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Fractures in Children: Practical Approach to Reduce Missed Diagnosis

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Abstract

Fractures in children are common due to increased physical activity and their regular engagement in sports. Pediatric fractures can be subtle and easily missed on plain radiographs. This can be caused by many factors including those related to patients, technical, clinical, and radiological. The immature skeleton has a few unique features that can add to increased incidence of missed non-displaced fractures, however, some of these structural characteristics play a positive favourable role in the healing process of these fractures. Missed fractures in pediatrics can lead to long-term deformities or physical disabilities. In this mini-review article, we go through some of the factors contributing to missed diagnosis, go through few examples of subtle fractures in upper limb and the best technique to decrease the incidence of missed diagnosis.

Keywords: Fracture; Pediatric; Buckling; Greenstick; Radiology; X-ray

Introduction

The incidence of acute injury is up to 90% of orthopaedic emergency patients. It forms almost 85% of skeletal injuries in pediatrics [1-3]. In daily practice in the emergency department, it is common to miss the diagnosis of a subtle fracture in children, which can cause delayed treatment, and depending on the fracture's location, malfunction or serious disabilities can occur [4,5]. Up to 24% of harm-causing missed diagnosis in emergency departments are caused by misinterpretation of fractures [6,7]. Diagnosing a fracture in children has some challenges related to the presence of the growth or physeal plate, anatomical skeletal variation and the variation in bones, ligaments, and tendons structural anatomy in children. Hereby we will discuss these anatomical variations, technical factors and the radiological reasons for missing fractures in children.

Bones and tendons anatomical structural variations

Immature skeletons in children have specific anatomical variations from adults that predispose children to specific fracture types [8]. These unique features include the more porous cortical bones, the thickened strong periosteum, the strong tendons attachment to apophyses, and the open cartilaginous physeal plates. The cortical bones are more porous than adults' bones due to wider Haversian canals in the compact bones in children [9], which results in increased elasticity of pediatric bones and predispose to plastic fractures in children. The periosteum's increased strength adds to the elasticity of bones. The thick strong periosteum prevents the cortical break in torus, buckling, fractures and green stick fractures, (Figure 1). Therefore, prevents the bony fragments displacement that can obscure the non-displaced fracture on a plain x-ray. However, both features of increased porosity and thick periosteum help in stabilizing the fracture by reducing fragments' displacement, thus, promote a faster healing process and better re-modelling in children's fractures [10]. Tendons in growing skeleton attach strongly to the periosteum, which results in frequent avulsion fractures in sports injuries. The apophyseal injury prevalence is higher in the immature bones of children playing sports due to the anatomically weaker apophysis compared to the attached tendon of muscles [11]. Lastly, the characteristic cartilaginous physeal plates are considered a weak point in immature long bones, if injured, can lead to growth deformity or to a premature growth plates' closure. However, they enhance the bone re-modelling during the healing process. Salter-Harris classification categorizes fractures around the physeal plate as per the adjacent bony parts or physis involvement [10,12].

Technical clinical and radiographic factors

The injured child can present to the emergency department with no obvious limb deformity or localized swelling. The pain may radiate to areas other than the injured bone. This can affect the

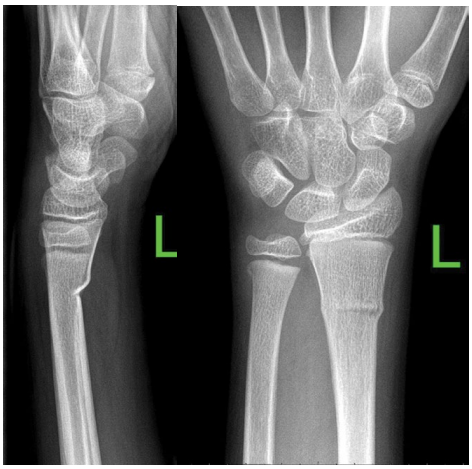

Figure 1: AP and lateral views of the left wrist and distal forearm, buckling fracture of distal radial metaphysis and focal cortical step off at distal ulnar metaphysis.

