# Validation of the Ottawa Knee Rules

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**Study objective:** We sought to validate the Ottawa Knee Rules for determining the need for radiography in patients with acute knee injury.

**Methods:** A prospective cohort study was performed in emergency departments of 11 hospitals of the Osakidetza–Basque Country Health Service. The patient population was composed of a convenience sample of 1,522 eligible adults of 2,315 patients with acute knee injuries. The attending emergency physicians assessed each patient for standardized clinical variables and determined the need for radiography according to the decision rule. Radiography was performed in each patient, irrespective of the determination of the rule, after clinical evaluation findings were recorded. The rule was assessed for the ability to correctly identify fracture of the knee.

**Results:** The decision rule had a sensitivity of 1.0 (95% confidence interval [CI] 0.96 to 1.0), identifying 89 patients with clinically important fractures. The potential reduction in use of radiography was estimated to be 49%. The probability of fracture, if the decision rules were negative, is estimated to be 0% (95% CI 0% to 0.5%).

**Conclusion:** Prospective validation has shown the Ottawa Knee Rules to be 100% sensitive for identifying fractures of the knee and to have the potential to allow physicians to reduce the use of radiography in patients with acute knee injuries.

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## INTRODUCTION

Acute knee injury is a common presenting complaint in patients seen in emergency departments. In our setting, all such patients are examined radiographically. One of the reasons for this is the need to exclude a clinically im-

portant fracture and the fear of litigation in the case of missing such a fracture. Because the majority of knee injuries involve meniscal or ligamentous tissue and the main diagnostic utility of knee radiographs is for detecting fractures, a low percentage of radiograms demonstrate fracture.[1]

Clinical prediction rules are potentially useful tools for this type of clinical problem, helping physicians manage these patients. Clinical prediction rules can help clinicians cope with the uncertainty of medical decisionmaking and improve efficiency.[2] Methodologic standards for the development of clinical decision rules have been described, originally by Wasson et al[3] and Feinstein[4] and more recently by Stiell and Wells[5] and Laupacis et al.[6]

Stiell et al[1,7,8] successfully derived and validated a clinical decision rule (Figure) to determine the need for knee radiographs that has proved to be 100% sensitive for clinically important fractures of the knee in a validation study carried out in Canada.

Clinical prediction rules frequently do not perform as well when tested in patients other than those from whom the rule was derived. This study prospectively evaluates the Ottawa Knee Rules (OKR) used by physicians not involved in their development on a new set of patients to determine the classification accuracy and potential for reducing use of radiography.

## MATERIALS AND METHODS

The study was conducted in the emergency departments of 11 of the 12 hospitals of the Osakidetza–Basque Country Health Service (Spain), serving a population of more than 2 million. The joint annual volume of emergencies for these 11 hospitals is close to 710,000. The attending physicians are internists or family physicians who have followed the unofficial training program of the Spanish Society for Emergency Medicine. The inclusion criteria and definitions adopted were the same as those used to develop the OKR.[7] All adult patients who presented with acute knee injuries were potentially eligible, and "knee" was broadly defined to include the patella, the head and neck of the fibula, the proximal 8 cm of the tibia, and the distal 8 cm of the femur. We excluded patients who were younger than 18 years, were pregnant, had isolated injuries of the skin, were referred from outside the hospital with radiographs, had knee injuries occurring more than 7 days previously, had returned for reassessment of the same injury, had an altered level of consciousness, were paraplegic, or had multiple injuries. The study was approved by the institutional research committee.

Patients were assessed for the 5 variables included in the OKR. Additional information on time from injury, mechanism of injury, activity at time of injury, patient sex, mode of referral to the ED, and previous surgery on the injured knee was collected. Patients were assessed by the attending staff physicians, who were trained in a 1-hour lecture to assess the clinical variables and to interpret the decision rules.

A standardized description of examination techniques was appended to the data collection sheet that the physicians completed before radiography. The data collection sheet was designed to be read by an optical mark recognition scan. In addition, physicians were given a small card (credit card size) with the inclusion and exclusion criteria and the rules as a reminder. At least 2 posters (80 × 120 cm) were displayed on the walls explaining the objective of the study, the criteria, and the rules.

In accordance with our usual practice, radiographs were ordered for all the patients. All patients had at least 2 views, posteroanterior and lateral, and the tangential view of the patella was at the discretion of the attending physician. The result of the radiographic examination was recorded on the data collection sheet. The sheet was sent for processing, and a carbon copy was attached to the patients' charts.

The criterion standard that the decision rules was developed to identify was a clinically important fracture of the knee demonstrated on a standard knee radiographic series. Clinically unimportant fractures were defined as an avulsion fragment that was less than 5 mm in breadth and that was not associated with a complete tendon or ligament disruption.

