Diagnostic accuracy of point-of-care ultrasound of the posterior fatpad in elbow fractures

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ABSTRACT

Background Point-of-care ultrasound (POCUS) can potentially be used in the triage of patients with elbow injuries. However, the diagnostic accuracy of POCUS performed by non-radiologists for the exclusion of elbow fractures is yet unknown. This study aimed to investigate the diagnostic potential of POCUS of the posterior fatpad performed by non-radiologists in the workup of adult patients presenting with elbow injuries.

Methods A multicentre, prospective cohort study was conducted between January 2021 and August 2022 in four EDs to determine the diagnostic accuracy of an elevated posterior fatpad on POCUS to demonstrate or exclude an elbow fracture in patients presenting with elbow injuries to the ED. The study population consisted of a convenience sample. In patients ≥16 years of age with an elbow injury for which an X-ray was ordered, POCUS was performed by emergency physicians trained in ultrasound. POCUS (index test) results were compared with X-ray outcomes (reference standard) to determine the diagnostic accuracy of POCUS.

Results A total of 215 patients were included, 143 (67%) of whom had a fracture confirmed on X-ray. POCUS was positive based on a visualised elevated posterior fatpad in 127 (59%) patients. An elevated posterior fatpad on POCUS had a sensitivity of 91% (95% CIs 85% to 95%), a specificity of 93% (95% CI 85% to 98%), a negative likelihood ratio of 0.10 (95% CI 0.06 to 0.16) and a positive likelihood ratio of 13.09 (95% CI 5.61 to 30.54) for the presence of an elbow fracture. Post hoc review of the images by expert sonographers improved sensitivity to 96% (95% CI 91% to 99%).

Conclusion POCUS of the posterior fatpad is a promising adjunct to physical examination to determine the need for further diagnostic studies in the triage of patients with elbow injuries. Sensitivity after a limited training is high, but not perfect, and can likely further be improved with additional training.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Point-of-care ultrasound (POCUS) is a radiation-free alternative imaging modality for diagnosing or excluding elbow fractures, but its diagnostic accuracy when used by non-radiologists is unknown.

WHAT THIS STUDY ADDS

⇒ In this multicentre prospective study, POCUS of the posterior fatpad was found to have a sensitivity of 91% and a specificity of 93% for the presence of an elbow fracture.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ POCUS of the posterior fatpad is a promising adjunct to physical examination to determine the need for further diagnostic studies in the triage of patients with elbow injuries.
⇒ The use of POCUS may reduce the need for X-rays in patients presenting with elbow injuries.

INTRODUCTION

Background

Clinical assessment of the elbow has been shown to be of limited value in patients presenting with an elbow injury.[1–3] X-rays are therefore made with a low threshold in patients who present with elbow injuries in the ED to exclude the presence of a fracture.[1–3] However, liberal use of X-rays results in potentially unnecessary radiation exposure and higher healthcare costs.[2 4–6]

Elbow fractures can be diagnosed on X-ray by direct visualisation of a fracture, and an occult fracture can be suspected by the presence of a positive fatpad sign.[7] The three fatpads of the elbow lie extrasynovial and intracapsular, of which two anterior fatpads lie in the radial and coronoid fossa and one on the posterior side of the humerus in the olecranon fossa.[4 7] Traumatic joint effusion elevates these fatpads, making them visible on a lateral X-ray.[4 7] Elevation arises with fractures within the elbow joint capsule, including fractures of the distal humerus (eg, supracondylar and lateral condylar fractures) and the proximal ulna and radius.[4] Previous MRI studies performed in adults suggest that occult fractures and bone injury are often present in patients with an elevated posterior fatpad on X-ray.[7 8]

Importance

Point-of-care ultrasound (POCUS) is a radiation-free alternative imaging modality that may be used to diagnose or exclude elbow fractures.[4–6 9–12] Previous studies in children have shown that identification of a positive posterior fatpad by POCUS is a feasible, fast and easy-to-learn skill for physicians, with a sensitivity ranging from 68% to 97% and a specificity ranging from 74% to 97%.[4–6 9–11] So far,

