ORIGINAL ARTICLE

Can a normal range of elbow movement predict a normal elbow *x* ray?

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Background: Elbow injuries account for approximately 2–3% of presentations to the emergency department. This is associated not only with a very high rate of *x* rays but also with a very high rate of ''missed fractures'' This study examines which components of elbow examination have the best correlation with a normal radiograph.

Design setting: A district general hospital's emergency department seeing 83 000 new attendances per annum (pa) (approximately 1600 elbow injuries pa).

Methods: After estimating the power before data collection, all patients presenting with elbow injuries were considered for inclusion, and were excluded only if they were unable to follow instructions owing to either reduced conscious levels or mental conditions. A proforma was completed after patient examination, indicating the features of clinical examination, and the results of radiographs if any. The formal report of all radiographs taken was sought from the radiology department.

Results: 407 patients were entered into the study, of whom 331 received a radiograph of the elbow. Full extension of the elbow had a specificity of 0.916 (95% confidence interval (CI) 0.863 to 0.969, sensitivity 0.478) for detection of a normal radiograph. An equal range of movement ROM had a specificity of 0.976 (95% CI 0.940 to 0.991, sensitivity 0.211). Subgroup analysis of patients aged <16 years showed a specificity of equal ROM of 1 (95% CI 0.941 to 1.000) for the detection of a normal *x* ray.

Logistic regression analysis showed that best predictive values were achieved by a combination of full extension, flexion and supination.

Conclusion: A two-tier clinical rule for management of elbow injury is proposed: (1) Those patients aged ⩽16 years with a ROM equal to the unaffected side may be safely discharged; (2) Those patients with normal extension, flexion and supination do not require emergent elbow radiographs.

Elbow injuries account for a considerable proportion of attendances to any emergency department. They affect all age groups, although the exact pathology at each age varies. It is also well recognised that interpretation of the elbow *x* ray is difficult and that there is a marked ''missed fracture'' rate. A New York University Hospital[1] reported that 2–3% of their attendances were due to elbow injury. They experienced a missed fracture rate despite radiography of 10.8% of all fractures presenting the third most frequently missed fracture group.

The introduction of clinical rules for joints, such as the Ottawa ankle, knee and cervical spine rules, and the Pittsburgh knee rule, have aided junior staff in the assessment of joints, and have guided the use of investigation.[2–6] Two groups have previously looked at the use of abnormal elbow extension as a predictor of significant injury.[7 8] Both groups noted that extension alone some fractures judged clinically significant, although not requiring active intervention.

Our study prospectively assessed the ability of a normal range of movement during elbow examination to predict a normal elbow radiograph. We were especially interested in specific movements or combinations of movements that would increase the sensitivity of clinical examination to predict a normal radiograph.

METHOD

The study was set in Derbyshire Royal Infirmary (Derbyshire, UK), a district general hospital seeing 83 000 new attendances per annum. A statistician was consulted to ensure that the study design would detect abnormalities in *x* rays in patients with a ''normal'' range of movement with an incidence between 2% and 10% at a power of 95%. These figures were based on results from an internal review of notes at the hospital. This showed a rate of *x* ray requests of 33% from those presenting with elbow injury, and showed an abnormality rate of 6% on *x* rays in case of a normal examination. It was calculated that 136 patients would need to receive an *x* ray in order to achieve the required power. On the basis of an *x* ray rate of 33%, 409 patients were needed to be included in the study. Ethical approval was obtained from the local committee.

All patients presenting with elbow injury during January–September 2003 were considered for inclusion at their time of presentation. Patients were excluded only if they were unable to follow instructions owing to mental incapacity as a result of illness or injury. The patients were seen by a practitioner (either medical or emergency nurse practitioner), and investigations/treatment was initiated according to the practitioner's clinical judgement. On completion of treatment, a proforma detailing the mechanism of injury, symmetry of clinical examination and the results of any plain radiography (if requested) was completed by the practitioner. This proforma was then returned to the research team for analysis. If a radiograph had been taken, a formal radiology report was sought and the findings added to the patient database.

RESULTS

The study collected data from 407 patients, of whom 331 received an *x* ray. The demographics of the sample are displayed in table 1. Those who were not *x* rayed were not included in the analysis although their attendances were cross-referenced to

Abbreviations: PPV, positive predictive value; ROM, range of movement

Table 1 Demographics

Number of patients entered	407
Average age (range)	29.24 (2–96)
Male:female	1.09:1
Time from injury to presentation (h)	
<24	320
24–48	39
>48	37
Not recorded	11
Seen by	
ENP/ANP	140
SHO	160
Middle grade	38
Consultant	59
Number receiving *x* ray (%)	331 (81.3)
Number of abnormals (% of those *x* rayed)	
Fracture	122 (36.9)
Fat pad	52 (15.7)
Dislocation	9 (2.7)

note any re-attendance. The data were then used to assess the specificity and sensitivity of four measures (full extension, full flexion, pro/supination, and equal range of movement in both arms) in identifying a normal patient (table 2). The specificity of each of the four factors is high. This suggests that if a patient with an abnormal *x* ray is being examined, then there is a high probability that one or more of the four factors would be abnormal. However, sensitivity is low, suggesting that patients with normal *x* rays could have an abnormal examination.

If these factors are used in a test to ascertain whether patients should be sent for an *x* ray, then the positive predictive values (PPVs) need to be considered. Each of the four factors has a high PPV, suggesting that, at examination, if any ROM is normal, then the radiograph has a high probability of being normal (table 3).

However, the 95% confidence limits for the negative predictive values of these factors are grouped around 0.5. Therefore, if any of the four factors are abnormal on examination then the chances of a normal or abnormal radiograph are approximately equal.

