

# Ultrasound in Emergency Medicine

## THE CHILD WITH A PAINFUL ARM: A POCUS SCREENING PROTOCOL TO IDENTIFY FRACTURE IN CHILDREN WITH UPPER EXTREMITY INJURY

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**Abstract—Background:** Young children present frequently to the emergency department with an immobile, painful arm. It is often difficult to discern a point of tenderness in a frightened, injured child. Common approaches included sending the child for x-ray studies of the extremity or empirically attempting reduction of radial head subluxation. We created a step-by-step point-of-care ultrasound screening protocol of the upper extremity to increase or decrease the probability of fracture before x-ray study or reduction. **Case Report:** We present the cases of 6 children younger than 4 years without a clear history of pulled elbow and without swelling or deformity on examination, for whom this protocol revealed fracture or lowered the probability of fracture, thereby increasing the safety of radial head reduction. **Why Should an Emergency Physician Be Aware of This?:** In most cases, identification of a single fracture on ultrasound allows for focused x-ray study on the area of fracture. Children with a normal ultrasound screen can undergo reduction of radial head subluxation safely. © 2020 Elsevier Inc. All rights reserved.

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### INTRODUCTION

Upper extremity fracture is common in the pediatric emergency department (PED). More than half of fractures (54.5%) in children of all ages involve the radius, followed by the supracondylar area in 18.3% and proximal humerus in 8.6% (1). Children often present with an

immobile arm, without swelling or point tenderness, and without either a clear story of a pull mechanism consistent with radial head subluxation (RHS) or a significant injury suggesting fracture. Traditionally, the physician will either attempt reduction of RHS, causing pain to children with fracture, or obtain an x-ray study of the extremity, resulting in radiation exposure in the context of RHS.

Point-of-care ultrasound (POCUS) is both sensitive and specific for forearm fractures, supracondylar fractures, and proximal humerus fractures (2–5). POCUS is without ionizing radiation and, when done without applying pressure on the area of injury, is no more painful than radiography (6).

We developed a POCUS protocol that augments the physical examination. This protocol allows for reduction of RHS without worsening an existing fracture and can, conversely, identify an occult fracture, thereby allowing for focused radiography of the injury rather than radiography of the entire limb. We present a case series drawn from a convenience sample of children who benefitted from this protocol.

### METHODS

This study was conducted in a PED with an annual volume of 29,000 visits. We routinely use POCUS in the evaluation of children, including those with upper extremity injury. We collected a series of cases from



Figure 1. From left to right: lateral, dorsal, and palmar views of the distal radius.

January 2019 to January 2020 of children younger than 4 years who presented with an immobile arm, without a mechanism of injury consistent with pulled arm, without the ability to report a location of tenderness, without tenderness to a specific location, and who were evaluated prior to radiography with this POCUS protocol. Children older than 4 years were excluded, as it is easier to evaluate older children clinically, and children older than 4 years rarely present with RHS. For this series, we identified six cases that demonstrate the utility of this protocol.

The protocol for the ultrasound screen includes the following areas: distal radius (palmar, dorsal and coronal, all including epiphysis) (Figure 1), olecranon notch at the posterior distal humerus (transverse and sagittal, Figure 2), and humerus (anterior, posterior sagittal, and coronal, all including epiphysis) (Figure 3). In several children, we also captured an anterior sagittal view of the radial head and distal humerus to view the “hook sign” indicating RHS (Figure 4), although this view might not change management (7). A flowchart of the protocol can be found in Figure 5.

Images were captured by a pediatric emergency physician experienced in POCUS using a Zonare machine (Zo-

nare Medical Systems, Mountain View, CA) with a linear high-frequency probe on hip presets. Children with fracture on POCUS were sent for focused radiography. Children with a normal ultrasound screen underwent reduction of RHS.