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radiographs requested by the emergency physicians. As a result, if the thumb is injured, it is common to miss the thumb fracture on a hand anterioposterior, AP, and oblique views without dedicated thumb views, (Figures 2 and 3). Similarly, the distal radial subtle fracture can be missed on the two views forearm x-ray because it is not in the focus of the radiation beam (Figure 4).

Some of the factors to obscure the fracture is the initial treatment at the emergency department, including dressing or a splint application as they reduce the fine details visibility of small bones in hands and feet, leading to missing fractures in the inherently small and osteopenic bones (Figure 5). Proper positioning of the imaged part of the body helps to align bones in an orthogonal position, which is crucial to diagnose a fracture. Therefore, when the injured children are in pain and cannot position their extremities properly, the radiological assessment can miss an occult fracture. The lateral view of elbows is a common example, it shows the displacement of fat planes that suggests joint effusion or hemarthrosis in a trauma setting, and the drawn lines through the intact distal humerus should normally align with the intact proximal radius and ulna. When the position in a lateral view of elbow is sub-optimal, the radiologist cannot assess the elevated anterior fat pad or positive posterior fat pad, the indirect signs of an occult fracture of an elbow bone (Figures 6 and 7).

One of the essential orthopedic assessment rules is to image each body part or limb in two perpendicular-orthogonal views, and to include the proximal and distal joints. Occasionally, the images of the contralateral limb provide a good comparative image, especially in elbows, (Figure 7c, d). If clinical suspicion is high despite negative radiologic reports, doing a follow-up imaging can increase fracture

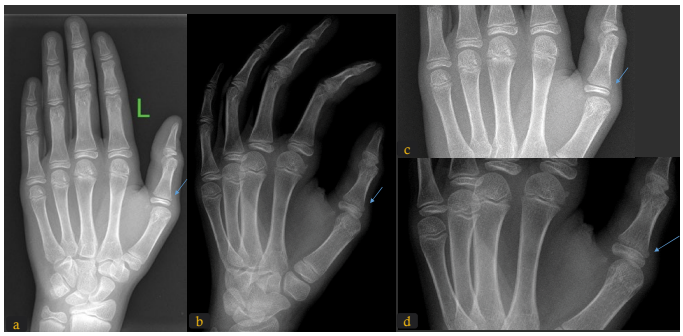

Figure 2: AP and Oblique view of left hand, the fracture is manifested as a cortical step off on the oblique view, and very faint vertical fracture line through the proximal metaphysis of the proximal phalanx of the thumb. Mild soft tissue swelling at the 1st MPJ. Salter II fracture, through the metaphysis, reaching the physeal plate, not going through the epiphysis.

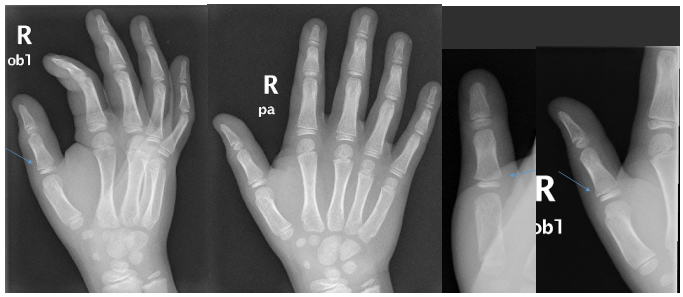

Figure 3: AP and oblique views of right hand, the fracture at the proximal metaphysis of proximal phalanx of right thumb is more conspicuous on dedicated thumb views but seen very subtle on hand views.

Figure 4: AP and lateral views of the left forearm that doesn't show the fracture at distal radial metaphysis due to overlap with distal ulna on lateral view. The center of radiation in forearm view did not help to image the fracture unlike the wrist lateral view, which showed the cortical abrupt change denoting the fracture site.

