ORIGINAL ARTICLE

How do clinical features help identify paediatric patients with fractures following blunt wrist trauma?

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Objective: Wrist injuries are a common presentation to the emergency department (ED). There are no validated decision rules to help clinicians evaluate paediatric wrist trauma. This study aimed to identify which clinical features are diagnostically useful in deciding the need for a wrist radiograph, and then to develop a clinical decision rule.

Methods: This prospective cohort study was carried out in the ED of Sheffield Children's Hospital. Eligible patients were recruited if presenting within 72 hours following blunt wrist trauma. A standardised data collection form was completed for all patients. The outcome measure was the presence or absence of a fracture. Univariate analysis was performed with the χ^2 test. Associated variables ($p<0.2$) were entered into a multivariate model. Classification and regression tree (CART) analysis was used to derive the clinical decision rule.

Results: In total, 227 patients were recruited and 106 children were diagnosed with fractures (47%). Of 10 clinical features analysed, six were found by univariate analysis to be associated with a fracture. CART analysis identified the presence of radial tenderness, focal swelling, or an abnormal supination/pronation as the best discriminatory features. Cross fold validation of this decision rule had a sensitivity of 99.1% (95% confidence interval 94.8% to 100%) and a specificity of 24.0% (17.2% to 32.3%). The radiography rate would be 87%.

Conclusions: Radial tenderness, focal swelling, and abnormal supination/pronation are associated with wrist fractures in children. The clinical decision rule derived from these features had a high sensitivity, but low specificity, and would not substantially alter our current radiography rate. The potential for a clinical decision rule for paediatric wrist trauma appears limited.

Wrist injuries are a common reason for children to present to the emergency department (ED), with a fracture rate of up to 50%.[1] For inexperienced clinicians, deciding whether to request radiography can be difficult as they have little experiential learning on which to base their decisions. Even for experienced clinicians, a previous unexpected poor outcome, such as missing a fracture, may lead them to order investigations due to the fear of missing further fractures, even when the risk is acceptably low.

There have been previous studies looking at the value of clinical findings following wrist trauma. These studies were limited by analysing a cohort including any type of limb trauma[2–5] or because of small sample size.[1] At the present time there are no sensitive or specific rules routinely used by emergency physicians to decide on radiography for wrist fractures.

The benefits of a clinical decision rule include a reduction in resources consumed, potential cost savings, earlier discharge for patients who would not need to wait for unnecessary investigations, and a reduction in radiation exposure. This must be balanced against potential costs of missing a fracture, which include possible pain, suffering, poor outcome, and possible medicolegal consequences.

The aims of the study were (*a*) to estimate the diagnostic accuracy of individual clinical features from the patient history and examination for identifying fracture of the wrist following acute blunt wrist trauma, and (*b*) to derive and internally validate a clinical decision rule to categorise those at high and near zero risk for substantial fracture after blunt wrist trauma.

METHODS

Study setting and population

This prospective cohort study was carried out in the ED of Sheffield Children's Hospital, an urban teaching hospital seeing around 40 000 patients per year.

The study recruited children aged between 3 and 16 years presenting within 72 hours following blunt wrist trauma. Exclusion criteria were children <3 years of age (due to the difficulties in an objective examination), altered mental status or developmental delay, metabolic bone disease where there is a high risk of fracture occurring with even minimal trauma, wounds suspicious of an open fracture, and gross deformity (which was left to individual discrimination of the doctor) as they are clearly associated with the presence of a fracture.[3–5] Either the reception staff or triage nurse highlighted potentially eligible patients, with the study material left in the clinical notes. The clinician evaluating the patient made a final decision on eligibility and took written consent from either the patient or parent where appropriate. The daily patient attendance records were examined (by AW) to determine the proportion of potentially eligible patients recruited.

The South Trent regional ethics committee gave approval for the study to be performed.

