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Review

Usefulness of Ultrasonography and Radiography in the Evaluation of Distal Forearm Fractures in Children: A Narrative Review

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ABSTRACT

Pediatric fractures, especially distal forearm fractures, represent a significant global medical concern, affecting up to 50% of pediatric fracture cases. This narrative review aims to compare diagnostic modalities to determine which offers higher accuracy, minimizes radiation exposure, and is adaptable to diverse clinical settings. In the choice between ultrasound and X-ray for diagnosing distal forearm fractures in children, each modality has its merits. X-ray provides accuracy and value in well-equipped facilities, while ultrasound, being radiation-free, is effective in resource-limited areas and is essential for pediatric patients to avoid radiation exposure. Professional training and continual updates are crucial. Moreover, it underscores that alongside diagnostic imaging, comprehensive clinical assessment remains pivotal for making informed medical decisions. The choice of method should consider individual case factors and prioritize patient safety.

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Utilidad de la ecografía y la radiografía en la evaluación de las fracturas distales del antebrazo en niños: una revisión narrativa

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RESUMEN

Las fracturas pediátricas, especialmente las fracturas distales del antebrazo, representan una importante preocupación médica mundial y afectan hasta el 50% de los casos de fracturas pediátricas. Esta revisión narrativa tiene como objetivo comparar modalidades de diagnóstico para determinar cuál ofrece mayor precisión, minimiza la exposición a la radiación y es adaptable a diversos entornos clínicos. A la hora de elegir entre ecografía y rayos X para diagnosticar fracturas distales del antebrazo en niños, cada modalidad tiene sus ventajas. Los rayos X proporcionan precisión y valor en instalaciones bien equipadas, mientras que el ultrasonido, al no tener radiación, es eficaz en áreas con recursos limitados y es esencial para que los pacientes pediátricos eviten la exposición a la radiación. La formación profesional y la actualización continua son cruciales. Además, subraya que, junto con el diagnóstico por imágenes, la evaluación clínica integral sigue siendo fundamental para tomar decisiones médicas informadas. La elección del método debe considerar factores de cada caso individual y priorizar la seguridad del paciente.

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1. INTRODUCTION

Currently, pediatric fractures are a significant medical concern due to their high prevalence. Globally, fractures account for one-third of pediatric trauma visits, with an incidence of 20 per 1,000 children. In the United States, around 12 percent of the 10 million annual pediatric emergency department visits are due to these injuries [1].

The most affected anatomical sites in pediatric fractures are the upper limbs (66%) and lower limbs (21%). Males are more frequently affected, with a 1.5 times higher risk than females, possibly due to differences in high-risk activities. For developing countries, this trend remains consistent, with 58 to 72% of fractures occurring in boys.

Among upper limb fractures, the forearm, particularly the distal third, accounts for a significant portion, making up 75% of pediatric forearm fractures and 20 to 25% of all pediatric fractures. These fractures primarily involve the distal radioulnar and radiocarpal joints, complex structures comprising bone, muscles, ligaments, and tendons that provide joint stability and function. Extraarticular fractures are prevalent in the pediatric population [2].

The most common injury mechanism in this population is a fall onto an outstretched hand, placing maximum tension on the joint and resulting in distal forearm fractures [3, 4].

Fractures occurring in the distal third of the forearm in children present a notable clinical challenge and represent a noteworthy focus in the field of pediatric traumatology. Consequently, it becomes imperative to determine the most effective diagnostic instrument for the evaluation of these injuries. While the prevailing choice remains conventional X-rays, ultrasound has emerged as a valuable alternative, particularly for pediatric patients confronted with fractures in this anatomical region. Ultrasound, in addition to its status as a non-invasive technique, is distinguished by its avoidance of radiation exposure, rendering it significantly relevant for the pediatric demographic. Moreover, its ease of accessibility deems it suitable for application across various clinical contexts. The objective of this investigation is to conduct a comparative analysis of the diagnostic efficacy between ultrasound and X-ray in the evaluation of distal forearm fractures in children. This analysis considers critical factors encompassing diagnostic precision, the mitigation of radiation exposure, and its adaptability to a wide spectrum of clinical scenarios [5].

