Reduction of Radiography with Point-of-Care Elbow Ultrasonography for Elbow Trauma in Children

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Objectives To determine whether point-of-care elbow ultrasound (US), with history and physical examination, can decrease radiography for patients with elbow trauma. Secondary outcomes included evaluation of pediatric emergency department (PED) length of stay (LOS) and test performance characteristics.

Study design This was a prospective study of patients up to age 21 years with elbow trauma necessitating radiography. After clinical examination and before radiography, pediatric emergency physicians performed elbow ultrasonography of the posterior fat pad and determined whether radiography was required. All patients underwent elbow radiography and received clinical follow-up. Times for US and radiography were recorded.

Results A total of 100 patients with a mean age of 7.9 years were enrolled, 42 of whom had a fracture. In 23 patients, the physician determined that radiography could be eliminated. Elbow US combined with clinical suspicion for fracture had a sensitivity of 100% (95% CI, 92%-100%). Elbow US took a median of 3 minutes (IQR, 2-5 minutes), and completion and interpretation of elbow radiography took a median of 60 minutes (IQR, 43-84 minutes). The overall sensitivity of elbow US was 88% (95% CI, 75%-96%).

Conclusions Elbow US has a high sensitivity to rule out fracture and is best used in patients with a low clinical suspicion of fracture. The use of conventional radiography and PED LOS may be reduced in patients with a low clinical concern for fracture and normal elbow US. *(J Pediatr 2018;■■:■■-■■).*

Elbow trauma is a common reason for visits to the pediatric emergency department (PED). Although there are well-established imaging guidelines for some musculoskeletal injuries,[1-3] including those of the cervical spine, knee, and ankle, which decrease unnecessary radiographic studies, there are currently no guidelines for elbow injuries. Furthermore, the physical examination cannot reliably predict elbow pathology.[4] Therefore, information beyond to the history and physical examination is needed to reduce elbow radiographic studies in children.

The posterior fat pad (PFP) sign has been shown to be highly sensitive to rule out fracture.[5,6] An elevated PFP, as well as lipohemarthrosis, or blood within the joint capsule in the setting of trauma that displaces the PFP, can easily be identified on ultrasound (US). Previous studies of point-of-care US for elbow injuries have demonstrated high sensitivities of 97%-100% and negative predictive values of 0.95-1 for diagnosis of elbow fractures in children,[7-10] suggesting that a negative elbow US may reduce the need for radiography in children with elbow injuries. A reduction in radiography may result in decreased radiation exposure, as well as decreased PED length of stay (LOS).

The primary objective of this study was to determine whether point-of-care elbow US, in conjunction with history and physical examination, could decrease the use of standard radiography for patients in the PED with possible elbow fractures. Secondary outcomes included evaluation of PED LOS and test performance characteristics for US.

Methods

This prospective, observational study was performed from October 2014 to August 2016 in an urban PED. A convenience sample of patients with elbow injuries necessitating radiographic evaluation for fracture, presenting when a trained study physician was available, was eligible for enrollment. Written informed consent was obtained from each patient, parent, or guardian, and written assent was obtained from patients aged 7-17 years. The hospital's Institutional Review Board granted approval for this study.

LOS	Length of stay
LR–	Likelihood ratio of a negative test
LR+	Likelihood ratio of a positive test
NPV	Negative predictive value
PED	Pediatric emergency department
PFP	Posterior fat pad
PPV	Positive predictive value
US	Ultrasound

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Patients up to age 21 years with a possible elbow fracture necessitating radiographic evaluation, as determined by the attending pediatric emergency physician, were included in this study. Patients were excluded who arrived at the PED with a previously performed elbow radiograph or with a confirmed diagnosis of elbow fracture.

Before the start of the study, all enrolling pediatric emergency medicine attending and fellow physicians attended a 1-hour didactic and hands-on teaching session including live models. A teaching manual for reference, complete with images and instructions, was available in the PED for the duration of the study.

An attending physician evaluated all patients, and pain was managed as necessary. Before US, the treating physician completed a data collection sheet that included physical examination findings (eg, point tenderness, swelling, ecchymosis, deformity, decreased range of motion) and pretest clinical suspicion of fracture (ie, ≤1%, 2%-25%, 26%-50%, 51%-75%, 76%-98%, or ≥99%).