Patient assessment

Clinicians involved in the study were permanent members of staff, and included experienced nurse practitioners, and

Abbreviations: CART, classification and regression tree; ED, emergency department doctors of senior house officer grade or higher. All clinicians involved in recruiting patients to the study underwent a training session with one of the study investigators, to detail how the data collection form should be completed and the method of standardised examination. Each patient who was entered into the study had the data collection form completed prior to any radiography being performed. The decision whether or not to order radiography was made by the clinician. Patients who did not have a radiograph were asked to return within 5 days if they still had significant symptoms.

The choice of variables to be analysed in this study was made following evaluation of the previous studies and consensus agreement from the study investigators. A reduction in grip strength was a clinical impression, in comparison to the uninjured limb. We did not use a specific instrument to measure grip strength, as such an instrument would not be available to most emergency physicians. The classification of zones of tenderness followed the anatomical zones described in a previous paper[1] (zone 1 including distal radius, zone 2 being the distal ulna, zone 3 the carpal bones excluding scaphoid, and zone 4 scaphoid tenderness).

Outcome measure

The outcome measure was the presence or absence of a fracture on a dual view wrist radiography as reported by a paediatric radiologist, who was aware only of the standard clinical information. In indeterminate reports that suggested clinical correlation, the medical records and further investigations were evaluated, and the final decision was made by an emergency physician, who was blinded to the predictor variables when determining outcome. For patients who did not have radiological evaluation on their initial presentation, the hospital records were examined for 30 days following attendance to identify repeat attendances for missed injuries.

Data analysis

Univariate variables were analysed with the χ^2 test. All variables associated with outcome ($p<0.2$) were entered into a multivariate model (logistic regression) to determine which were independently associated with the outcome. Sensitivity, specificity, and likelihood ratios were calculated for each independent clinical feature. SPSS software (version 11.5) was used for both univariate and multivariate analysis. Confidence intervals for likelihood ratios, sensitivity, and specificity were performed using plug in software for Microsoft Excel. All variables with moderate association were analysed with classification and regression tree (CART) software (version 5.0; Salford Systems, San Diego, CA) to determine the best combination of features to diagnose a fracture.

The fracture rate in a previous study was 50%.[1] With 10 key clinical features and 10 outcomes per variable as a minimum, it was calculated that we would need to recruit at least 100 patients with a fracture to produce meaningful results.[6]

Table 1 Comparative characteristics for recruited and non recruited patients

	Recruited patients	Non-recruited patients
Age, years (IQR)	10.6 (9 to 13)	10.3 (9 to 12)
Female sex, %	52.9	51.9
Fracture rate, %	47.3	39.4

IQR, interquartile range.

Table 2 Characteristics of patients presenting with a wrist injury (n = 227)

Characteristic	n (%)
Mechanism	
Fall onto outstretched hand	151 (66.5)
Direct blow	40 (17.6)
Unknown	12 (5.3)
Hyperflexion	8 (3.5)
Hyperextension	11 (4.8)
Twisting	4 (1.8)
Miscellaneous others	1 (0.4)
Site of fracture	
Ulna	2 (1.8)
Radius	64 (60.3)
Radius/ulnar	35 (33.0)
Carpal (excluding scaphoid)	0 (0)
Scaphoid	5 (4.7)
Fractures (%)	106 (47.3)

RESULTS

During the study period (28 January to 14 May 2004), 565 children presented to the ED with a wrist injury. There were 468 potentially eligible patients, of whom 227 were recruited to the study. The slightly higher fracture rate in the recruited patients was the only significant difference between the two groups (table 1).

Of the 227 patients recruited, 106 children had fractures diagnosed. In total 200 radiographs were requested (88.5% of all patients), identifying all the fractures on the initial visit. Only four patients required admission for a manipulation under anaesthesia. The other fractures were treated conservatively either with plaster immobilisation or a canvas splint as appropriate. For the patients not radiographed, there were no further attendances to our ED within 4 weeks. Table 2 shows the characteristics of the study population. The commonest mechanism of injury was a fall onto an outstretched hand (66.5%). Overall, 93% of all children with a fracture had a radial fracture; only 4.7% of the fractures involved the scaphoid.

