should be optimized, including activity type and frequency, skeletal alignment, footwear, and nutritional habits.

**Table 1.** Typical locations of stress fracture sites by type of activity.

| Location of fracture site  | Type of activity           |
|----------------------------|----------------------------|
| Ulna/coronoid              | Throwing                   |
| Humerus-distal diaphysis   | Throwing                   |
| Ribs                       | Golf, carrying heavy items |
| Cervical spine             | <i>Lacrosse</i>            |
| Lumbar spine               | Lifting, ballet            |
| Obturator foramen          | Gymnastics, <i>bowling</i> |
| Neck and femoral diaphysis | Ballet, running            |
| Distal fibula              | Running                    |
| Proximal fibula            | Jumping                    |
| Tibia                      | Running                    |
| Calcaneus                  | Jumping                    |
| Navicular                  | Running                    |
| Metatarsal diaphyses       | Walking                    |

It is essential to distinguish stress fractures from neoplastic processes, often referred to as tumor-like lesions.<sup>5</sup> Although radiographs may show features suggestive of a stress fracture, detection is not always straightforward, and additional imaging may be required (Table 2). Necessary diagnostic imaging methods may include:

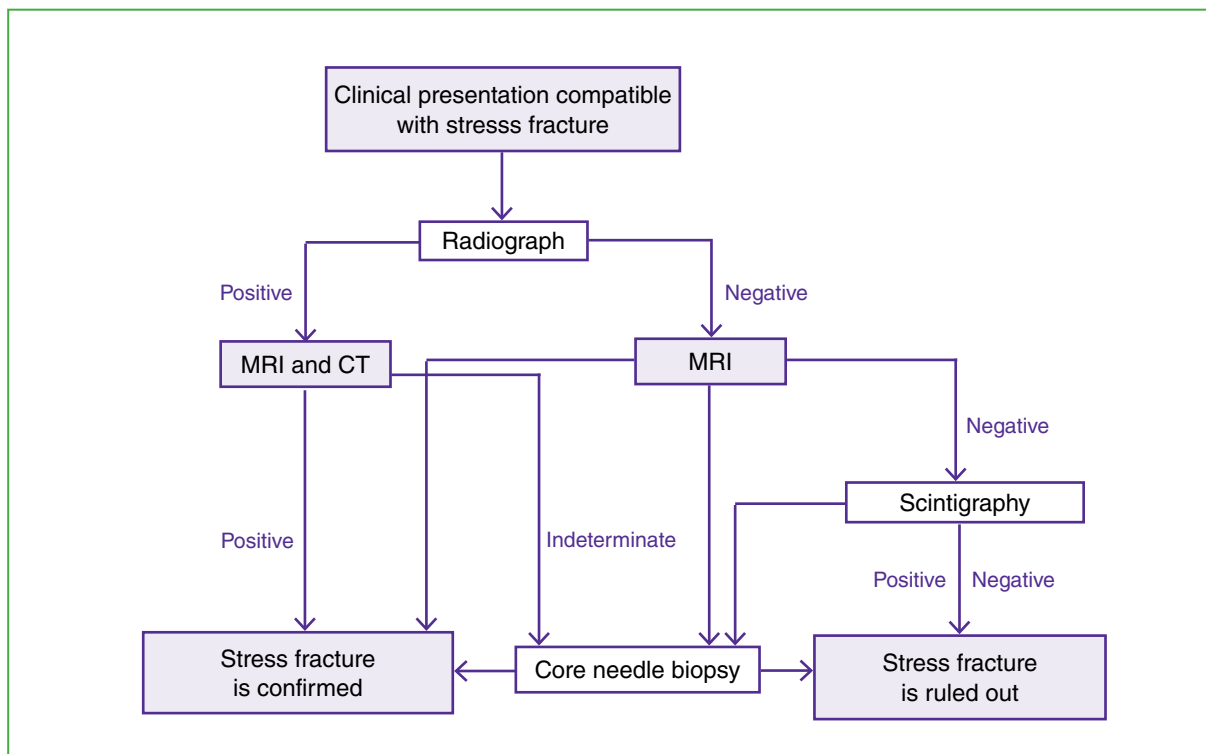
- Radiographs: The initial imaging modality. Early stress fractures may not be visible on radiographs, with changes appearing between the second and fourth week after symptom onset. Findings may include cortical thickening, benign periosteal reaction, a cortical radiolucent line, or medullary sclerosis during the repair process.
- CT: Depending on the stage of the fracture, CT can show focal cortical thickening, benign periosteal reaction, and a hypodense line perpendicular to the cortical axis, surrounded by reparative bone tissue, in up to 79% of cases.<sup>6</sup> Soft tissue edema may also be seen. Unlike tumor lesions, stress fractures do not present with endosteal thinning, medullary involvement, pathological calcifications, permeative or punched-out cortical destruction, soft tissue involvement, malignant periosteal reactions (e.g., sunburst pattern, Codman's triangle, or onion skin periosteal reaction), or hypodense cortical lesions like *nidus*. Contrast-enhanced CT can highlight hyperemic tissue, although it is not routinely used.
- MRI: The most sensitive and specific imaging modality for diagnosing stress fractures. In early stages, MRI reveals bone marrow and periosteal edema, often with adjacent soft tissue edema. T2 or STIR sequences typically show an increased medullary signal, which is nonspecific. T1-weighted sequences provide better definition, distinguishing circumscribed hypointensity in neoplastic lesions (due to tumor components) from the diffuse hypointensity seen in stress fractures (due to edema). Contrast enhancement can help differentiate neoplastic lesions by outlining the inflammatory component and highlighting the tumor mass. As the fracture progresses, cortical thickening develops, and in advanced cases, a hypointense fracture line may be visible on T1 or T2 sequences, although bony changes are best visualized on CT. Bone marrow edema may persist for up to six months after symptom resolution due to ongoing bone remodeling.