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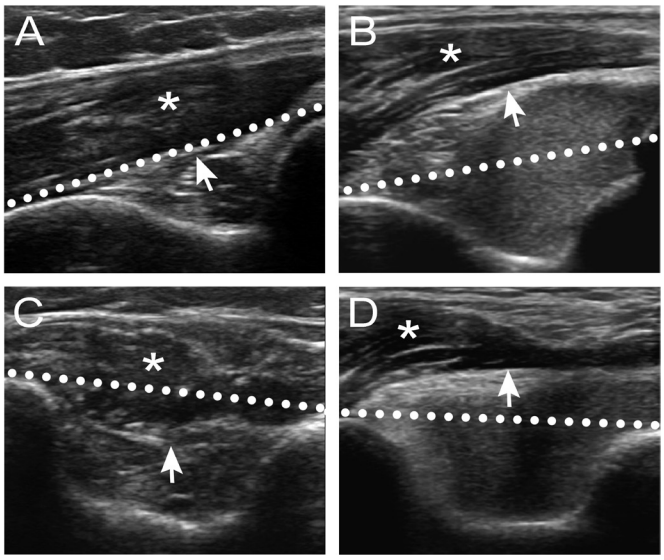

Figure 1 (A) Longitudinal view of a normal posterior fatpad (border marked with arrow) with the extended distal humeral line (dashed line) and the triceps muscle (asterisk). (B) Longitudinal view of an elevated posterior fatpad. (C) Transverse view of a normal posterior fatpad with the dashed line to connect the borders of the olecranon fossa. (D) Transverse view of an elevated posterior fatpad.

it is unclear if similar results can be obtained in adults, who have different injury patterns and a mature skeleton.

Goals of this investigation

This study aimed to investigate the diagnostic potential of POCUS of the posterior fatpad performed by non-radiologists in the workup of adult patients presenting with elbow injuries.

MATERIAL AND METHODS

Study design and setting

A multicentre prospective study was performed between January 2021 and August 2022 in the ED of four hospitals in the Netherlands (hospital details are described in online supplemental appendix A). Patients were referred to the ED by a general practitioner (GP), by emergency medical services or self-presented to the ED due to an elbow injury. The diagnostic accuracy of POCUS of the posterior fatpad of the elbow (as a proxy for an elbow fracture) was determined, both as a standalone test and as part of a stepwise protocol. After written informed consent was obtained, physical examination was performed as part of usual care and POCUS of the posterior fatpad was obtained, after which an X-ray of the elbow was performed in all patients. The formal radiology report served as the reference standard. An X-ray was regarded positive if it showed either a visible fracture or a positive fatpad sign.

This study was conducted and reported according to the Standards for Reporting Diagnostic Accuracy (STARD).[13] The methods of this study closely follow those outlined in our previous work.[14]

Patient and public involvement

Patients and the public were not involved in the design, conduct, reporting or dissemination of our research.

Selection of participants

The study population consisted of a convenience sample including patients aged 16 years or older with an elbow injury, for whom at triage in the ED an X-ray was ordered to exclude an elbow fracture by the triage nurse or treating physician. Including all patients with suspected elbow fractures was not feasible for logistical reasons, as in some participating hospitals, patients referred with a suspected elbow fracture are directly referred to the radiology department, precluding ultrasound prior to X-ray. Patients meeting the inclusion criteria were informed about the study by the treating physician. Excluded were patients presenting with an (already) radiologically confirmed elbow fracture, patients with an open fracture, (suspicion of) serious accompanying injury (high energy trauma, thoracic injury, neurotrauma or haemodynamic instability), neurovascular compromise, suspected elbow dislocation or a history of previous elbow osteosynthesis.

