

Clinical Predictors of Fracture in Patients with Shoulder Dislocation: Systematic Review of Diagnostic Test Accuracy Studies.

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BACKGROUND

Pre-reduction radiographs are conventionally used to exclude fracture before attempts to reduce a dislocated shoulder in the Emergency Department. However, this step increases cost, exposes patients to ionising radiation, and might delay closed reduction. Some studies have suggested that pre-reduction imaging may be omitted for a sub-group of patients with shoulder dislocations.

OBJECTIVES

To determine whether clinical predictors can identify patients that might safely undergo closed reduction of a dislocated shoulder without pre-reduction radiographs.

METHODS

A systematic review and meta-analysis of diagnostic test accuracy studies that have evaluated the ability of clinical features to identify concomitant fractures in patients with shoulder dislocation. The search was updated to 23rd June 2022 and language limits were not applied. All fractures were included except for Hill-Sachs lesions. Quality assessment was undertaken using the Quality Assessment of Diagnostic Accuracy Studies (QUADAS-2) tool. Data were pooled and meta-analysed by fitting univariate random effects and multi-level mixed effects logistic regression models.

RESULTS

Eight studies reported data on 2,087 shoulder dislocations and 343 concomitant fractures. The most important potential sources of bias were unclear blinding of those undertaking the clinical (6/8 studies) and radiographic (3/8 studies) assessment. The prevalence of concomitant fracture was 17.5%. The most accurate clinical predictors were age ≥ 40 (LR+ 1.8 [95% CI 1.5-2.1]; LR- 0.4 [0.2-0.6]), female sex (LR+ 2.0 [1.6-2.4], LR- 0.7 [0.6-0.8]), first time dislocation (LR+ 1.7 [1.4-2.0]; LR-0.2 [0.1-0.5]), and presence of humeral ecchymosis (LR+ 3.0-5.7; LR- 0.8-1.1). The most important mechanisms of injury were: high-energy mechanism fall (LR+ 2.0-9.8, LR-0.4-0.8), fall >1 flight of stairs (LR+ 3.8 [95% CI 0.6-13.1]; LR- 1.0 [95% CI 0.9-1.0]), and motor vehicle collision (LR+ 2.3 [0.5-4.0]; LR- 0.9 [0.9-1.0]). The Quebec Rule had a sensitivity of 92.2% (95% CI 54.6-99.2%) and specificity (33.3%, 23.1-45.3%) but the Fresno-Quebec rule identified all clinically important fractures across two studies: sensitivity 100% (95% CI 89-100%) in the derivation dataset and 100% (90-100%) in the validation study. The specificity ranged from 34% (95% CI 28-41%) in the derivation dataset to 24% (16-33%) in the validation study.

CONCLUSION

Clinical prediction rules may have a role in supporting shared decision making after shoulder dislocation, particularly in the pre-hospital and remote environments when delay to imaging is anticipated.

What is already known on this subject?

- Shoulder dislocations are commonly associated with fractures of the proximal humerus, which may preclude closed reduction in the ED.
- Plain radiographs are used to identify fractures but expose the patient to ionising radiation, delay definitive treatment, and may inhibit appropriate pre-hospital attempts at reduction.

What this study adds:

- Clinical predictors can help risk stratify patients with a shoulder dislocation based on the likelihood of a concomitant clinically significant fracture.
- Clinical prediction rules can help identify patients that could safely forgo radiography before closed reduction of a dislocated shoulder.

How this study might affect practice:

- Clinical prediction rules can support shared decision making about early closed reduction of dislocated shoulders, particularly when there is an anticipated delay to imaging.