- Bone scintigraphy: Detects areas of increased metabolic activity. It is highly sensitive but nonspecific. Stress fractures typically exhibit linear or localized hyperuptake, whereas neoplastic lesions show diffuse hyperuptake, but these patterns are not specific. Bone scintigraphy has been largely replaced by MRI.
- Positron Emission Tomography (PET-CT): Combines metabolic activity detection with improved anatomical precision compared to scintigraphy, though it is more costly and involves higher radiation exposure. Stress fractures tend to show linear or localized uptake, while neoplastic processes display diffuse uptake, although these patterns are not specific.

**Table 2.** Characteristics of stress fractures and neoplastic processes in imaging studies.

| Imaging study                | Stress fracture  | Tumor lesion  |
|------------------------------|--|---|
| Radiography                  | Cortical thickening<br>Benign periosteal reaction<br>Cortical radiolucent line<br>Spinal cord sclerosis (reparative sign)  | Endostic irregularity<br>Malignant periosteal reaction<br>Radiopaque “shadow” in soft tissues<br>Alteration of medullary morphology   |
| Computed tomography          | Cortical thickening<br>Benign periosteal reaction (formation of bony callus)<br>Cortical hypodense line (fracture line)  | Endosteal scalloping<br>Malignant periosteal reaction<br>Destructive cortical pattern<br>Soft tissue and spinal cord involvement<br>Calcification   |
| Magnetic resonance imaging   | Medullary, periosteal and soft tissue edema.<br>Poorly defined medullary hypointensity in T1 sequence<br>Cortical thickening<br>Hypointense line in T1 sequence (fracture line). | Medullary, periosteal and soft tissue edema.<br>Well-defined medullary hypointensity in T1 sequence (tumor component).<br>Extension to soft tissues<br>Signal heterogeneity due to liquid, hemorrhagic, necrotic or solid component |
| Bone scintigraphy            | Focal or linear hyperuptake  | Diffuse hyperuptake   |
| Positron emission tomography | Focal or linear hyperuptake  | Diffuse hyperuptake   |