2. METHODS

To collect the information for this review, searches were performed in Scopus, Web of Science, PubMed, and

MEDLINE. Articles published worldwide between 2010 and 2022 were included.

3. EPIDEMIOLOGY

Distal forearm fractures are a common and prevalent injury in the pediatric population, accounting for 40 to 50 percent of all pediatric fractures and about 74 percent of pediatric upper limb fractures [6, 7]. Several studies have concluded that the behavior of distal forearm fractures in children is on an increasing trend, despite the increase in global attention to the care and safety of children [7-10].

The overall incidence of distal forearm fractures in children is 738.1 children per 100,000 inhabitants per year. When discriminating by sex, it is observed that in boys there is a higher incidence, reaching 800.2 children per 100,000 inhabitants per year, on the other hand, women represented a lower incidence with 672.4 girls per 100,000 inhabitants per year [7].

Recent studies also explain the incidence by age of greatest presentation of these lesions in both sexes, the female incidence at the peak age of 10 years was 1,140.6 girls per 100,000 inhabitants per year and the male incidence at the age of 13 years was 1,228.1 per 100,000 inhabitants per year [7].

According to the types of distal forearm fracture in the pediatric population, the most frequent type was the radial greenstick fracture with an incidence of 48 percent, followed by the Salter Harris type I fracture with an incidence of 17% [7].

Although the types of fractures and the affected population are of great importance in this review, we are interested in knowing the traumatic mechanisms that lead to these events, in the literature it has been described that sports activities represent 39 percent of the causes of distal forearm fractures in children, followed by falls with 37 percent [8, 9, 11], these data represent great relevance when it comes to identifying the risks to which children are exposed according to their daily activities. The data presented according to the mechanism of injury are correlated with the information described on the periods of the year with the highest occurrence of distal forearm fractures in the pediatric population, with a higher frequency in the summer period (due to increased outdoor activities) and a lower frequency in the winter period [7, 11-13].

It has also been described that distal forearm fractures in the pediatric population have been associated with poor bone health and deficient mineralization leading to an increased risk of developing bone injury from minimal or low-energy trauma. This is associated with a low intake of fundamental components for bone well-being such as calcium and vitamin D, childhood obesity is also related to a higher risk of wrist fractures. While changes in bone mineralization can occur due to dietary deficiency as mentioned, this phenomenon can also occur thanks to pubertal growth. At this time of life, bone structures lengthen progressively and slowly compared to bone mineral status [13, 14].

4. ULTRASONOGRAPHY VERSUS RADIOGRAPHY IN THE EVALUATION OF DISTAL FOREARM FRACTURES

The choice between ultrasonography and radiography in the evaluation of distal forearm fractures in children is a topic of great relevance in the field of diagnostic medicine. In this context, it is essential to address critical aspects that affect clinical decision-making, particularly regarding diagnostic accuracy, radiation exposure, and applicability in various medical settings (Table 1). The purpose of this analysis is to gain a deeper understanding of these two imaging modalities and their respective advantages and disadvantages (Table 2). We will explore how each of these techniques addresses clinical challenges and provides solutions in the context of distal forearm fractures, thus contributing to informed decision-making in medical practice.

Table 1: Comparison of key aspects between ultrasonography and X-Ray in the evaluation of distal forearm fractures

Aspect	Ultrasonography	X-Ray
Diagnostic Accuracy	Sensitivity: 83% to 100%. Specificity: 73 to 91%.	Sensitivity 86%, Specificity 92% (for distal forearm fractures in the pediatric population).
Radiation Exposure	It does not involve ionizing radiation, making it safe in terms of exposure.	It involves exposure to ionizing radiation, with possible risks of adverse effects, especially in pediatric patients.
Applicability in Medical Settings	Affordable, portable, and accessible in most clinical settings.	Widely accepted in well-equipped medical settings, it requires radiography equipment and trained personnel.