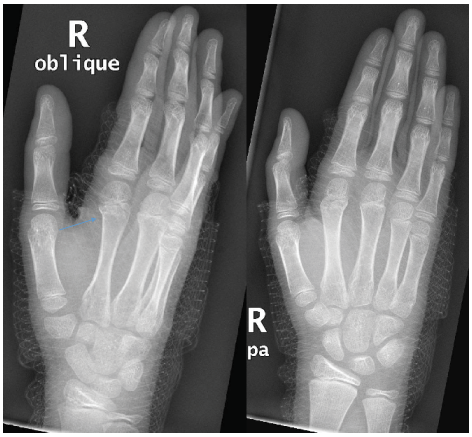

Figure 5: AP and Oblique views of the right hand after application of dressing in ED, which may obscure the non-displaced fracture at distal metaphysis 2nd MTC (arrow).

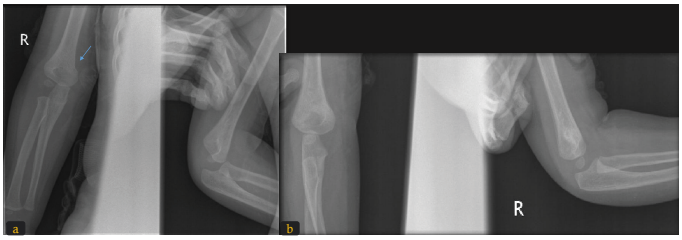

Figure 6: AP and lateral view of right elbow (**a**). The patient at presentation to ED with acute pain, lateral view is suboptimal due to poor positioning. The fracture is seen on the AP view as abrupt cortical step off (arrow). 2-week follow up AP and lateral elbow x-ray (**b**) shows the periosteal reaction at the fracture site.

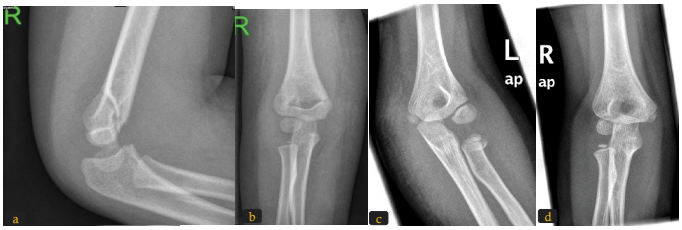

Figure 7: AP and lateral views of right elbow in patient A (**a, b**) show supracondylar fracture, notice the positive posterior fat pad indicative of hemarthrosis. AP views of both elbows of patient B (**c, d**). Fracture of proximal metaphysis left radial head, notice the soft tissue swelling of left elbow. Since the epiphyseal centers in the elbow are unique and appear in specific chronological sequence, CRITOE, the contralateral elbow is frequently imaged for comparison.

visibility due to disuse-osteopenia and hyperemia following a fracture [8,13].

Radiological reporting factors

Reporting fractures in pediatrics can be confusing for the non-radiologists physicians or residents in the emergency department, the junior radiologists or the radiologists in training due to the unique different morphology of the immature skeleton including the presence of physis, the anatomical variations related to epiphyseal centers, and the radiologic features of some specific unique fractures in children. Radiologists experienced in pediatric imaging are familiar with pediatric orthopedic images. However, many factors can affect the inter-observership variations including the workload, time or shift of radiologic reporting, and distraction while reporting [15]. Therefore, following a thorough systematic assessment of the extremity radiograph in children can decrease incidence of missed fractures in children. Here are some of the practical tips:

1. Following each bone individually is helpful when assessing hand or foot x-rays including passing the eye and even a finger on each part of the bones. This meticulous systematic assessment can help detect the focal buckling (Figure 1, 8), or a greenstick fracture, (Figure 9) or subtle cortical step-off injury, (Figures 10-12).

2. Comparing, when possible, side to side and finger or toe

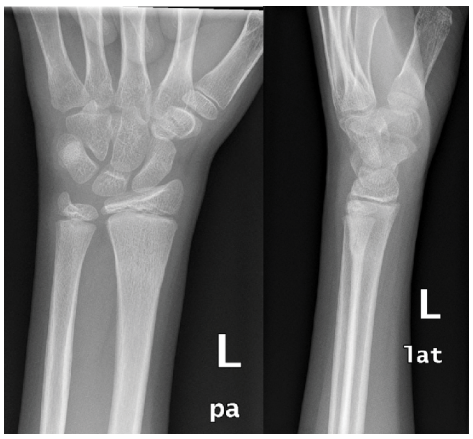

Figure 8: AP and lateral views of left wrist and distal forearm. The buckling fracture of distal radial metaphysis is well seen on the posterior cortex on the lateral view. It appears as subtle buckling on the AP view with subtle band of increased density at the fracture site.