BACKGROUND

Shoulder dislocation is a commonly encountered injury in the Emergency Department¹. Isolated shoulder dislocations should undergo prompt closed reduction in the ED to alleviate pain, limit tension on soft tissue structures, and restore anatomical alignment². However, up to 25% of shoulder dislocations are associated with fracture of the proximal humerus³⁻⁵. Concomitant fractures are important to identify as fracture of the humeral neck contraindicates closed reduction in the ED^{6 7}. Although tuberosity fractures are not an absolute contraindication^{6 7}, they are important to identify as they increase the risk of iatrogenic humeral neck fracture during attempts at reduction⁸. It is therefore conventional to obtain plain radiographs before attempting closed reduction of a clinically dislocated shoulder². However, the need for plain radiographs increases cost, delays reduction, and exposes the patient to ionising radiation⁹⁻¹¹, which is a particular concern for young patients with recurrent dislocations. The perceived need for imaging might also inhibit pre-hospital attempts at closed reduction¹², which may be particularly important in remote environments such as mountainous ski resorts¹³.

A number of studies have therefore tried to identify whether there is a sub-group of patients for whom it is safe to omit pre-reduction radiographs despite a clinical diagnosis of shoulder dislocation^{9 10}.

This systematic review sought to determine whether clinical predictors can safely identify a sub-group of patients that might safely undergo closed reduction of a dislocated shoulder without pre-reduction radiographs.

METHODS

This systematic review was conducted according to the Preferred Reporting Items for Systematic Review and Meta-Analysis of Diagnostic Test Accuracy studies (PRISMA-DTA) guidelines¹⁴.

Search strategy

Literature searches were designed with and performed by a specialist information librarian using PubMed, Ovid MEDLINE (1946 to November 2021), EBSCO CINAHL, Embase (1947 to 2021) and Web Of Science. The search strategies are available in Supplementary File 1. The reference lists of included studies were screened for further items and a forward citation

search undertaken for new studies using Google Scholar on 23rd June 2022. Duplicates were removed using EndNote (Clarivate, PA, USA) and unique items then imported into the specialist systematic review package Rayyan (Qatar Computing Research Institute, Doha, Qatar) for abstract screening.

Study selection

Studies were included if they reported the diagnostic characteristics of clinical findings (individually or in combination) for fracture in patients with a clinically dislocated shoulder. All glenohumeral joint dislocations (i.e. anterior, posterior, or inferior) were included. The reference standard was plain radiography and a positive outcome was defined as the identification of a clinically significant fracture, which we defined pragmatically as any fracture with the exception of Hill-Sachs lesions. Studies were excluded if they did not include sufficient data to construct a 2x2 table. Two authors (IO and LC) independently screened abstracts and then full-texts with a third author (DM) available to arbitrate if necessary.

Data Extraction and Quality Assessment

Data were extracted independently by two authors (IO and LC) and then compared for errors. Any inconsistencies were resolved through discussion with a third author (DM). If further data or clarification was required to construct 2x2 tables, the corresponding authors of included studies were contacted. Risk of bias was assessed using the Quality Assessment of Diagnostic Accuracy Studies 2 (QUADAS-2) tool¹⁵. This assessment was performed independently by two authors (IO and LC) and then checked by a third (DM).

Statistical analysis

Sensitivity, specificity, and likelihood ratios were calculated for each feature together with their 95% confidence intervals. The unit of analysis was individual shoulders. Clinical predictors reported by only one study were presented as individual data points and two studies as a range. Data about the same clinical predictor reported by three studies were pooled using univariate random effects models and data reported by four or more studies using multi-level mixed effects logistic regression models. Studies pooled using multi-level mixed effects logistic regression were also summarised using hierarchical summary receiver operating characteristic curve (HSROC) plots. Heterogeneity was evaluated using the I^2 test and by visualising HSROC plots before data were pooled. However, we anticipated significant heterogeneity and so planned to pool data using mixed effects models. Publication bias was assessed by visually inspecting scatter plots and by regressing the log diagnostic odds ratio

against 1/ESS1/22 weighted by ESS (where ESS represents the effective sample size) with $p < 0.05$ for the slope coefficient used as the threshold for significant asymmetry, as recommended by Deeks et al¹⁶. Meta-analysis was undertaken using the diagti, midas, metan, and metandi modules in Stata SE v.15 (StataCorp LLC, College Station, Texas). We planned to specifically highlight clinical features with a positive likelihood ratio (LR+) of >2.0 or a negative likelihood ratio (LR-) of <0.5 .