4.1. DIAGNOSTIC ACCURACY

In current clinical practice, radiography is consolidated as the preferred initial diagnostic method for the detection of

distal forearm fractures in children. It offers a significant advantage by providing crisp and clear images of bone lesions, allowing for targeted and accurate assessment of fracture location, extent, and alignment. In addition, it makes it possible to identify bone fragments or displacements, which makes it a highly favored option in this context. Studies have supported its efficacy by showing a sensitivity of 86% and specificity of 92% in the detection of distal forearm fractures in the pediatric population. The radiography is characterized by a positive likelihood ratio (LR) of 6.86, indicating its ability to accurately diagnose bone lesions in the distal forearm, while a negative LR of 0.05 is advantageous in ruling out such lesions [15].

Table 2: Advantages and disadvantages between ultrasonography and X-Ray in the evaluation of distal forearm fractures

Aspect	Ultrasonography	X-Ray
Advantages	High sensitivity. It does not involve ionizing radiation. Portability and accessibility in various environments.	Acceptable sensitivity and specificity. It provides crisp and clear images of bone lesions. Widely accepted in well-equipped medical facilities.
Disadvantages	It may depend on the experience of the operator and the quality of the equipment. Less suitable for evaluating bone structures and hard tissues. Limitations in the evaluation of hard tissues and bones.	It involves exposure to ionizing radiation, with possible risks for pediatric patients. Risk of adverse effects from radiation exposure, especially in young patients. It requires specialized facilities and personnel.

On the other hand, ultrasonography has been gaining popularity in diagnosing distal forearm fractures in children. Unlike radiography, ultrasonography is presented as a non-invasive method that does not involve ionizing radiation. Its portability and accessibility position it as a major competitor in clinical settings in terms of availability. Studies have shown that ultrasonography, performed at the patient's bedside, offers remarkable reliability and accuracy in detecting bone lesions in the distal forearm, with sensitivity ranging from 83% to 100%, and specificity ranging from 73% to 91% [27–30]. The probability ratios (LR) of ultrasonography are favourable since a negative result has the ability to rule out the presence of fractures in the distal forearm (negative LR = 0.0 to 0.2). On the other hand, a positive result (positive LR = 3.2 to 9.1) is beneficial for the diagnosis of fractures in this area. In addition to assessing the location, extent, and alignment of bone fragments, ultrasonography provides additional information about the surrounding soft tissues, which can be crucial for detecting fracture-associated damage tags [16-20].

4.2. RADIATION EXPOSURE

In clinical practice, the constant use of tools involving radioactive materials or ionizing radiation is a reality. X-rays are part of this complex group of tools. It is essential to recognize that exposure to ionizing radiation carries significant consequences, such as structural and molecular damage to biological tissues, which can lead to inherited defects or the induction of neoplasms. The magnitude of these adverse effects will depend on the time of exposure and the dose received [21-23]. In Table 3, we can see recommended x-ray exposure limits for pediatric patients across different age groups [24, 25].

To quantify exposure to ionizing radiation, the concept of KERMA (Kinetic Energy Released in Materials) in incident air is used. This refers to the measurement of the energy released in the form of radiation into the air and is essential for determining the radiation dose that patients may receive during radiological examinations and radiotherapy treatments. For example, in 2020, European guidelines recommend an exposure of 0.08 mGy (milligrays) of Ki for chest x-rays, while for forearm x-rays an exposure range ranging from 0.001 to 0.02 mGy of Ki has been described [21].

Table 3: Recommended X-ray exposure limits for pediatric patients across different age groups

Age Group	Recommended X-Ray Exposure Limit (mSv)
Newborn	0.1 - 0.2
1 year	0.2 - 0.5
5 years	0.3 - 0.7
10 years	0.5 - 1.0
15 years	0.7 - 1.5

Although there are established reference values for exposure to ionizing radiation, these limits are not always adhered to in healthcare settings. Exposures of up to 0.195 mGy, almost twice the baseline, have been documented in neonates [26]. Studies have highlighted the importance of the age at which patients are exposed to ionizing radiation. The risk of developing sequelae increases as the patient is younger and has a smaller body size. This is explained by the fact that young patients tend to live longer, leading to a higher likelihood of experiencing defects throughout their lives. Radiation exposure can trigger genomic instabilities that can manifest at some point in life or even be passed on to the next generation. Some authors have evaluated the cancer risk associated with X-ray radiation exposure in the pediatric population, and an odds ratio (OR) of 1.5 has been documented for the development of lymphoblastic leukemia with one or two diagnostic tests involving ionizing radiation. For three or more exams, the OR increases to 2.0. Canadian

studies have found similar behavior, with an OR of 1.78 for the development of leukemia from exposures to ionizing radiation on two or more occasions [27].