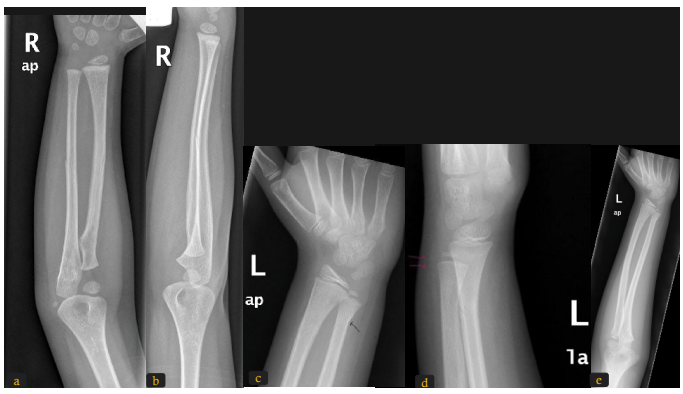

Figure 9: AP and lateral views of right forearm of patient A (**a, b**) shows the buckling fracture of mid shaft of radius and greenstick fracture of mid shaft ulna. AP and lateral views of the left wrist and AP of left forearm of patient B (**c-e**), buckling fracture of distal ulnar metaphysis (arrow).

Figure 10: AP and oblique view of the right hand after an acute injury. There is subtle disproportionate soft tissue swelling of the little finger. The fracture is seen on oblique view as a cortical step off at neck, distal metaphysis of 5th MTC bone. Fracture does not reach physeal plate.

Figure 11: AP and oblique view of the left hand, the fracture is very subtle as horizontal radiolucent line through the proximal metaphysis of the proximal phalanx of the middle finger. Notice the helping signs of the soft tissue swelling at the base of left ring finger which is disproportionate to other digits. Fracture is not reaching the physeal plate.

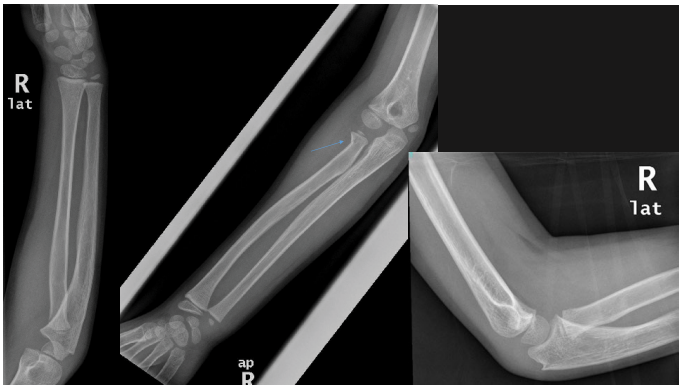

Figure 12: AP and lateral views of the right elbow and forearm, non-displaced oblique fracture through the proximal ulnar metaphysis is seen only on the AP view of the elbow.

of suspected fracture to others. The soft tissue assessment is a helpful tool to detect the site of injury. The injured digit or toe has generally associated soft tissue swelling, (Figure 11) [16]. Injury-associated soft tissue swelling manifests by displaced fat planes in the X-rays (Figure 9d).

3. Careful examination of the edges of the film, some of the foot fractures can be detected from an ankle X-ray, or a wrist bone fracture from a forearm X-ray.

4. Direct communication with the clinician can help solve the dilemma of an occult fracture and helps to request further radiographic views if the region of suspicion is masked or not imaged properly.

Conclusion

Occult fractures are frequently missed in adults and children. However, the unique immature skeletal structural anatomy and the normal variations contribute to the increased incidence of missing pediatric fractures. Cortical bone and periosteum characteristics may result in undisplaced and occult fractures, however, promote remodelling and healing process. Following a systematic radiologic assessment of bones combined with thorough knowledge of the unique fracture types in the pediatric population can decrease the incidence of missed fractures and prevents deformities or long-term malfunction.

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