CASES

Case 1

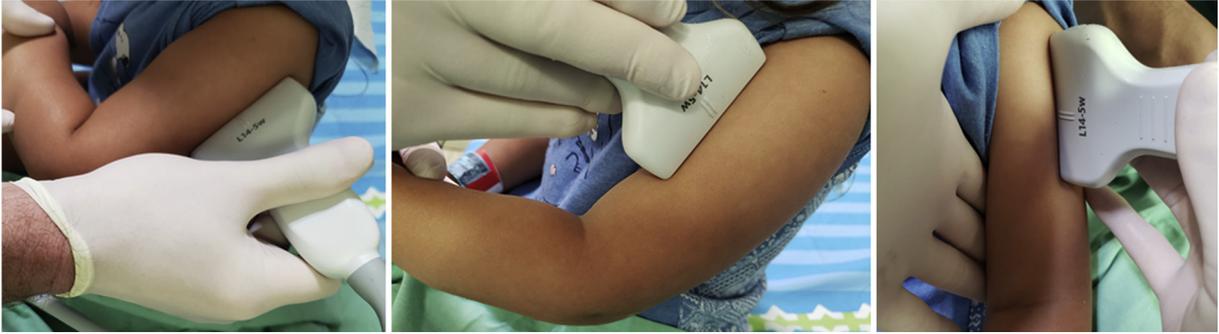
A 3-year-old boy fell on an outstretched arm. He reported pain over the entirety of the arm and cried out to palpation of all points proximal to the wrist. His arm was internally rotated and in slight flexion and he held the wrist with his uninjured hand. He had no obvious deformity or swelling. On POCUS, a nonangulated torus fracture was identified in the proximal humerus (Figure 6), which was confirmed on radiography (Figure 7).

Case 2

A 2-year-old girl fell from a slide at daycare. Mother noted that since returning home, the child had not been



Figure 2. From left to right, sagittal and transverse views of the olecranon notch at the distal humerus.



**Figure 3.** From left to right: posterior, anterior, and lateral views of the proximal humerus.

using her left arm. The child was apprehensive, but no clear point of tenderness was elicited. There was no swelling. POCUS was unremarkable and reduction of an RHS was successful.

#### Case 3

A 2.5-year-old boy was injured after his brother jumped on his arm. Exactly 1 year prior, he had RHS reduced in our PED, and his parents were concerned that he had RHS again. He held his arm in mild flexion, refused to use the arm, and seemed tender along the entire extremity. POCUS showed a torus fracture of the radius (Figure 8), which was confirmed on x-ray study (Figure 9).

#### Case 4

A 2.5-year-old girl was injured playing with her brother on a slide when the brother slid onto her arm. She then complained of pain to the arm and would not use the arm. The resident examination was significant for distal



**Figure 4.** The proper positioning of the linear transducer on the antecubital in the evaluation of radial head fracture or subluxation.

forearm tenderness. The arm had no swelling and attending examination elicited general apprehension and withdrawal of the arm when examining the forearm. POCUS showed a “hook sign” (Figure 10) and the child had successful reduction of RHS.

#### Case 5

An 18-month-old boy presented to the PED after “coming down the slide wrong.” Mother reported that he seemed to have pain along the entire arm. His examination was nonfocal and he had no swelling. POCUS showed a raised fat pad consistent with supracondylar fracture (Figure 11). The finding was confirmed on x-ray study (Figure 12).

#### Case 6

A 2.5-year-old girl with a history of two episodes of RHS returned from daycare with an immobile and painful left arm. Her sister reported that she had been pushed down by another child. Her left arm was without point tenderness. POCUS was unremarkable and RHS reduction was successful.

## DISCUSSION

Seventy percent of upper extremity fractures in children are in the distal radius, supracondylar area, and proximal humerus, and POCUS is sensitive and specific in all three (1). Breaks in the cortex at the distal radius and proximal humerus are common and found easily without manipulating the arm. We chose not to evaluate the ulna because isolated ulna fracture in this age group without swelling or deformity is rare, and the outcome of these fractures relies on associated fracture of the radius (8). Although radius fractures are highly associated with ulnar styloid fracture, they seldom require intervention and the ulnar styloid is not visible radiographically in those younger than 5 years (9).