The patients' dataset was also analysed in two age-differentiated groups, as it was felt that the developmental differences between the paediatric and the adult elbow could lead to a difference in results. The overall pattern is similar, but it is worth noting that the specificity for a normal *x* ray of an equal ROM tends to 1.

Logistic regression was used to assess whether a combination of the four factors would be useful in predicting a normal patient. It was found that the three factors extension, flexion and supination should be used in such a model, but the addition of equal ROM was not statistically significant, probably because of the small number of patients with this sign—it would be a poor discriminator in general use.

CONCLUSIONS

There is a high specificity for physical examination to predict a normal elbow radiograph. In one group (the under 16 years), this means that the PPV is so high that we can effectively rule out abnormality on *x* ray with clinical examination alone (table 4) . In older patients the PPV is slightly lower, which means that there is a small risk of incorrectly predicting a normal *x* ray from a normal examination.

DISCUSSION

This study shows that clinical examination is successful in being able to predict a normal *x* ray in most patients presenting with elbow injuries. However, in our study, one patient presented with an equal ROM, and full extension/flexion/pro-supination, was *x* rayed and found to have a fracture of the radial head. Two further patients with similar examinations

Table 2 Radiographic abnormality versus normal

	Full extension	Full flexion	Full pro	Equal ROM
Sensitivity	0.478 (0.403, 0.555)	0.565 (0.488, 0.639)	0.509 (0.433, 0.585)	0.211 (0.155, 0.281)
Specificity	0.916 (0.863, 0.949)	0.777 (0.708, 0.834)	0.795 (0.727, 0.850)	0.976 (0.940, 0.991)
PPV	0.846 (0.758, 0.906)	0.711 (0.627, 0.782)	0.707 (0.618, 0.782)	0.895 (0.759, 0.958)
NPV	0.664 (0.581, 0.702)	0.648 (0.580, 0.711)	0.626 (0.559, 0.688)	0.561 (0.503, 0.617)

NPV, negetive predictive value; PPV, positive predictive value; ROM, range of movement.

Table 3 Radiographic abnormality versus normal for age ⩾17 years

	Full extension	Full flexion	Full pro	Equal ROM
Sensitivity	0.541 (0.436, 0.643)	0.612 (0.505, 0.708)	0.518 (0.413, 0.621)	0.259 (0.178, 0.361)
Specificity	0.924 (0.857, 0.961)	0.743 (0.652, 0.817)	0.800 (0.714, 0.865)	0.962 (0.906, 0.985)
PPV	0.852 (0.734, 0.923)	0.658 (0.548, 0.753)	0.677 (0.556, 0.778)	0.846 (0.665, 0.939)
NPV	0.713 (0.632, 0.783)	0.703 (0.612, 0.780)	0.672 (0.586, 0.748)	0.616 (0.540, 0.687)

NPV, negetive predictive value; PPV, positive predictive value; ROM, range of movement.

Table 4 Radiographic abnormality versus normal for age <16 years

	Full extension	Full flexion	Full pro	Equal ROM
Sensitivity	0.408 (0.304, 0.520)	0.513 (0.403, 0.622)	0.500 (0.390, 0.610)	0.158 (0.093, 0.256)
Specificity	0.902 (0.802, 0.954)	0.836 (0.724, 0.908)	0.787 (0.669, 0.871)	1.000 (0.941. 1.000)
PPV	0.838 (0.689, 0.923)	0.796 (0.664, 0.885)	0.745 (0.611, 0.845)	1.000 (0.757, 1.000)
NPV	0.550 (0.452, 0.644)	0.580 (0.475, 0.677)	0.558 (0.453, 0.658)	0.488 (0.402, 0.575)

NPV, negetive predictive value; PPV, positive predictive value; ROM, range of movement.

were found to have a positive fat pad. In common with previous studies of relying on elbow extension alone, clinical examination has failed by a small proportion (0.3%). This has clinical risk repercussions. This might be because the manner of examination used by each different practitioner was not rigorously controlled (only the general movement groups were requested in the proforma, not how each group was assessed), or because there exists a subset of patients who are able to move their elbow despite bony injury. Extrapolating these data to our own hospital population could result in 16 patients/year not having their elbow abnormality (including fat pad sign) detected by *x* ray at first attendance. However, in common with previous studies, all these injuries would be treated with conservative management, and mobilised early.

There is a possibility for observer bias in this study: the variance in radiography request rate before our study in our internal retrospective analysis and that noted during the study may be attributable to this, although might be it unlikely to have altered the outcomes detected.

Further studies are required to delineate whether an isolated fat pad sign (ie, no visible fracture on presentation) requires any treatment other than early mobilisation. This possibility was considered in our initial study design. However, we believe that there is not enough information to recommend conservative management without the use of *x* rays in this group, even though incidence of occult fracture has been reported to be as low as 6%.[9] In our study, if effusion was to be treated without differentiating from a normal patient, then 72.1% of the patients would be correctly predicted as normal by the logistic model using full extension/flexion/pro- supination and supination. This compares with a rate of 57.1% in our study as presented. This could mean a reduction in radiography of 15%, but a doubling of ''missed patients'' from 0.3% to 1% of attendances by the inclusion of those with isolated fat pads on *x* ray.

We would propose the following two-tier clinical rule.

1 Those patients aged $\leqslant$ 16 years with a ROM equal to the unaffected side may be safely discharged. The high specificity of equal range of movement for a normal *x* ray in this age group supports this.

2 Those patients with normal extension, flexion and supination do not require emergency elbow radiographs.

An open return clinic appointment may act as a safety net to identify those with injury who have not been detected at first presentation, although we would predict that the missed fat pad signs would probably not re-present to this clinic.

A further study examining the long-term outcomes of those not *x* rayed is also needed to assess the viability of early mobilisation without radiography as viable management plan.

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