Can the Ottawa knee rule be applied to children? A systematic review and meta-analysis of observational studies

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ABSTRACT

Background: The Ottawa knee rule (OKR), a clinical decision aid is used to reduce unnecessary radiography. It is not clear whether this rule can be applied to children.

Objective: To establish whether the OKR had adequate sensitivity and acceptable specificity in children to advocate widespread use.

Methods: A systematic review and meta-analysis was conducted of observational studies that examined the diagnostic characteristics of the OKR in children.

Data sources: Relevant English language articles were identified from Medline (1950 to date), EMBASE (1974 to date), CINAHL (1982 to date), the Cochrane Library, Google Scholar and a hand search of bibliographies.

Study selection: Observational studies that included children and have used the OKR for ruling out fractures in children either radiologically or in combination with follow-up.

Results: Four relevant studies were identified. Three studies were suitable for inclusion in the meta-analysis, representing 1130 children. The pooled negative likelihood ratio was 0.07 (95% CI 0.02 to 0.29), the pooled positive likelihood ratio was 1.94 (95% CI 1.60 to 2.36), the pooled sensitivity was 99% (CI 94.4 to 99.8) and the pooled specificity was 46% (CI 43.0 to 49.1). The reduction in radiography was between 30% and 40%.

Conclusion: The OKR has high sensitivity and adequate specificity for children over the age of 5 years. There are not enough good data to advocate application of the OKR in children less than 5 years.

Among children and adolescents visiting emergency departments (ED) for trauma, between 10% and 20% present with an injury involving an extremity.[1 2] In this group, more than 90% of them undergo radiographic studies.[1–4] Knee injuries account for 8%[2] of these injuries and are typically caused by sport-related injuries, road traffic collisions and falls. Approximately 5% of children presenting with knee injuries will have a fracture.[5]

The Ottawa knee rule (OKR) is a clinical decision rule that was developed to reduce radiography for knee injuries, see fig 1.

This clinical rule is designed to have high sensitivity and moderate specificity, so that it confidently rules out a bony injury and reduces the need for a radiograph. The OKR was derived and subsequently validated in adults.[6–8] Neither the derivation, validation studies nor the subsequent meta-analysis included patients under 18 years of age. There are other decision rules to guide radiograph requesting, but the OKR is based on the largest number of subjects and most sound methodology.[9–11] The OKR is also the most widely used and known knee decision rule. Children have different injury patterns and complain of different symptoms to adults. Children are also more vulnerable to the effects of radiation; both physicians and parents want to reduce unnecessary radiation exposure. Previous work evaluating the OKR in children has been with relatively small studies with wide confidence intervals around the sensitivity, limiting the confidence of clinicians to apply the rule in practice.

We wanted to establish whether the OKR had adequate sensitivity and acceptable specificity in children to advocate widespread use. We also aimed to see if the OKR could be applied safely to children under 5 years of age. Children under 5 years have different injury patterns and presentations; 5 years was chosen arbitrarily. We hoped pooling results would provide us with narrower confidence intervals and provide additional reassurance in the safety of the rule. We also wanted to estimate the likely reduction in radiograph requesting if the OKR was applied to children.

METHODS

Identification

Relevant English language articles were identified from Medline (1950 to date), EMBASE (1974 to date), CINAHL (1982 to date), the Cochrane Library, Google Scholar and a hand search of bibliographies. We did not define the upper age limit, as this varies between countries. The search strategy is shown in table 1. We included all papers that studied the performance of the OKR in children. Papers were excluded from the meta-analysis that did not report diagnostic parameters of the OKR.

Quality assessment

We (DV and AAB) graded the papers according to the level of evidence described by the Oxford Centre for Evidence-based Medicine.[12] Concordance of grading was perfect. We included prospective observational studies in the meta-analysis, as only those studies provided suitable data. Data were extracted by a single, unblinded abstracter (DV).

Statistical analysis

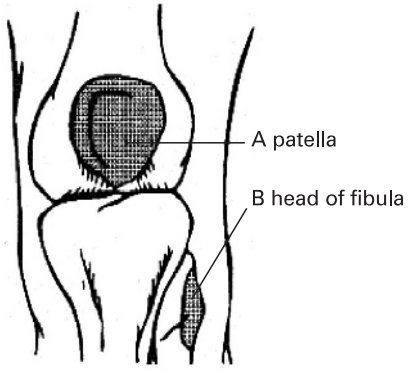
We performed a random effects meta-analysis to produce pooled positive and negative likelihood ratio tests using STATA version 7 on the prospective observational studies. We estimated pooled sensitivities, specificities, predictive values and a

Figure 1 The Ottawa knee rule.