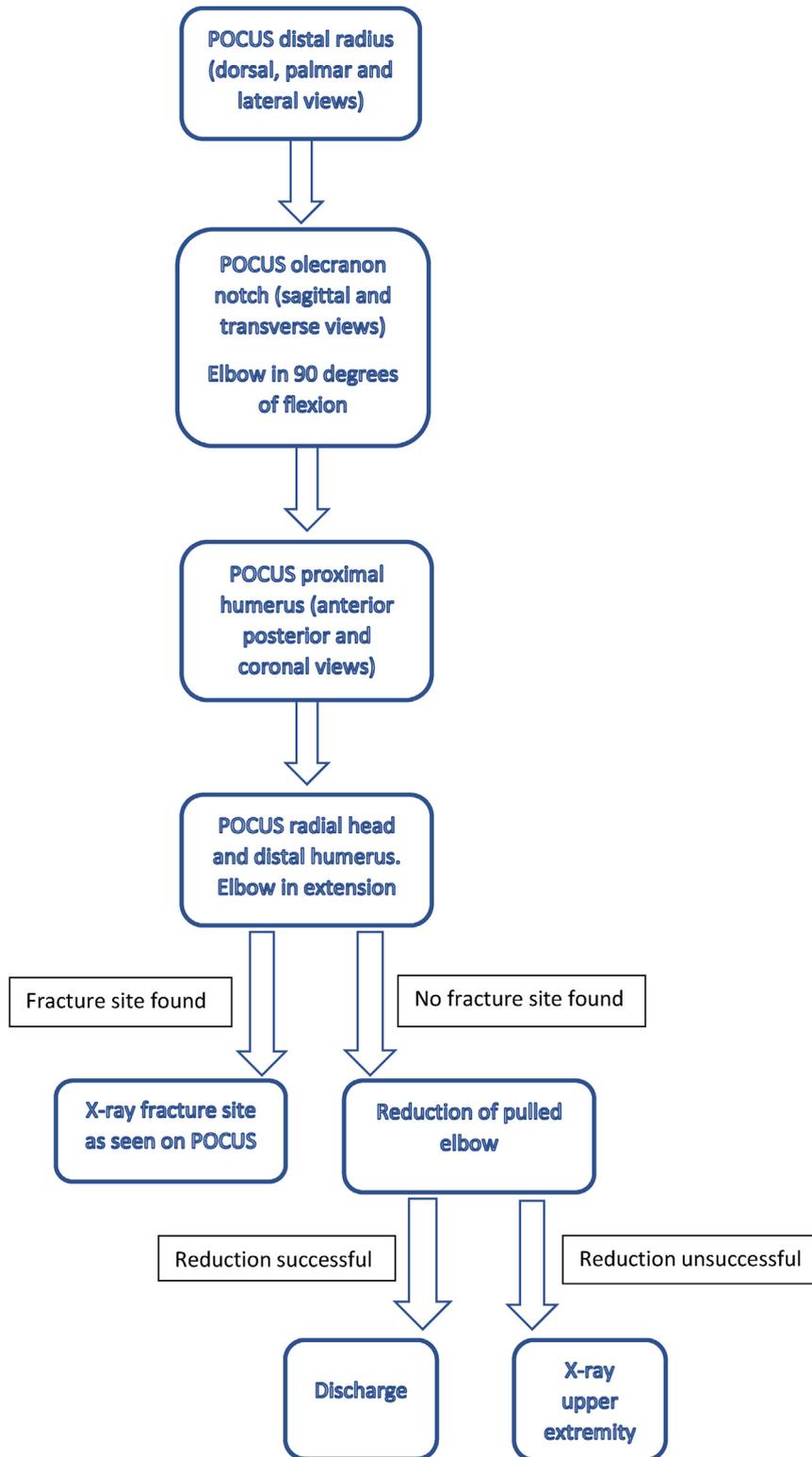
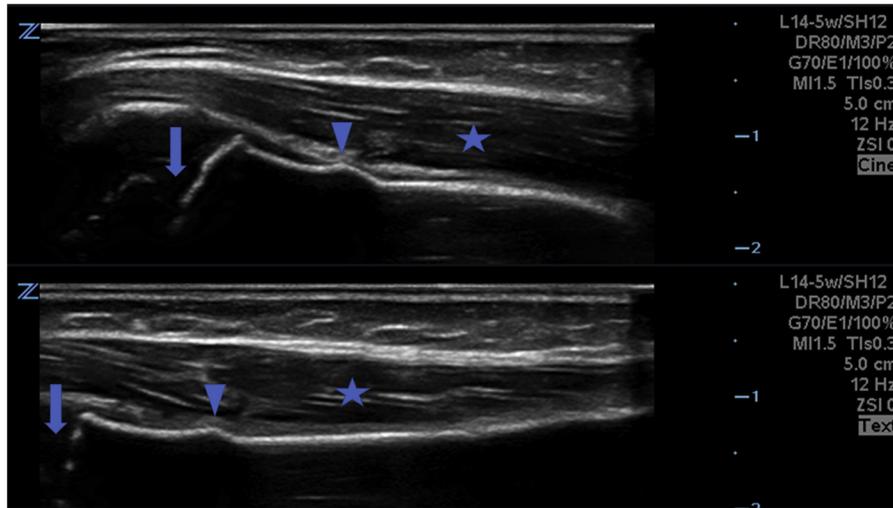


Figure 5. Flowchart describing our ultrasound protocol for the upper extremity. POCUS = point-of-care ultrasound.