RESULTS

There were 4,688 unique items retrieved from the search process that included eight eligible^{3-5 17-19} studies reporting data on 2,087 individual shoulder dislocations and 343 concomitant fractures (Figure 1). There was no evidence of publication bias.

Study and participant characteristics

The included studies are described in Table 1. There were five retrospective^{3-5 17 20} and three prospective studies^{18 19 21} from Emergency Departments in Australia²⁰, Canada^{4 18 19}, France¹⁷, Iran²¹, and Turkey^{3 5}. Three were published by a single research team^{4 18 19} but over non-overlapping time periods. Most studies included all adults aged ≥ 18 ^{4 5 17-19 21} or ≥ 16 ³ but one study limited its population to patients aged <40 years²⁰.

Risk of bias

Table 2 shows the risk of bias assessment for each study using the QUADAS-2 tool. Six studies were at low risk of bias in the patient selection category because they reported data from consecutive patients^{4 5 17-19 21}. However, two studies were at high risk of patient selection bias^{3 20}. This is because one only included younger patients (aged <40 years) which may have distorted the diagnostic characteristics of predictors for fracture²⁰ and the other because only a minority (30%) of patients with a dislocated shoulder had complete medical records available³. These issues also gave rise to the only applicability concerns across all of the QUADAS-2 domains. Six studies were at unclear risk of bias in the index test category because they were retrospective studies and did not explicitly state that the assessor recording clinical features was blinded to the results of the radiograph^{4 5 17 18 20 21}. Similarly, three studies were at unclear risk of bias in the reference standard category because they did not explicitly confirm that the assessor was blinded to the clinical features^{4 20 21}. All eight studies were judged to be at low risk of bias in the flow and timing category because a fracture was unlikely to have developed or resolved between clinical assessment and imaging.

Prevalence of concomitant fracture

Seven of the eight studies^{3-5 17-19 21} were used to estimate the prevalence of clinically significant fractures amongst the ED population with shoulder dislocations because Ong et al only included younger patients (aged <40)²⁰. There were therefore 331 clinically significant fractures amongst the group of 1,891 shoulder dislocations (prevalence 17.5%). Four studies described the prevalence of different fracture types. The most common fractures affected one or more tuberosities in isolation (121/183, 66.1%; four studies^{3 4 18 19}). The prevalence of fractures that would preclude closed reduction in the ED (e.g. fractures of the humeral head or neck) was up to 15%. Other fractures included bony Bankart lesions (5/125, 4.0%; two studies^{4 19}) as well as isolated fractures of the glenoid and coracoid.

Accuracy of clinical assessment

The most useful clinical features were: age ≥ 40 (LR+ 1.8 [95% CI 1.5-2.1], LR- 0.4 [0.2-0.6]; 1,406 dislocations, 4 studies), female sex (LR+ 2.0 [1.6-2.4], LR- 0.7 [0.6-0.8]; 1,497 dislocations, 5 studies), first time dislocation (LR+ 1.7 [1.4-2.0], LR- 0.2 [0.1-0.5]; 1,745 dislocations, 6 studies), and presence of humeral ecchymosis (LR+ 3.0-5.7, LR- 0.8-1.1; 426 dislocations, 2 studies). The most important mechanisms of injury were: high-energy mechanism fall (LR+ 2.0-9.8, LR- 0.4-0.8; 381 dislocations, 2 studies), fall >1 flight of stairs (LR+ 3.8 [95% CI 0.6-13.1], LR- 1.0 [95% CI 0.9-1.0]; 760 dislocations, 3 studies), and motor vehicle collision (LR+ 2.3 [0.5-4.0], LR- 0.9 [0.9-1.0]; 1,362 dislocations, 4 studies).