An x-ray is indicated if the patient has any of the following features:

Age > 55 years
Inability to bear weight both immediately and in the emergency department (4 steps) **
Isolated tenderness of the patella*
Tenderness at head of fibula
Inability to flex to 90˚

*No bone tenderness of knee other than patella
**Unable to bear weight twice onto each limb regardless of limping[6]



summary receiver operator characteristic (ROC) curve using dr-ROC version 2.1. In the meta-analysis, studies were weighted by their size alone. Two studies had a zero value in their cells and we corrected this by a continuity correction of 0.5 to all values.[13 14]

RESULTS

Four studies were identified. Table 2 shows the evidence level, sensitivity and specificity and negative likelihood ratios of the selected studies. No additional studies were found on Google Scholar, in the Cochrane Library or the hand search. The three level two studies were included in the meta-analysis. We did not include the study by Cohen *et al*,[15] as the data could not be abstracted in a suitable form for meta-analysis. This represents 1130 children with 98 fractures. All the children in the three prospective studies underwent radiography. One fracture was missed by the OKR, this was an 8-year-old boy who had a fracture of his proximal tibia following a fall.[16] The pooled negative likelihood ratio was 0.07 (95% CI 0.02 to 0.29), the positive likelihood ratio was 1.94 (95% CI 1.60 to 2.36), the pooled sensitivity was 99% (95% CI 94.4 to 99.8) and the pooled specificity was 46% (95% CI 43.0 to 49.1). Pooled test characteristics are presented in table 3 and pooled likelihood ratios in fig 2 and fig 3.

There was little heterogeneity between the studies with an I^2 score of 0.27 and a Cochrane's Q of 2.77 (2 df) $p = 0.29$. There was a greater degree of heterogeneity on the estimate of pooled positive likelihood ratio tests, but this is a relatively less important measure for the rule.

We constructed a summary ROC curve, the pooled area under the curve was 0.90 (95% CI 0.74 to 0.97) using a random effects model and 0.92 (95% CI 0.83 to 0.97) using a fixed effects model.

The fixed effects model is probably more valid as there is little heterogeneity between the three studies. Only one study performed a subgroup analysis based on age, 45 children between 2 and 5 years of age.[14] Although sensitivity was high,

Table 1 Search strategy

	Search term	No of references found by database: Medline from 1950	Embase 1974 to date	CINAHL 1982 to date
1	Knee injuries	11 316	4010	2102
2	Rules	57 594	45 363	14 142
3	Children or adolescents or infants	2 402 616	842 119	164 581
4	1 and 2	87	69	97
5	3 and 4	29	13	21
	Total no of references with duplicates excluded	51		
	Studies specifically focused on children and the OKR	4		

OKR, Ottawa knee rule.

Table 2 Diagnostic performance of the OKR in primary studies

Study, year and (no of patients) reference	Quality level	True positive	False positive	False negative	True negative	Sensitivity (95% CI)	Specificity (95% CI)	Negative likelihood ratio (95% CI)	Reduction in *x* ray requests (%)
Khine *et al*, 2001 (234)[16]	2b	12	113	1	108	92.3 (66.1 to 99.3)	48.6 (42.4 to 56.7)	0.02 (0.00 to 0.26)	46.0
Bulloch *et al*, 2003 (750)[14]	2a	70	390	0	290	100 (94.9 to 100)	42.8 (39.1 to 46.5)	0.02 (0.00 to 0.26)	31.2
Moore *et al*, 2005 (146)[13]	2b	15	54	0	77	100 (82.3 to 100)	58.7 (50.0 to 67.6)	0.05 (0.00 to 0.82	53.0
Cohen *et al*, 1998, (254)[15]	4	12	NR*	0	NR*	100 (75.8 to 100)	76.4 (70.7 to 81.4)	NR	73.0

*These values were not reported in the text. OKR, Ottawa knee rule.

