



## Original Contribution

# Performance of the 4-way range of motion test for radiographic injuries after blunt elbow trauma<sup>☆,☆☆</sup>



David R. Vinson, MD<sup>a,b,c,\*</sup>, Gregory S. Kann, MD, MSc<sup>a,d</sup>, Samuel D. Gaona, BS<sup>e</sup>, Edward A. Panacek, MD, MPH<sup>f</sup>

<sup>a</sup> The Permanente Medical Group, Oakland, CA

<sup>b</sup> Kaiser Permanente Division of Research, Oakland, CA

<sup>c</sup> Department of Emergency Medicine, Kaiser Permanente Sacramento Medical Center, Sacramento, CA

<sup>d</sup> Department of Emergency Medicine, Kaiser Permanente South Sacramento Medical Center, Sacramento, CA

<sup>e</sup> Department of Emergency Medicine, University of California Davis School of Medicine, Sacramento, CA

<sup>f</sup> Department of Emergency Medicine, University of South Alabama Medical Center, Mobile, AL

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## ABSTRACT

**Objectives:** Acute elbow injuries are common in the acute care setting. A previous study observed that limited active range of motion (ROM) was highly sensitive for radiographic injuries after blunt trauma. Our aim was to validate these findings in patients  $\geq 5$  years old with an acute ( $< 24$  hours) nonpenetrating elbow injury.

**Methods:** This prospective study included a convenience sample of patients undergoing plain radiographs of an injured elbow in 3 emergency departments. Before imaging, treating clinicians completed a standardized data collection sheet including mechanism of injury and 4-way ROM findings (full extension, flexion to 90°, full pronation and supination). Radiographic interpretation by a staff radiologist was used to ascertain the presence of fracture or joint effusion.

**Results:** The median age of the 251 patients was 24 years. Ninety-two patients (36.7%) had active 4-way ROM, and 159 patients (63.3%) demonstrated limited ROM. Negative radiographs were present in 152 patients (60.6%), whereas 99 patients (39.4%) had abnormal radiographs: 75 with explicit fractures and 24 with only joint effusions. The 4-way ROM elbow test had a sensitivity of 0.99 (95% confidence interval [CI], 0.94–1.00), specificity of 0.60 (95% CI, 0.52–0.68), positive predictive value of 0.62 (95% CI, 0.54–0.69), and negative predictive value of 0.99 (95% CI, 0.94–1.00).

**Conclusions:** Active 4-way ROM test is 99% sensitive for all radiographic injuries following blunt elbow trauma and 100% sensitive for injuries requiring surgical intervention. Caution should be used in relying on this test in the pediatric population until it is validated in a larger cohort.

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## 1. Introduction

Acute traumatic elbow injuries are common in primary care and emergency medicine, accounting for approximately 1% of emergency visits [1]. Radiographs are often obtained to distinguish fracture from soft tissue injury because the management of each injury can be substantially different. Yet the prevalence of acute radiographic abnormalities among patients undergoing plain radiographs of the elbow can be as low as 25% [2]. If a set of physical examination findings could be identified to predict which patients were at very low risk of fracture, many of

these radiographs could be safely avoided. This could save the patient the inconvenience, cost, and radiation risk of unnecessary radiographic evaluation. Foregoing needless radiographs could also shorten emergency department (ED) length of stay and facilitate patient throughput.

Many have sought to derive a clinical prediction rule to guide the selective use of radiographs in patients with acute nonpenetrating elbow trauma [1–12]. Shortcomings of these studies include absence of radiographs in all patients at the time of the initial evaluation [1,2,11], failure to apply the predictive test to both children and adults [4,8,11], and failure to include a community setting [1–6,8–11].

We performed a prior study of patients with acute elbow injuries that included only those undergoing radiographs, enrolled both adults and children, and involved both academic and community facilities [7]. After examining several potential predictors, we noted that preservation of active 4-way range of motion (extension, flexion to at least 90°, full supination and pronation) was 100% sensitive in predicting abnormal radiographs [7]. However, our cohort was only of modest size and the confidence intervals (CIs) were relatively wide (0.92–1.0). We undertook this current study to prospectively validate those findings.

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\* Corresponding author at: Department of Emergency Medicine, Kaiser Permanente Sacramento Medical Center, 2025 Morse Ave, Sacramento, CA 95825.

E-mail address: [drvinson@ucdavis.edu](mailto:drvinson@ucdavis.edu) (D.R. Vinson).

## 2. Methods

### 2.1. Study design and setting

This prospective study with convenience sampling was undertaken at 3 medical centers in the greater Sacramento region between August 2012 and January 2015. Two are suburban community medical centers within Kaiser Permanente Northern California, a large integrated health care delivery system. The third facility is an urban academic Level I trauma center with an emergency medicine residency training program. The census of each of the 3 EDs during 2013 was between 75,000 and 85,000. The study was approved by the respective institutional review boards with waiver of consent in the community medical centers and written informed consent of the patient or parent/guardian in the academic medical center.

### 2.2. Selection of participants

Patients 5 years and older with an acute (<24 hours) nonpenetrating elbow injury were eligible for enrollment if the clinician felt that radiographs of the affected elbow were clinically indicated. No clinical policy or practice guideline was in place throughout the study period to specify which injuries warranted radiographs. This decision was entirely in the hands of the treating clinician. We excluded patients with a preexisting condition in the affected limb that limited mobility (eg, palsy), altered mental status, a significant distracting injury (in the clinician's judgment), obvious elbow deformity, or neurovascular abnormality in the affected limb.