The radiographs were interpreted, as usual, by the physicians treating the patient in the ED. Fractures were

**Figure.**
*Decision rule for radiography in acute knee injuries.*

A knee radiographic examination is only required for patients with acute knee injuries with 1 or more of these findings related to age, tenderness, or function:
- Age 55 years or older
- Tenderness at head of fibula
- Isolated tenderness of patella*
- Inability to flex to 90°
- Inability to bear weight both immediately and in the ED (4 steps)†

Adapted with permission from Stiell IG, Greenberg GH, Wells GA, et al. Derivation of a decision rule for the use of radiography in acute knee injuries. *Ann Emerg Med.* 1995;26:405-412.

*No bone tenderness of knee other than patella.

†Unable to transfer weight twice onto each lower limb, regardless of limping.

also seen by the traumatologist on duty, who made the final diagnosis.

The performance of the decision rule for identifying patients with a clinically important fracture was assessed by calculating sensitivity and specificity with 95% confidence intervals (CIs). Proportions are given as point estimates in percentage and 95% interval estimation (exact binomial or normal approximation when appropriate). The potential relative reduction in radiography referral was estimated by comparing the theoretic referral rate in this study with the usual rate.

Statistical analyses were done with SYSTAT 7.0 (SPSS Inc., Chicago, IL) statistical software.

## RESULTS

During the study period, from January to September 1999, a total of 1,522 (65.7% of patients with acute knee injuries) patients were eligible and hence were enrolled in the study (Table 1). The remaining 793 patients were ineligible because of exclusion criteria: the most common was age younger than 18 years (345 patients), followed by multiple injuries (207 patients).

Overall, 89 (5.85%) patients were determined to have clinically important fractures; 5 had 2 fractures, making the total number of fractures 94. Another 4 (0.26%) patients were found to have clinically unimportant fractures (Table 2). Four of the 5 patients with 2 fractures had proximal tibia and head of fibula fractures, and 1 had head of fibula and tibial tuberosity fractures.

The prospective performance of the decision rules is shown in Table 3. All 94 clinically important fractures were identified by the decision rule (sensitivity 1.0; 95% CI 0.96 to 1.0). Furthermore, 745 patients without fractures did not require radiography according to the rule

**Table 1.**
*Patient characteristics.*

| Characteristic | No. of Patients (%, n=1,522) |
|---|---|
| **Male sex** | 883 (58) |
| **Mechanism of injury** | |
| Direct blow | 746 (49) |
| Twisting | 776 (51) |
| **Activity at time of injury** | |
| Work | 191 (12.6) |
| Sports | 359 (23.6) |
| Motor vehicle crash | 126 (8.3) |
| Other | 846 (55.6) |
| **Mode of referral** | |
| Self-referral | 1,324 (87) |
| Primary care physician | 112 (7.4) |
| Nonhospital emergency service | 86 (5.6) |
| **Time since knee injury** | |
| <24 h | 1,118 (73.5) |
| >24 h | 404 (26.4) |
| **Previous surgery** | 111 (7.3) |
| **Hospital** | |
| Alto Deba | 54 (3.6) |
| Aranzazu | 111 (7.3) |
| Basurto | 103 (6.8) |
| Bidasoa | 129 (8.5) |
| Cruces | 145 (9.5) |
| Gipuzkoa | 259 (17) |
| Mendaro | 139 (9.1) |
| San Eloy | 90 (5.9) |
| Santiago | 33 (2.2) |
| Txagorritxu | 346 (22.7) |
| Zumárraga | 113 (7.4) |

**Table 2.**
*Fracture characteristics.*

| Characteristic | No. of Patients (%, n=1,522) |
|---|---|
| **Clinically important fractures** | 94 |
| Patella | 46 (3%) |
| Proximal tibia | 21 (1.4%) |
| Head of fibula | 12 (0.8%) |
| Distal femur | 5 (0.3%) |
| Tibial spine | 5 (0.3%) |
| Tibial tuberosity | 5 (0.3%) |
| **Clinically unimportant fracture** | 4 (0.3%) |
| **Radiography performed** | |
| Knee | 1,522 (100%) |
| Patella | 156 (10%) |

There were 89 patients, 5 of whom had 2 fractures each.

**Table 3.**
*Classification performance of the decision rule for identifying clinically important knee fractures among the study patients.*

| | Fracture | |
|---|---|---|
| **Decision Rule** | **Yes** | **No** |
| Positive | 89 | 688 |
| Negative | 0 | 745 |

Sensitivity was 1.0 (95% CI 0.96 to 1.0), specificity was 0.52 (95% CI 0.49 to 0.55), negative predictive value was 1.0 (95% CI 0.99 to 1.0), and positive predictive value was 0.11 (95% CI 0.09 to 0.14).