Table 3 Pooled test values of the OKR

Sensitivity (95% CI)	Specificity (95% CI)	Positive predictive value (95% CI)	Negative predictive value (95% CI)	Prevalence of fracture (95% CI)
99.0 (94.4 to 99.8)	46.0 (43.0 to 49.1)	14.8 (12.3 to 17.8)	99.8 (12.3 to 17.8)	8.7 (7.2 to 10.5)

OKR, Ottawa knee rule.

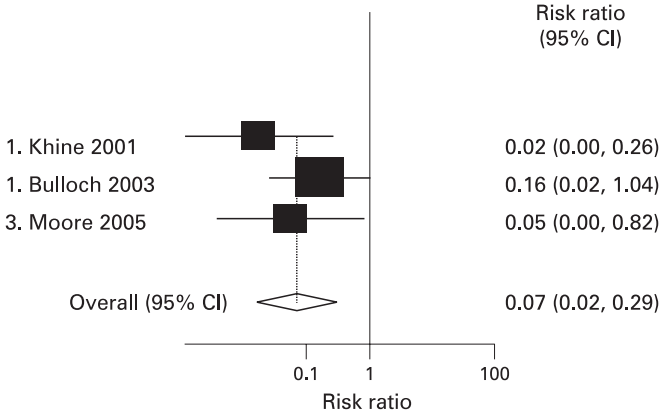


Figure 2 Pooled negative likelihood ratios. Heterogeneity $\chi^2 = 2.25$ (df = 2) p = 0.325. Estimate of between-study variance $\tau^2 = 0.1926$. Test of relative ratio 1: z = 3.64, p = 0.000.

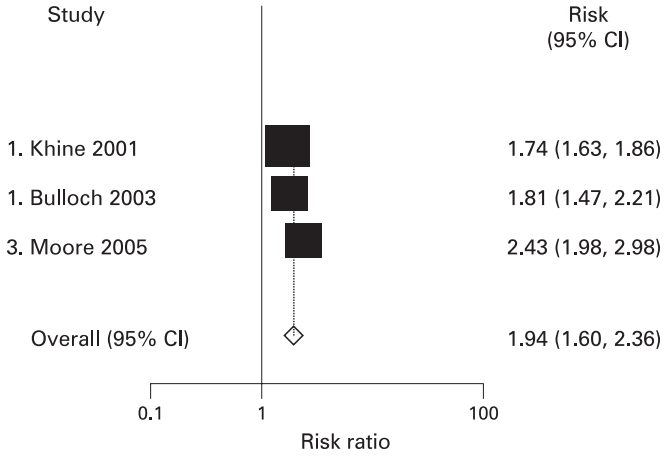


Figure 3 Pooled positive likelihood ratios. Heterogeneity $\chi^2 = 9.46$ (df = 2) p = 0.009. Estimate of between-study variance $\tau^2 = 0.0231$. Test of relative ratio 1: z = 6.64, p = 0.000.

the confidence intervals were wide, sensitivity 100% (95% CI 47.8 to 100). The other two prospective studies did not present data specifically about children under 5 years.

DISCUSSION

We have found that the OKR is a sensitive and specific decision rule for children over the age of 5 years. The sensitivity is high enough for this to be used to rule out fractures and have an adequate specificity. There are insufficient good data to advocate application of the OKR in children less than 5 years. Fractures around the knee are relatively rare in the under fives, tibial and femoral fractures are more common. Children under 5 years of age can be harder to assess. Unlike many diagnostic studies, the prospective primary studies all applied the gold standard (radiography) to all the participants. These studies estimate that the reduction in radiography is likely to be approximately 30–40%, depending on local practice. Evidence from adults suggests that the ability of the OKR to reduce *x* ray requesting is mixed and depends on local practice.[17]

There are some limitations to our study. There were only three studies suitable for inclusion in the meta-analysis. The quality of these studies was not high, with little blinding. However, the results across all of these studies are consistent. There are always concerns about publication bias in systematic reviews, although the failure of a well-known decision rule would have been very interesting to most journal editors. The definition of "child" is arbitrary and covers a wide range of stages in physical development. We did not present an economic evaluation as this has been done previously and comparing across healthcare systems is complex.[18] We only searched in English and may have missed relevant papers published in other languages, although we feel this is unlikely. The paucity of studies we had made subgroup and sensitivity analyses impractical.

CONCLUSION

The available evidence suggests that the OKR can safely be applied to children over the age of 5 years. There is insufficient evidence to justify the use of the OKR in children less than 5 years.

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