**Figure 6. Top: Coronal view of proximal humerus. Bottom: Posterior sagittal view of the proximal humerus. Probe indicator is proximal. An arrow indicates the proximal physis, a triangle points to the fracture site, and a star sits in the triceps muscle.**

POCUS finding of a raised posterior fat pad has a sensitivity of 96% to 98% and specificity of 70% to 81% for elbow fracture (10,11). Although elevated posterior fat pad on POCUS is a possible finding in RHS, in our experience true lipohemarthrosis (separation of blood and fat layers within the posterior fat pad effusion), which increases specificity for supracondylar fracture, will not be seen in RHS (12). Nor, for that matter, will a spiral fracture of the humerus or Gartland 2/3 supracondylar fracture present in this age group without signs of more severe injury on examination. We hypothesized that a negative POCUS screen allows reduction of RHS with little concern for missed fracture.

Clavicle fractures are technically more difficult to evaluate using POCUS. Given that fracture apex is generally upward, bringing the fracture site closer to the skin, the POCUS examination of the clavicle can be painful, and clavicle fractures rarely require treatment.

A recent series of children with RHS reported that the mechanism was a fall, direct hit to the elbow, or rollover in 80% of cases. Half of the children underwent x-ray studies prior to attempted reduction (13). Frequently, children with an immobile arm are sent for x-ray studies of the entire extremity, and some suggest that this be routine (14). Although POCUS can guide the evaluation of RHS, this is the first description of a POCUS protocol that evaluates the entire extremity (7). Our series includes cases thought to be pulled elbow until POCUS revealed fracture, sparing the child a painful and potentially dangerous manipulation, and cases in which the mechanism is more consistent with fracture, but a normal POCUS allowed for safe reduction of RHS, thereby sparing the child unnecessary radiation and a longer PED stay. Even in children

with a history and examination consistent with trauma to the extremity, the protocol can minimize radiation exposure by identifying the fracture site (as in case 1). Although radiography is standard of care in our facility, further study may eliminate the need for radiography of torus fractures found on POCUS.

Imaging from the proximal humerus and out of the child's direct line of sight can cause unnecessary anxiety and we therefore recommend a protocol that examines the limb from distal to proximal. Imaging from distal to proximal is also correlated with the prevalence of fracture. Multiple fractures of the upper extremity are rare—a study of more than 50,000 children with distal forearm fracture found only 0.8% to have an elbow injury as well (15). The child can then be sent for radiographic confirmation of the fracture found on POCUS. If no fracture site is found on POCUS, the physician can proceed with reduction of a possible pulled elbow, which, if unsuccessful, can lead to radiography of the upper extremity.

Our conclusions are limited by the small number of cases presented and by the need for the physician to be proficient in long-bone POCUS. Ours was a single-center case series collected by physicians with 1 to 4 years of experience with long-bone POCUS. Proficiency in long-bone POCUS is within reach of most busy pediatric emergency physicians—in a meta-analysis of diagnostic accuracy in long-bone POCUS, 9 of 16 studies that included training time noted fewer than 2 hours of training time prior to study participation (16).

We present this protocol as a quick, comfortable, radiation-free way to better tailor further evaluation of the young child presenting with an immobile arm and no clear history of trauma or pulled elbow. In our