Five studies (1,410 dislocations; 216 fractures) reported data on the accuracy of the Quebec Rule, which mandates pre-reduction radiography for injuries satisfying any one of the following criteria: age ≥ 40 (one study used a threshold of ≥ 35 years³), first shoulder dislocation, and high-risk mechanism^{3 4 17 20 21}. High-risk mechanisms were fall down more than one flight of stairs, fight/assault, and motor vehicle collision⁴. Four of the five studies reported overall favourable diagnostic characteristics of the Quebec Rule but a single study from Australia (limited to younger patients aged <40 years) was less encouraging²⁰. This latter study reported a sensitivity of only 42% (95% CI 16-71%) and specificity 40% (33-47%). When all five studies were pooled using a multi-level mixed effects logistic regression model, the Quebec Rule had a sensitivity of 92.2% (95% CI 54.6-99.2%) and specificity (33.3%, 23.1-45.3%) (Figure 2).

One study presented an algorithm (the Fresno-Quebec Rule) to determine which patients with a clinically dislocated shoulder should undergo pre-reduction radiographs¹⁸. The factors

incorporated into this algorithm were: atraumatic recurrent episode, age ≥ 35 , and high-risk mechanism (Figure 3). High-risk mechanisms in the FQR are defined as motor vehicle collision, assault, sports-related or fall >10 feet. According to the derivation study (207 dislocations; 24 fractures), the algorithm achieved a sensitivity of 100% (95% CI 89-100%) and specificity of 34% (28-41%) for identifying fractures (LR+ 1.9 [95% CI 1.6-2.3], LR- 0.1 [0.0-0.6])¹⁸. This finding has been reproduced by a single retrospective study in Turkey (135 dislocations; 34 fractures), which also reported a sensitivity of 100% (95% CI 90-100%, specificity 24% [16-33%], LR+ 1.3 [1.1-1.5], LR- 0.1 [0.0-0.9])³.

DISCUSSION

This systematic review suggests there is a sub-group of patients with shoulder dislocations for whom radiographs may be safely omitted before closed reduction. Identifying this group could reduce costs, exposure to ionising radiation, and time to joint reduction^{9 10}.

All eight included studies defined clinically significant fractures as including all fracture patterns except for Hill-Sachs lesions. However, the most common bony injury (isolated tuberosity fractures) does not preclude closed reduction in the ED^{6 7} and so identifying this injury may not affect the immediate management. Nevertheless, there are a number of reasons why it might be helpful to identify this fracture before reduction. First, tuberosity fracture may herald an undisplaced fracture across the humeral neck and has been associated with iatrogenic humeral neck fracture during closed reduction⁸. The identification of a tuberosity fracture should therefore lead to careful examination of the radiographs (i.e. two orthogonal views) for evidence of an undisplaced fracture across the humeral neck¹⁵. Second, tuberosity fractures may be difficult to appreciate on post-reduction radiographs but often require orthopaedic follow-up and interval radiographs to exclude further displacement of the fragment²². Finally, identification of a tuberosity fracture may reassure both the patient and emergency physician that this injury preceded attempts at closed reduction.

Studies across a range of settings have been consistent about the clinical features that are most useful for identifying patients with fractures. These features have been combined into a clinical decision rule – the Quebec Rule – which recommends pre-reduction radiography in the case of a patient aged ≥ 40 years, a first episode of dislocation, or a high-risk mechanism⁴. The derivation study identified high-risk mechanisms as fall down more than one flight of stairs, fight/assault, and motor vehicle collision⁴. A number of validation papers supported this rule³

^{4 17 20 21} but it performed much less well in a case-control study of younger patients from Australia²⁰. In that study, the rule was only 42% sensitive for fracture. A sub-group analysis by Bolvardi et al similarly found that the rule was only 50% sensitive for fracture in patients aged <40 years²¹. Although promising in some studies, the Quebec Rule requires further validation in younger populations before it can be recommended for use in clinical practice.