Interventions

POCUS was performed by an ED registrar (doctor in specialty training) or ED consultant. All sonographers had considerable POCUS experience, having passed the national ED POCUS certification programme (attended POCUS courses, built a portfolio of >250 ultrasound examinations and passed a practical examination).[15] Each sonographer received additional dedicated training to perform POCUS of the posterior fatpad of the elbow in the month prior to study inclusions. This training consisted of an instruction video (≤2 min) and presentation (circa 10 min) by a member of the study team, including study methods, anatomy and examples of normal and elevated posterior fatpads. Thereafter, the physician scanned the posterior fatpad in three healthy volunteers supervised by a member of the study team. The instruction video and the study protocol were available for reference during the study period. A POCUS trained ED consultant or registrar was present 24/7 in the ED during the study period, except for the participating level 3 trauma centre where patients could not be included during night hours. In most cases, POCUS was performed by the ED physician responsible for the patient's care, except when the patient was treated by a physician without POCUS certification.

A positive posterior fatpad (elevation of the fatpad) on POCUS was used as a proxy for the presence of an elbow fracture. Longitudinal and transverse views of the posterior fatpad were obtained using a linear array ultrasound probe (4–12 MHz) placed in the midline on the posterior side of the distal humerus (online supplemental figure 1). POCUS was performed with the elbow flexed in approximately 90 degrees. An elevated posterior fatpad was defined as: an elevation above the extended distal humeral line on the longitudinal view and above the line that connects the border of the olecranon fossa on the transverse view (figure 1).[5] All POCUS images were obtained and rated (positive, negative or inconclusive) by the physicians performing the examination at the time of the examination. All scans were reviewed at a later moment by two members of the study team (SH and TvdV, an ED consultant and registrar with expertise on POCUS research, and the study designers) blinded for the rating of the treating physicians. At review, the images were rated on image quality (sufficient to review the posterior fatpad) and the presence or absence of a positive posterior fatpad.

After POCUS, an X-ray of the elbow was obtained as a gold standard to evaluate the presence or absence of a fracture of the elbow (standard of care). Anterior-posterior (AP) and lateral views were obtained, additional views were performed on

indication. An X-ray was regarded positive if it showed either a visible fracture or a positive fatpad sign. POCUS outcome was compared with the formal radiology report. It was at the discretion of the treating physician to decide on treatment and follow-up according to local and regional guidelines.

An electronic case report form was used to collect patient and POCUS data, including baseline demographic data, physical examination findings, POCUS and X-ray outcomes and the treatment plan at ED discharge.

Outcomes

The primary analysis was defined as the diagnostic accuracy (ie, sensitivity, specificity and likelihood ratios) of POCUS of the posterior fatpad to demonstrate or exclude an elbow fracture in adult patients presenting with elbow injuries to the ED. POCUS outcome (posterior fatpad positive, negative or inconclusive) served as an index test and diagnosis of an elbow fracture on X-ray (including a positive fatpad sign only) served as a reference test. For diagnostic accuracy analysis, inconclusive POCUS ratings (sonographer could not reliably evaluate posterior fatpad elevation) were considered as positive findings, as POCUS is primarily used as a rule out test, and in these patients, X-rays cannot be omitted based on POCUS.

Sample size calculation

Prior research in the paediatric population demonstrated a sensitivity of 96% and a specificity of 81% for POCUS for the detection of elbow fractures.[2] Based on historical data of one of the participating EDs, the prevalence of elbow fractures among patients presenting with elbow injuries to the ED was set at 63%. Using the lower limit of the 95% CIs for sensitivity (91%), an accuracy (W) of 0.05 and a confidence level (Z) of 1.96, this yielded a sample size of 215 patients.

Analysis

Distribution of continuous variables was tested using the Kolmogorov-Smirnov test with Lilliefors' correction. Continuous variables were expressed as means with 95% CI when normally distributed and medians with an IQR when skewed. Categorical data were presented as absolute numbers and percentages. Missing data were reported. Diagnostic accuracy measures (sensitivity, specificity and likelihood ratios) with corresponding 95% CIs were calculated using 2×2 contingency tables. A two-tailed p value <0.05 was considered statistically significant. Inter-rater agreement for POCUS outcome was measured by the Cohen's kappa test. All analyses were performed with IBM SPSS Statistics V.28.