Table 3 shows the results of univariate analysis. Using a significance level of $p<0.2$, six of 10 clinical features were associated with a fracture. Table 4 shows the results of multivariate analysis. Only radial tenderness, reduced supination/pronation and focal swelling were independently associated with a fracture at a significance level of $p<0.05$.

Table 5 demonstrates the sensitivity, specificity, and positive and negative likelihood ratio for the significant features. Absence of radial tenderness reduces the likelihood of a fracture by around a fifth, normal supination and

Table 3 Clinical features for diagnosis of a wrist fracture

Clinical feature	Proportion who had feature with a fracture (%)	OR (95% CI)	p
Injury to ED <6 hours	55.4	5.9 (2.8 to 12.7)	<0.001
Focal swelling	63.5	4.1 (2.4 to 7.2)	<0.001
Grip strength	54.5	2.2 (1.3 to 3.7)	<0.01
ROM supination and pronation	58.1	3.3 (1.9 to 5.7)	<0.001
ROM DF	50.0	1.6 (0.8 to 2.8)	0.17
ROM PF	49.2	1.3 (0.8 to 2.3)	0.38
Zone 1 tenderness	55.4	5.9 (2.8 to 12.7)	<0.001
Zone 2 tenderness	51.1	1.4 (0.8 to 2.3)	0.35
Zone 3 tenderness	43.8	0.9 (0.3 to 2.4)	1.0
Zone 4 tenderness	43.2	1.0 (0.5 to 2.0)	1.0

ROM, range of motion; DF, dorsiflexion; PF, plantar flexion.

Table 4 Multivariate analysis of clinical features

Clinical feature	Adjusted OR	p
Injury to ED <6 hours	1.8	0.06
Focal swelling	3.1	<0.001
Grip strength	1.2	0.53
ROM pron/sup	2.1	<0.05
ROM DF	0.5	0.12
Zone 1 tenderness	3.8	<0.01

ROM, range of motion; DF, dorsiflexion.

pronation and absence of focal swelling reduces the likelihood of a fracture by a half.

The performance of the rule produced by 10 fold cross validation is shown in table 6; this considered the rule to be positive if there was the presence of at least one of the following: radial tenderness, focal swelling, or a reduction in range of supination and pronation. The overall sensitivity of the rule was 99.1% (95% CI 94.8% to 100%), with a specificity of 24% (95% CI 17.2% to 32.3%). Application of this rule to the study population would have resulted in a radiography rate of 87%.

DISCUSSION

This is the largest prospective study to describe the value of clinical features in assessing paediatric wrist injuries. Previous studies have demonstrated that gross clinical signs such as deformity, fracture crepitus, and less obvious signs such as point radial tenderness, focal swelling, and reduction in grip strength increased the likelihood of a fracture being present.[1 2 4 5] The previous studies have significant limitations. The studies by Rivara *et al*, McConnochie *et al*, and more recently by Al-Adhami *et al*, analysed all extremity injuries together. It is possible that significant examination findings for the wrist may differ from significant findings for other regions of the limbs. The study by Rivara *et al* was a retrospective examination of case records, with the danger of incomplete recording of examination findings, which may result in the loss of important clinical data. The study by Pershad *et al* was a prospective trial that looked specifically at wrist injuries in children. The study only recruited 24 patients with fractures, which leads to higher type 2 error rates, with other clinical variables not being found to predict fractures owing to the study being underpowered to detect any difference.