### 2.3. Study protocol and measurements

Before the commencement of the study, participating clinicians were instructed on how to perform the 4-way range-of-motion maneuvers and given explicit printed instructions on the standardized data collection instrument. Clinicians prospectively recorded the patient's age, sex, and the mechanism of injury (free text). Before obtaining radiographs of the elbow, clinicians examined the patient in the seated or standing position with the injured arm at the patient's side in the anatomical position, extended at the elbow with the palm forward. We recorded the patient's ability to actively extend to a full locked position (0°), to actively flex to at least 90°, and to actively pronate and supinate to full range of motion (180°) while flexed as close to 90° as possible. In individuals who were unable to flex to at least 90° or extend to locked position, a comparison between the degree of flexion and extension was made with the uninjured arm. In such cases, inability to flex or extend equal to the unaffected limb was considered a positive (ie, abnormal) finding.

Any limitation of range of motion, in any of the 4 maneuvers, was considered a positive test result. Patients able to meet target end points in all 4 directions were considered to have preserved 4-way range of motion—a negative test result. A positive range-of-motion test result was our primary independent, or predictor, variable.

All enrolled individuals received at a minimum standard 3-view radiographs of the injured elbow, including lateral and anteroposterior views.

The main outcome, or dependent measure, was a set of elbow radiographs with fracture or joint effusion (anterior sail sign, posterior fat pad sign, or both). Radiographs were interpreted by board-certified radiologists unaware of the study and blinded to the results of range-of-motion examination. Radiographic results were obtained through investigator review of the radiology reports. Individuals without obvious radiographic fracture but with the presence of a joint effusion were considered positive for occult fracture, a conservative assumption.

Association between physical examination and radiographic findings was performed to determine performance characteristics of our independent variable, impaired active 4-way range of motion, in predicting abnormal radiographs (positive predictive value). We also determined the utility of full 4-way range of motion (test negative) to predict normal radiographs (negative predictive value).

**Table 1**

Age distribution of ED patients with acute nonpenetrating elbow injuries

Age range, y	N = 251 n (%)
Pediatric (5–17 y)	111 (44.2)
5–12	69 (27.5)
13–17	42 (16.7)
Adult (≥18 y)	140 (55.8)
18–64	116 (46.2)
65–89	24 (9.6)

## 3. Statistical analysis

Continuous variables are presented as medians with interquartile ranges, and categorical data are presented as the percentage of frequency of occurrence (Microsoft Excel 2013 v. 15; Redmond, WA). Frequencies observed between groups were compared by means of Fisher exact test (GraphPad Software 2015; La Jolla, CA). Sensitivity and specificity of the 4-way range-of-motion test were calculated (Vassarstats.net; Poughkeepsie, NY). We included 95% exact CIs. A 2-tailed P value of less than .05 was considered to indicate statistical significance.

## 4. Results

A total of 251 individual patients were enrolled; 124 (49.4%) were female. No patient was enrolled on more than 1 occasion. The age breakdown is summarized in Table 1, with a median age of 24 years (interquartile range, 12–50 years; range, 5–89 years); nearly half of the cohort was pediatric. The most common mechanism of injury was fall (n = 189; 75.3%); 20 patients (8.0%) injured their elbow in a motor vehicle accident (automobile, or automobile vs. pedestrian, or motorcycle).

Ninety-two patients (36.7%) had preserved active 4-way range of motion on physical examination (a negative test result). One hundred fifty-nine patients (63.3%) demonstrated some limitation of active range of motion in 1 or more directions (a positive test result). One hundred fifty-two patients (60.6%) had negative radiographs. Ninety-nine patients (39.4% prevalence) had fracture or occult fracture on elbow radiographs. Of those, 75 had explicit fractures and 24 only had joint effusions. The relation between range-of-motion findings and radiographic findings is reported in Table 2. Patients with limited range of motion were more likely to have an elbow fracture or effusion than those with preserved range of motion (62% vs 1%;  $P < .001$ ).

There were 45 patients with active range-of-motion limitations isolated to only 1 of 4 directions. Eighteen of these had abnormal radiographs (Table 2). Fractures and effusions were more common in patients with range-of-motion limitations in 2 or more directions than those with limitations isolated to 1 direction (70% vs 40%;  $P < .001$ ).

The 4-way range-of-motion test has a 99% sensitivity and a 60% specificity. The full performance characteristics of the 4-way range-of-motion test are reported in Table 3.

One patient had a false-negative range-of-motion test result; that is, he had preserved active range of motion yet was found to have traumatic radiographic abnormalities. This 7-year-old boy had tripped and suffered a ground-level fall. Radiographs in the ED revealed a nondisplaced

**Table 2**

Results of elbow range-of-motion examination and radiographic findings (N = 251)

4-Way range of motion	n	Fracture or effusion	
		No n (% of row)	Yes n (% of row)
Complete (test result negative)	92	91 (99)	1 (1)
Limited (test result positive)	159	61 (38)	98 (62)
In only 1 direction <sup>a</sup>	45	27 (60)	18 (40)
In 2 or more directions	114	34 (30)	80 (70)

<sup>a</sup> Distribution: extension (n = 35), flexion (n = 1), pronation (n = 8), supination (n = 1).

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