RESULTS

Characteristics of study subjects

A total of 223 patients were screened for inclusion. In 8 patients no informed consent was obtained, leaving 215 patients to be analysed. Baseline characteristics of the study population are presented in table 1. The majority of the enrolled patients were female (64%) and were injured during a fall (97%). The study flow chart is presented in figure 2.

Table 1 Baseline characteristics, physical examination features and ED treatment

	n=215
Age	
Median in years (IQR)	39 (16-89)
Sex	
Female	137 (64%)
Trauma mechanism	
Fall	208 (97%)
Other*	7 (3%)
Injury characteristics	
Side (right)	96 (45%)
Previous fracture of the injured arm	13 (6%)
Deformity present	9 (4%)
Haematoma	6 (3%)
Swelling	109 (51%)
Swelling and haematoma	42 (20%)
ROM affected	180 (84%)
Location fracture X-ray†	
Proximal radius	68 (32%)
Proximal ulna	42 (20%)
Distal humerus	13 (6%)
Only fatpad	23 (11%)
Treatment plan at ED discharge	
Conservative treatment	99 (72%)
► Pressure or supportive bandage	53 (38%)
► Splint	44 (32%)
► None	2 (1%)
Operative repair	39 (28%)
No fracture	77 (36%)

Data are presented in numbers and percentages; n (%).
*Direct impact, entrapment and arm wrestling.
†Six patients had two fracture sites: three ulna and radius fracture, two ulna and humerus fractures, and one radius and humerus fracture.
ROM, range of motion.

Primary outcome

In total, 143 (67%) patients were diagnosed with a fracture of the elbow on X-ray (table 2). In 28 (20%) of these patients, a positive fatpad sign was the only sign of a fracture on X-ray. POCUS was performed in all 215 patients and was considered positive based on a visualised elevated posterior fatpad in 127 (59%) patients, negative in 80 (37%) patients and inconclusive in 8 (4%). Diagnostic accuracy measures of POCUS are presented in table 3. In 13 patients (6%), POCUS was false negative (see online supplemental table 1 for patient characteristics). In 2 patients, POCUS was false positive: one had a triceps rupture and the other a distortion of the elbow not requiring further treatment. Of the eight patients with an inconclusive POCUS result, five had a fracture on X-ray. There was no missing data.

Quality control

Review of images by the study team was possible for 199 out of 215 patients, as images were not saved in 16 patients. The study team rated the image quality as sufficient to assess the posterior fatpad in 184 (86%) patients. Of the 13 patients with a false negative POCUS exam, scan review judged that 6 patients did have an elevated fatpad, and in the other 6 patients, the study team agreed there was no fatpad elevation on POCUS. Interestingly, in 2 of these patients, an olecranon fracture was directly visualised by POCUS of the posterior fatpad. Finally, in one patient POCUS images were not saved and therefore could not be reviewed. Diagnostic accuracy measures by the expert reviewers are presented in table 3, in online supplemental table 2 the patients with a visible fracture on POCUS were counted as positive cases.

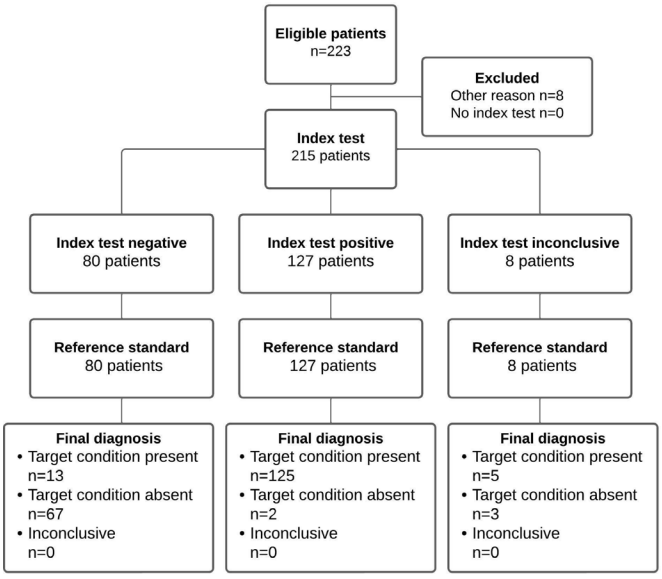

Figure 2 STARD (Standards for Reporting Diagnostic Accuracy) flow diagram. Index test: POCUS (point-of-care ultrasound), reference test: X-ray.