We showed that three clinical features (radial tenderness, reduced supination and pronation, and focal swelling) were independently associated with the presence of a fracture. Individually the features did not change the pre-test probability greatly. Even the best discriminatory clinical finding (the absence of radial tenderness, with a likelihood ratio of 0.2) only decreased the post test probability risk of fracture to 17%. Combining the three clinical features did produce a very sensitive rule, but because of the low specificity, the test would not perform much better than standard clinical practice. During the study, the clinicians felt confident from their evaluation that 11% of patients did not require a radiograph, and none of these patients returned with a fracture. Following our rule would mean that 87% of patients would have been radiographed. Additionally, although scaphoid tenderness did not appear helpful, we would not advise clinicians to ignore this sign, as the prevalence of scaphoid injuries in children is low and our study would be underpowered to detect the value of this sign.

Table 6 Performance of the clinical decision rule

Rule	Fracture present	Fracture absent	Total
Positive	105	92	197
Negative	1	29	30
Total	106	121	227

Our study has some limitations that should be borne in mind when interpreting the results. We only recruited approximately half the eligible patients. This is not surprising because the requirement to obtain written consent acts as a disincentive to the clinical staff who undertook recruitment. Recruitment might have been maximised by employing research staff to undertake recruitment or by conducting the study without written consent. Resources were not available to allow the former and the latter could not be ethically justified. Additionally, we were unable to get enough patients seen by two clinicians to check interobserver reliability of the findings. A final limitation is the group of patients who were not radiographed, due to the clinician putting them at a low clinical probability of fracture and thus believing they did not need radiography. Potentially, some of these patients could have been misclassified and could have had a fracture. We feel that this possibility is small. It is unlikely that they went to a different department, as the nearest centre seeing children is around 20 km away and we specifically asked the patients to return to us if they had significant symptoms after 5 days.

The reason that a decision rule for ankle and foot trauma has been shown to be effective in reducing the radiography rate is probably due to the higher proportion of soft tissue injuries.[7] It has been demonstrated that the introduction of the Ottawa ankle rule in a paediatric population was both safe and effective, reducing the radiography rate by 7.2%, but the fracture rate was <10% and the radiography rate before introduction of the rule was 64%.[8] If we compare this to wrist trauma, which has a prevalence of fracture of around 50%, then the yield of positive radiographs will be high even when most children have a radiograph taken. It appears unlikely there would be much value in the validation of this decision rule to improve the efficiency of resource use, as it appears not to be significantly better than clinicians at discriminating between soft tissue injuries and fractures. Alhough a small reduction in the radiography rate could be achieved, the investigation is a low cost procedure with limited potential

Table 5 Diagnostic value of significant features

Feature	Sensitivity (95% CI)	Specificity (95% CI)	Likelihood ratio + (95% CI)	Likelihood ratio to (95% CI)
Zone 1 tenderness	91 (86.1 to 95.3)	36 (30.8 to 38.8)	1.4 (1.3 to 1.6)	0.2 (0.1 to 0.4)
Focal swelling	69 (62.1 to 75.0)	65 (59.3 to 71.0)	2.0 (1.5 to 2.6)	0.5 (0.4 to 0.6)
ROM supination and pronation	75 (67.8 to 80.6)	53 (47.0 to 58.2)	1.6 (1.3 to 1.9)	0.5 (0.3 to 0.7)

ROM, range of motion.

for cost savings. Additionally, the increased risk of cancer from a limb radiograph is negligible, equating to a risk of only a few hours of background radiation or a risk per exposure of <1 in a million.[9] As Stiell would argue, if the test is already ''efficient'' there is no need for a clinical decision rule.[10]

In summary, although clinical features are associated with the presence of a fracture, their low discriminatory value means the potential for a clinical decision rule for paediatric wrist trauma appears limited.

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CORRECTION

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In the images in Emergency Medicine paper published in the March issue of EMJ (*Emerg Med J* 2006;**23**:239) the co-authors were omitted from the author list. The correct author listing is T Moutray, S Nabili, JA Sharkey. The journal apologises for this error.