Awareness of stress fractures and their clinical and imaging characteristics is essential for accurate diagnosis. As a diagnostic approach, we propose performing a detailed medical history and physical examination. If a stress fracture is suspected, we obtain a radiograph of the entire affected bone. If radiographic findings suggest a stress fracture, we proceed with CT and MRI. If radiographs are inconclusive, we request an MRI. If uncertainty remains after imaging, we perform a core needle biopsy to assess for atypical cells. If clinical suspicion persists despite negative imaging, we consider bone scintigraphy to assess hyperuptake and, if it is negative, we rule out a stress fracture. If it is positive, we proceed with a core needle biopsy for definitive diagnosis (Figure 6)



**Figure 6.** Diagnostic algorithm for suspected stress fracture. MRI = magnetic resonance imaging; CT = computed tomography

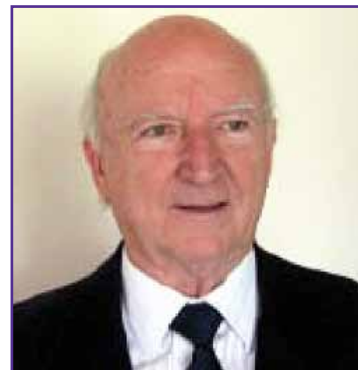
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# Dr. Jorge Abel Groiso



**D**r. Jorge Abel Groiso walked this mortal path as an enlightened man, as all who possess such a gift do—slowly but surely.

He trained as a Pediatric Orthopedist and Traumatologist at the Division of Orthopaedic Surgery of the Children’s Hospital of Philadelphia (USA).

Upon returning to Buenos Aires, he joined the Children’s Hospital “Ricardo Gutiérrez,” where, alongside other doctors, he helped establish the hospital’s first Pediatric Orthopedics and Traumatology Department.

Over the years, he earned a Doctor of Medicine degree, taught at the School of Medicine at the University of Buenos Aires and continued his work at the Children’s Hospital “Ricardo Gutiérrez”, culminating in his appointment as Chief of the Division of Orthopedics and Traumatology.

In 1986, he founded the Orthopedics and Traumatology Service at the National Pediatric Hospital “Prof. Dr. Juan P. Garrahan,” where he served as Chief of Service.

Additionally, he was President of the Argentine Society of Pediatric Orthopedics and Traumatology, a Full Member of the Argentine Association of Orthopedics and Traumatology—where he was honored as a Master Surgeon—a Member of the Argentine Society of Pediatrics, as well as a Member of the Pediatric Orthopaedic Society of North America and the American Academy of Orthopaedic Surgeons.

Yet, beyond his professional achievements, it is essential to remember the man himself.

In his absence, I find it important to write not only about his career but also about his remarkable personality. Dr. Jorge Groiso was an inventor at heart, perhaps one of his greatest virtues. He transformed everything he touched into a creation. Without being forceful, he was steadfast and determined. He calculated every step with precision, and that, undoubtedly, made him an enlightened man.

People like him move through life by doing. He led highly complex pediatric orthopedics and traumatology teams and developed both internal and external fixation instruments, along with other orthopedic systems that remain in common use today. This was his passionate way of life.

Those of us who had the privilege of working closely with him saw the simplicity with which he achieved his goals, turning ideas into real accomplishments.

His boundless energy and intense personality were supported by his wife, Viviana Diner, and their beautiful family—a sine qua non condition for a creator.

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Albert Einstein, who left nothing unnoticed, once said that the greatest sign of intelligence is imagination. Dr. Jorge Groiso belonged to that realm of intelligence.

Those of us who will always miss him will remember his generosity, his resilience in the face of adversity, and the deep, unwavering friendship he offered.

Now, it is up to us to ensure that he is never forgotten.

*Dr. Horacio F. Miscione  
Former Chief of Service and Consultant of the Orthopedics and Traumatology Service,  
Hospital "Prof. Dr. Juan P. Garrahan".*