Inter-rater agreement for POCUS between the physician performing POCUS and the study team was 0.745, indicating substantial (but not perfect) agreement.[16]

DISCUSSION

This multicentre prospective cohort study found that after limited training, POCUS of the posterior fatpad is a promising adjunct to physical examination to determine the need for further diagnostic studies in the triage of patients with elbow injuries. Sensitivity after a limited training is high, but not perfect, and can likely further be improved with additional training.

The sensitivity of POCUS of the posterior fatpad for the exclusion of fractures in patients with elbow injuries in this study was high, although not perfect. In total, 13 patients had a false negative POCUS examination, 7 of whom were either treated conservatively (splint or pressure bandage) or did not receive any treatment at all. Of the six patients who needed surgical repair, five had an olecranon fracture with diastasis and one patient had a radial head fracture. The absence of a positive fatpad sign in the patients with an olecranon fracture (and consequently a false negative POCUS result) can be explained by disruption of the joint capsule, resulting in the absence of joint effusion. As olecranon fractures are generally easily identified during physical examination due to prominent swelling and a palpable fracture, the clinical consequences of false negative POCUS are limited, as an X-ray will not be omitted in these patients. As our study was insufficiently powered to delineate specific subgroups that would benefit most from POCUS, we advocate to use POCUS in conjunction with physical exam in all patients with elbow injuries. This is in line with previous findings of Tokarski *et al*, who demonstrated in a paediatric population that history taking and physical exam in combination with POCUS can reduce the need for radiographs by 23%.[6] Our data demonstrate that in patients without an elevated fatpad on POCUS (n=80) and no olecranon fracture with diastasis (n=6), X-rays can possibly be omitted in 34% of the patients with an elbow injury.

Table 2 Outcome of POCUS in comparison to X-ray for diagnosis of an elbow fracture

	X-ray positive	X-ray negative	Total
POCUS positive	125	2	127
POCUS negative	13	67	80
POCUS inconclusive*	5	3	8
Total	143	72	215

*These patients were considered POCUS positive for the statistical analyses.
POCUS, point-of-care ultrasound.

Table 3 Diagnostic accuracy of POCUS for elbow fracture identification

Diagnostic accuracy measures	ED consultant/registrar*	Expert image review*
Sensitivity (95% CI)	91% (85–95)	96% (91–99)
Specificity (95% CI)	93% (85–98)	80% (68–90)
Positive likelihood ratio (95% CI)	13.09 (5.61–30.54)	4.97 (2.93–8.45)
Negative likelihood ratio (95% CI)	0.10 (0.06–0.16)	0.03 (0.01–0.09)

*ED consultant/registrar n=215, expert image review n=184.
POCUS, point-of-care ultrasound.

The high specificity of POCUS reported in this study demonstrates that positive POCUS results should prompt further evaluation with an X-ray to confirm the presence of a fracture and to obtain information about the fracture configuration, enabling the establishment of a treatment plan. It should be noted that inconclusive POCUS examinations were treated as positive POCUS examinations in this study to favour sensitivity over specificity. This is in line with how we propose inconclusive results should be treated in clinical practice. While this strategy protects patients by reducing the likelihood of missed diagnoses, it increases sensitivity possibly overestimating accuracy. Interestingly, the specificity of the expert sonographers who reviewed the images was lower than specificity obtained by the physicians performing POCUS. This can be explained by the fact that the physicians performing POCUS also had information about physical examination findings (confirmation bias), whereas at review the expert sonographers could only rely on the POCUS images. Another explanation might be that the experts more often qualified POCUS examinations as positive based on very subtle abnormalities.