Point-of-care US was performed using a SonoSite Edge machine (SonoSite, Bothell, Washington) with a 5-10 MHz linear transducer probe. With the patient's elbow flexed to 90 degrees, the US probe was placed over the posterior aspect of the distal humerus.[7] A copious amount of gel was used to reduce pressure applied to the injured elbow with the US probe, thereby minimizing discomfort to the patient. Both longitudinal and transverse views of the elbow were obtained, and still pictures and video clips in each orientation were recorded. The contralateral normal, uninjured elbow was imaged for comparison at the discretion of the enrolling physician.

A positive elbow US was defined as the enrolling physician's determination of elevation of the PFP and/or lipohemarthrosis of the PFP (**Figure 1**; available at www.jpeds.com). Elevation of the PFP was defined as rise of the fat pad above the extension of the distal humeral line on longitudinal view (**Figure 1**, C) or above a line connecting both lips of the olecranon fossa on transverse view[7] (**Figure 1**, D) and was characterized by the physician as mild, moderate, or severe. Lipohemarthrosis was defined as a heterogeneous appearance with hypoechoic areas in the PFP (**Figure 1**, E). The enrolling physician recorded the US findings immediately after the US and before reviewing any radiographic imaging studies and then categorized the US as positive, negative, or equivocal for fracture. Based on the history, physical examination, and US findings, the physician rated the post-test clinical suspicion of fracture (≤1%, 2%-25%, 26%-50%, 51%-75%, 76%-98%, or ≥99%) and indicated whether the patient still needed elbow radiography to evaluate for fracture. In addition, the time to perform the point-of-care US was recorded.

After completion of the US, all patients underwent radiography in accordance with the standard of care for evaluation of possible elbow fracture. The times at which the patient left the PED for radiology, returned to the PED, and had radiography results available (either preliminary or final readings by a radiologist) were recorded. Fracture on radiography was defined as "cortical irregularity" or "fracture" on the attending radiologist's report. Radiologists were blinded to the US findings. For patients without definite fracture on initial radiography in the PED, clinical follow-up consisted of a review of the electronic medical record and/or structured clinical telephone follow-up at 1-3 weeks to ascertain clinical outcomes. On follow-up, repeat imaging was performed at the discretion of the orthopedic surgeon. A diagnosis of fracture was defined as evidence of "cortical irregularity," "fracture," or "healing fracture" on imaging by the attending radiologist or orthopedic surgeon, or as clinical determination of "occult elbow fracture" by an orthopedic surgeon. In patients for whom no follow-up imaging was performed, the clinical diagnosis of no fracture was confirmed by resolution of all clinical symptoms.

Statistical Analyses

Rabiner et al[7] reported that 16% of patients without elbow fracture on radiography were estimated to have a ≤1% pretest clinical assessment of fracture. Therefore, we estimated a 15% reduction in radiography, because point-of-care elbow US may give the clinician confidence to forgo additional imaging in these patients. With an estimated 15% reduction in radiographs, a sample size of 100 patients would give a 95% CI of ±7%, with a lower limit of 8%.

Data were analyzed using SPSS (IBM, Armonk, New York) and are described using sensitivity, specificity, positive and negative predictive values, and 95% CIs. Descriptive statistical analyses were performed for categorical data.

Results

One hundred patients were enrolled, with a mean age of 7.9 ± 5.1 years (range, 0.9-19 years). Demographic and clinical characteristics of the study population are presented in **Table I** (available at www.jpeds.com). The study flow chart is presented in **Figure 2** (available at www.jpeds.com).

Fracture was diagnosed in 42 of 100 patients. There were 29 (69%) distal humerus fractures (25 supracondylar and 4 lateral condyle) and 11 (26%) proximal forearm fractures (8 proximal radius, 2 proximal ulna, and 1 ulna and radius). One patient was diagnosed with "occult fracture" and recasted on follow-up with orthopedics, although no healing fracture was visualized on repeat radiography. Another patient, who was diagnosed with an occult elbow fracture in the PED and given a sling, was still significantly symptomatic at a 3-week telephone follow-up.

Fifty-two patients had a positive point-of-care elbow US. Of these, 47 (90%) had an elevated PFP (26% mild, 59% moderate, and 15% severe), 36 (69%) had lipohemarthrosis, and 31 (60%) had both conditions. Thirty-three patients had a fracture detected on the initial radiograph in the PED. Four patients had an initial radiograph demonstrating effusion without fracture and were diagnosed with occult fracture on follow up; 2 of these patients had a healing fracture identified on repeat radiography, 1 patient had persistent pain at 3 weeks, and 1 patient was recasted at orthopedic follow-up for persistent symptoms.

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