Despite the exposure to ionizing radiation associated with the use of radiography as a diagnostic imaging technique, the benefits of this methodology outweigh the risks. However, there are diagnostic approaches that do not involve radiation, such as ultrasonography, a very useful tool for ruling out or confirming distal forearm fractures in the pediatric population.

4.3. APPLICABILITY IN THE ENVIRONMENT

When it comes to the diagnosis of distal forearm fractures, the choice between radiography and ultrasonography depends on the clinical context, the specific needs of the patient and, above all, the environment in which they are located.

As previously mentioned, radiography is the preferred diagnostic technique at first to evaluate bone lesions in the distal forearm. This methodology is highly effective in well-equipped medical environments, where X-ray equipment and trained professionals are available to operate on them and interpret the images. In such cases, radiography is widely applicable and efficient. However, in situations where resources are limited, such as in low-income countries or rural areas, the use of radiography becomes a significant challenge. In this context, ultrasonography emerges as a more attractive option due to its accessibility, lower costs, and ease of transportation [28].

It is important to note that ultrasonography is widely available as a diagnostic tool across various settings. Its portability facilitates on-the-spot imaging, thereby reducing the necessity of transporting patients to radiology departments, particularly beneficial in emergencies or with immobile patients. Furthermore, it proves beneficial in remote or field settings with limited access to traditional imaging facilities, such as in disaster situations, military deployments, or rural healthcare contexts [17].

The versatility of ultrasonography is accompanied by several distinct advantages. In addition to reducing radiation exposure, ultrasonography provides more detailed images at a lower cost compared to conventional X-rays. In addition, it is a simple and easy-to-learn method, allowing doctors without specialized training in osteosonography to use it successfully, and its results are highly reproducible. An additional aspect to highlight is the constant availability of ultrasonography training opportunities in a variety of settings, which contributes to the skill development of professionals over time [17].

Furthermore, the significance of integrating ultrasound education into the undergraduate medical curriculum for enhancing anatomical comprehension, physical examination skills, and diagnostic proficiency has been indicated by recent studies. Nevertheless, this matter is presently subject to debate within numerous scientific societies [29, 30].

5. CONCLUSIONS

The choice between radiography and ultrasonography for the evaluation of distal forearm fractures in children should be an informed and contextualized decision, considering diagnostic accuracy, radiation exposure, and the availability of resources in the clinical setting. Each modality has its advantages and disadvantages, and its selection will depend on individual factors in each case.

- Contextualized Choice: The decision about which method to use should be based on the specific clinical context. In well-equipped settings with access to radiography and trained personnel, radiography remains a valuable option for evaluating distal forearm fractures. However, in places with limited resources, ultrasonography is an effective alternative.
- Consider Patient Age: In pediatric patients and especially those younger, where radiation exposure could have a greater impact throughout their lives, ultrasonography should be prioritized whenever possible, as it avoids exposure to ionizing radiation.
- Education and Training: Health professionals should receive adequate training in both modalities to ensure accurate interpretation of results. Ultrasonography, in particular, is a technique that can be performed by doctors without specialized training in osteosonography, which expands its applicability.
- Follow-up and Update: It is important for medical professionals to be aware of the latest research and guidelines in diagnosing distal forearm fractures in children. Recommendations may evolve with new findings and advances in medical technology.
- Comprehensive Clinical Evaluation: In addition to diagnostic imaging, comprehensive clinical evaluation, which includes medical history and physical examination, remains crucial in the diagnosis of fractures. The results of imaging tests should be interpreted in conjunction with the clinical findings to make informed medical decisions.

6. CONFLICT OF INTERESTS

The authors have no conflict of interest to declare. The authors declared that this study has received no financial support.

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