Our results are in agreement with several previous studies conducted in the paediatric population where comparable high sensitivity (68–97%) and specificity (74–97%) were reported.[4–6 9–11] The diagnostic accuracy as reported in this study was obtained by ED consultants and registrars who were certified to use POCUS (with a broad range in experience years) but who were relative novices in musculoskeletal sonography, except for the (limited) extra training in POCUS of the posterior fatpad, reflecting real-world clinical practice. Scan review by expert sonographers from the study team yielded a higher sensitivity, which underlines that it is important to realise that POCUS test performance is operator dependent: more experienced operators will likely exhibit a higher diagnostic accuracy.[17]

The findings of this study have important clinical applications. First, our findings demonstrate that POCUS can be used as a screening tool for patients presenting with elbow injuries. Specifically, if a negative POCUS of the posterior fatpad is obtained in a patient without obvious clinical signs of a fracture on physical examination, omitting an X-ray may be considered. This is not only important in the ED environment, where it may contribute

to a reduction in both resources used (with likely a positive impact on throughput times and costs) and radiation exposure, but also in primary care or prehospital care, where POCUS can help to decide which patients need to be admitted to a hospital for further workup of their injuries.

This study also has some limitations. First, the study population was comprised of a convenience sample of patients attending the ED. In several of the participating hospitals, patients with a suspected elbow fracture based on physical examination on triage or by the general practitioner are directly referred to the radiology department during working hours. These patients were not included in this study, which could have affected the diagnostic accuracy of POCUS. Furthermore, due to the structure of the healthcare system in the Netherlands, most patients visit a GP before presenting at the ED. This probably led to a high incidence of elbow fractures in our study cohort, which may limit the generalisability of the findings to other healthcare systems. Second, the expert sonographers were blinded for the rating of the treating physicians, but unblinded to the study's aim. Third, the choice of the reference standard (X-ray), a pragmatic test to diagnose elbow fractures can be debated as MRI and CT can identify injuries undetectable by X-ray.[7 18] In our study, POCUS of the posterior fatpad was positive in two patients without any fracture or fatpad sign visible on X-ray. It is possible that MRI, CT or additional X-ray views would have confirmed the presence of a fracture in these patients, although the clinical consequences of missing these fractures are likely limited. Further, a considerable amount 14% (n=31) of the ultrasound images obtained were not saved or of insufficient quality to be reviewed by the study team, precluding quality review. Finally, as we only had ED discharge information and no long-term follow-up, our conclusions regarding the potential consequences of false negative POCUS refer to short-term effects only, and we cannot rule out that some patients later had undergone (delayed) surgery.

In conclusion, this multicentre prospective diagnostic accuracy study suggests that POCUS of the posterior fatpad is a promising adjunct to physical examination to determine the need for further diagnostic studies in the triage of patients with elbow injuries. Sensitivity after a limited training is high, but not perfect, and can likely further be improved with additional training.

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Contributors SH, TvdV, RS, JM, ETA and HL conceived the study and designed the trial. SH, TvdV, EA and HL supervised the conduct of the trial and data collection. SH, TvdV, ETA and HL undertook recruitment of participating centres, SH, TvdV, RS, AB, BYMvdK, JM, ETA and HL undertook recruitment of participating patients. SH and TvdV managed the data, including quality control. SH, TvdV, JM, ETA and HL provided statistical advice on study design and analysed the data. SH, TvdV, JM, ETA and HL drafted the manuscript, and all authors contributed substantially to its revision. SH takes responsibility for the paper as a whole; guarantor.

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Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval This study involves human participants and was approved by Ethical committee of Medical Centre Leeuwarden (RTPO 1101) and registered in the Dutch Trial Register: NL9046. Participants gave informed consent to participate in the study before taking part.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request. Data are available on reasonable request. The research protocol (written in Dutch) and database are available on request. Requests can be sent to SL Haak (s.l.haak@umcg.nl). Reuse is permitted after consultation.

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