(specificity 0.52, 95% CI 0.49 to 0.55). All 4 clinically unimportant fractures were identified by the rule.

Application of this decision rule to the study patients would have led to a relative reduction in the use of knee radiography of 49% from baseline levels (from 100% to 51%).

Age was associated with a higher probability of fracture: 14% (95% CI 10.3% to 18.4%) of patients age 55 years or older had fractures compared with 3% (95% CI 2.2% to 4.5%) of younger patients ($P<.05$). The sex distribution was the same among patients with and without fractures. Motor vehicle crashes and casual injuries were associated with a higher proportion of fractures (7%, 95% CI 2.7% to 13.8%) than work- and sport-related injuries (3%, 95% CI 0.9% to 5.5%, $P<.05$).

Fractures were more frequent among patients seen within the first 24 hours after injury (6.9%, 95% CI 5.2% to 8.7%) than among patients seen later (2.9%, 95% CI 1.3% to 5.5%, $P<.05$).

Direct blow was a more frequent mechanism of fracture (9.7%, 95% CI 7.3% to 12.3%) than torsion (1.9%, 95% CI 0.9% to 3.3%, $P<.05$).

Patients referred by SAU (nonhospital emergency service; 14.2%, 95% CI 6.6% to 24.4%) had more fractures than those with other modes of referral (family physician: 7.3%, 95% CI 2.6% to 14.6%; self-referral: 5.2%, 95% CI 3.9% to 6.7%, $P<.05$).

## DISCUSSION

This study confirms the high sensitivity of the OKR, as previously published by the researchers who developed it. The value of this study is twofold: first, the sensitivity has been calculated after prospectively applying the rule to a sample of consecutive patients in an independent setting, and second, we can be sure that no clinically important fracture has been missed because all the patients underwent radiographic examination.

Despite the different settings, the proportion of fractures is essentially the same, with a similar distribution of fracture sites. The similar distribution may account for the similar OKR performance in both studies.

The potential reduction of radiographs that could be achieved in our hospitals by applying the rule is much bigger than the reduction estimated in the original report of the OKR, which is obviously caused by the different baseline use of radiography.

Although not specifically examined in our study, the time spent waiting for nearly half of our patients could be shortened by not ordering a radiograph.

Among the decision rules developed to help with patients with knee injuries, we selected that of Stiell et al[8] because it is the only one that assessed its interobserver agreement and was developed fulfilling the methodologically accepted criteria. It is the most widely and prospectively assessed and implemented until now.

There are other rules[9-11] for the same clinical condition, but unlike the one we assessed, these have not been developed according to the standard criteria. Despite that, some evidence exists showing a higher specificity.[12]

Our study may have some limitations. We did not recruit all patients seen with acute knee injuries. Nevertheless, we do not believe that our study is biased, keeping in mind the great number of clinicians participating and the number of institutions involved. The rule performed equally well in each of them. We did not assess the interobserver agreement.

Radiographs were not interpreted by radiologists. Instead, they were interpreted by the clinician, as is usual in our EDs. Missing fractures will always be recognized a few days later, with the patient returning to the ED. It is unlikely that a patient with a given complaint seen once in one of our hospitals will self-refer to another center. The major limitation of this study is that the interpretation of the radiographs and the rating of the ankle rule were done by the same individual. This more than likely biased the sensitivity estimates in the positive direction. In that the degree to which the bias affected the data is unmeasurable, these results must be accepted with a great deal of reservation.

The different degrees of participation of the hospitals in our study lead to the suggestion that, for the clinical rules to be accepted and implemented, other strategies, over and above the provision of information, are needed.[13] A similar situation was found in other settings.[14,15] The implementation of the OKR would be associated with meaningful reductions in health care costs, without a reduction in quality of care.[2]

We have found that the OKR performs well in our centers, with a sample big enough to be certain of its performance, thus confirming previously published results.[16,17]

Author contributions: JIE and JRA conceived the study, designed it, and obtained research funding. In every one of the 11 hospitals, there were 2 researchers conducting the study locally, assuring data collection and quality control. These persons are the first 22 listed in the EMUORO Study Group list. The last 2 in that list, CS and JIP, provided statistical advice on study design and collaborated with JIE in managing the data and in the data analysis at the coordinator centre. JIE and JRA drafted the manuscript and all authors contributed to its revision. JIE and JRA take responsibility for the paper as a whole.

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## APPENDIX.

*EMUORO Study Group list.*

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