The Fresno-Quebec Rule has been externally validated³ and maintained a sensitivity of 100% across two studies consisting of 342 shoulder dislocations and 58 clinically significant fractures^{3 18 19}. The rule is also supported by other diagnostic test accuracy studies that previously supported the accuracy of these features for identifying fractures^{3 4 17 21}. Nevertheless, although Ong et al did not evaluate the FQR directly, their data suggest the underlying predictors may not be sufficiently sensitive to safely exclude fracture amongst younger patients²⁰. The FQR currently restricts its definition of “high-risk mechanism” to fall from >10 feet, sports related, assault, or motor vehicle collision¹⁹. Only one of the four tuberosity fractures reported by Ong et al was atraumatic – two occurred after a fall from standing height and one during a seizure²⁰. Clinicians should make their own judgement about the likelihood of fracture given each mechanism of injury and think more broadly than the specific high-risk mechanisms described by the FQR. However, reassuringly, all of the “missed” injuries reported amongst younger patients by Ong et al²⁰ and Bolvardi et al²¹ were greater tuberosity fractures²⁰ and so would not have precluded closed reduction in the ED⁶.

Limitations

This review identified eight diagnostic test accuracy studies that were broadly homogenous in terms of inclusion criteria, predictors, definitions, and choice of reference test. They included derivation and validation studies from EDs in a range of clinical settings. Reassuringly, the data from these studies were consistent, which lends considerable certainty to the findings of this evidence synthesis. However, the review suffers from a number of limitations. First, five of the eight studies used retrospective case control designs^{3-5 17 20} and suffered from missing data, which may have introduced bias. Second, continuous variables (such as age and height of fall) were dichotomised in the derivation studies, which makes predictors easier to use in clinical practice but discards valuable predictive information²³. For example, the FQR uses 35 years as its age threshold but the difference in fracture risk between a 34- and 36-year-old is likely to be much smaller than between a 36- and 90-year-old. Finally, rare populations (e.g. patients with shoulder dislocation caused by seizure) were not represented in sufficient numbers and so caution should be exercised before applying the FQR to all sub-groups.

Conclusion

The existing evidence suggests that clinical prediction rules may have a role in supporting shared decision making after shoulder dislocation, particularly in the pre-hospital and remote environments when delay to imaging is anticipated. Further external validation studies across different settings would however be helpful.

FIGURE LEGENDS

Figure 1: PRISMA flow diagram showing inclusion of studies.

Figure 2: Hierarchical summary receiver operating characteristic curve (HSROC) plot summarising accuracy of the Quebec Rule for fracture.

Figure 3: Fresno-Quebec Rule reproduced from Emond *et al*¹⁸.

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Table 1: Characteristics of studies included within the review.

Study	Design	Setting	Population	N	Clinically significant fractures (% of total)
Emond 2004 ⁴	Retrospective case-control	Canada	All patients aged ≥ 18	334	85 (25.4)
Emond 2009 ¹⁹	Prospective cohort	Canada	All patients aged ≥ 18	222	40 (18.0)
Ong 2011 ²⁰	Retrospective case-control	Australia	All patients aged < 40	196	12 (6.1)
Emond 2018 ¹⁸	Prospective cohort	Canada	All patients aged ≥ 18	207	24 (11.6)
Temiz 2018 ⁵	Retrospective case-control	Turkey	All patients aged ≥ 18	248	63 (25.4)
Bolvardi 2019 ²¹	Prospective cohort	Iran	All patients aged ≥ 18	143	4 (2.8)
Durak 2021 ³	Retrospective case-control	Turkey	All patients aged ≥ 16	135	34 (25.2)
Sousa 2022 ¹⁷	Retrospective case-control	France	All patients aged ≥ 18	602	81 (13.5)

Table 2: Risk of bias assessments for included studies using the QUADAS-2 tool.

Study	Patient selection		Index test		Reference standard		Flow and timing
	Risk of bias	Applicability	Risk of bias	Applicability	Risk of bias	Applicability	Risk of bias
Emond 2004	+	+	?	-	?	-	+
Emond 2009	+	+	+	-	+	-	+
Ong 2011	-	-	?	-	?	-	+
Emond 2018	+	+	?	-	+	-	+
Temiz 2018	+	+	?	-	+	-	+
Bolvardi 2019	+	+	?	-	?	-	+
Durak 2021	-	-	+	-	+	-	+
Sousa 2022	+	+	?	-	+	-	+