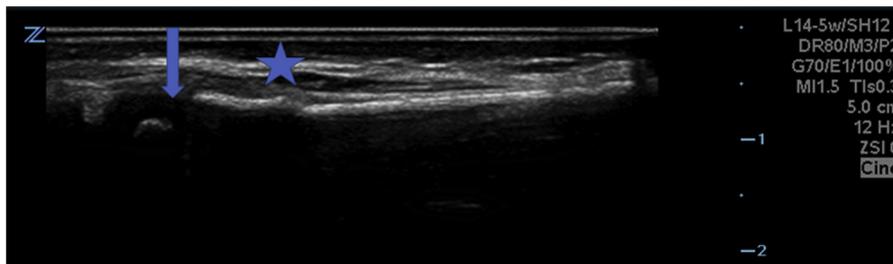


**Figure 7. Anteroposterior view, torus fracture of the proximal humerus, indicated by the arrow.**

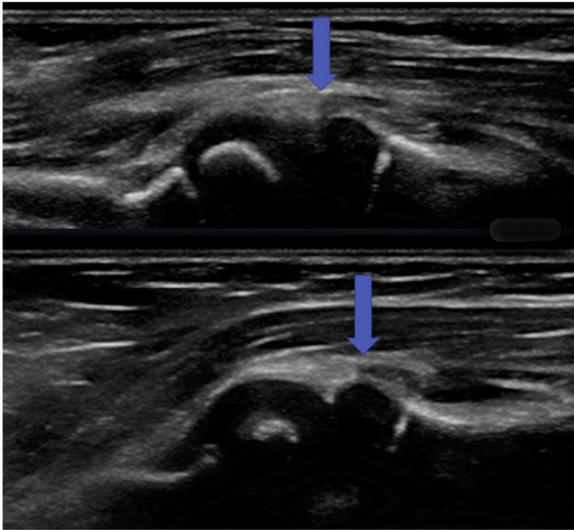


**Figure 9. Torus fracture of the distal radius, indicated by the arrow.**

experience, this protocol can be completed painlessly (cold gel can help) by an experienced practitioner in less than 1 min. Absence of fracture and unsuccessful reduction of RHS can be evaluated with radiography of the extremity and, if normal, should prompt investigation



**Figure 8. The probe indicator is at the distal end of the dorsal radius. An arrow indicates the distal physis, and a star indicates the fracture site.**



**Figure 10.** The distal humerus and capitellum sit at the left side of the screen and the radial head at the right side of the screen. The supinator muscle, pulled into the radiocapitellar joint, is marked with an arrow. The top image shows the supinator in radial head subluxation extending beyond the radial head and appearing as a “hook.” The bottom image, post reduction, shows that the supinator does not extend beyond the radial head.

for other etiologies of a painful, immobile arm, such as osteomyelitis, inflammatory processes, or hemoglobinopathy.

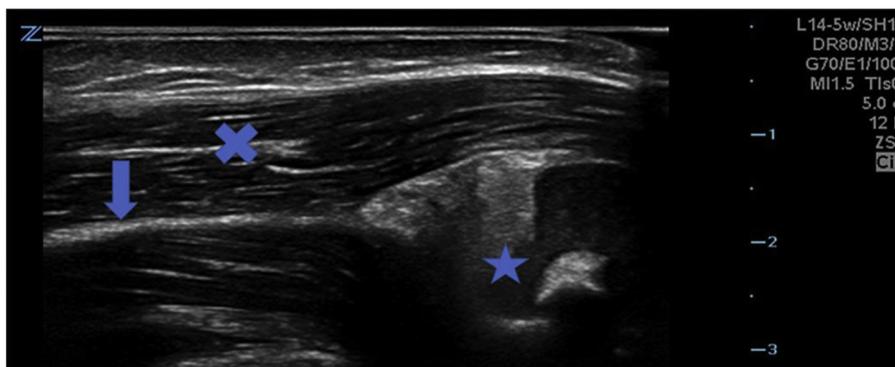
**WHY SHOULD AN EMERGENCY PHYSICIAN BE AWARE OF THIS?**

Young children who present with upper extremity pain often present without a clear history and without a localizing physical examination. Traditionally, these children are sent for x-ray studies of the entire extremity or an attempt is made to reduce RHS. A reduction might be at-



**Figure 12.** Lateral radiograph of the elbow, elevated fat pad indicated by arrow.

tempted on a fractured arm, and x-ray studies are often obtained for subluxations prior to reduction. Here, we present a brief, step-by-step POCUS screening protocol of the upper extremity. In most cases, identification of a single fracture on POCUS precludes existence of a second fracture in these children, and the x-ray study can be focused on the area of fracture. Children with a normal POCUS screen can undergo reduction of RHS safely. Prospective study is required to validate the sensitivity and specificity of this ultrasound screening protocol and to demonstrate the effect of this protocol on both the rate of x-ray studies in children with pulled elbow and the rate of attempted pulled elbow reduction in children found to have fracture.



**Figure 11.** Point-of-care ultrasound examination of the elbow, sagittal view. The sonographic “raised posterior fat pad sign” above the olecranon fossa is an elevation of the fat pad above the extension of the distal humeral line on sagittal view, and above the condyles on transverse view, and is associated with fracture of the elbow. The bony cortex of the distal humerus is indicated by an arrow, the triceps muscles by an X and the lipohemarthrosis in the olecranon fossa with a star.

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