Derivation of a Decision Rule for the Use of Radiography in Acute Knee Injuries

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Study objective: To derive a highly sensitive decision rule for the selective use of radiography in acute knee injuries.

Design: Prospectively administered survey.

Setting: Emergency departments of two university hospitals.

Participants: Convenience sample of 1,047 adults with acute knee injuries.

Results: Attending emergency physicians assessed each patient for 23 standardized clinical findings, which were recorded on data collection forms. A total of 127 patients was examined independently by two physicians to determine interobserver agreement. The outcome measure was fracture of the knee. Any patients who did not have ED radiography underwent a structured telephone interview to determine the possibility of a missed fracture. Those variables found to be both reliable (highest κ values) and strongly associated with a fracture (highest χ^2 values) were further analyzed by a recursive-partitioning multivariate technique. The derived decision rule included the following variables: (1) age 55 years or older, (2) tenderness at the head of the fibula, (3) isolated tenderness of the patella, (4) inability to flex to 90 degrees, and (5) inability to bear weight both immediately and in the ED (four steps). The presence of one or more of these findings would have identified the 68 fractures in the study population with a sensitivity of 1.0 (95% confidence interval [CI], .95 to 1.0) and a specificity of .54 (95% CI, .51 to .57). Application of the rule would have led to a 28.0% relative reduction in the use of radiography from 68.6% to 49.4% in the study population.

Conclusion: A practical, highly sensitive, and reliable decision rule for the use of radiography in acute knee injuries has been derived. Clinical application should await prospective validation of the rule.

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INTRODUCTION

The need for improved efficiency in the use of emergency department radiography has long been documented.[1,2] This need for selectivity has been identified clearly for patients with acute ankle injury, who generally are all referred for radiography, despite a yield for fracture of less than 15%.[3-6] The referral patterns and yield of radiography for patients with knee injuries have been less well described but may be more inefficient than for patients with ankle injuries.[7] More than 80% of the 580,000 patients with knee injuries seen annually in US EDs undergo radiography.[8] Knee radiographs, which are one of the most common radiographic examinations for trauma[9,10], have a low yield for fracture.[2,11] We recently demonstrated that although 68.6% of 1,296 patients with knee injuries underwent radiography, 93.4% of the radiographs ordered were negative for fracture.[12]

Nonselective use of knee radiography in EDs is an important issue in this era of fiscal restraint in health care. The sheer volume of low-cost tests such as plain radiography may contribute as much to rising health care costs as do high-technology, low-volume procedures.[13,14] We estimate, on the basis of our experience in Ontario, that more than $1 billion is spent annually in Canada and the United States on knee radiographs for outpatients.[15] Guidelines for the appropriate use of knee radiography could allow money spent for some of the negative radiographs to be used elsewhere in the health care system.

Although guidelines have been developed for the use of ankle radiography[16-20], there are no widely accepted guidelines for the use of knee radiography. Previous studies either have not addressed knee injuries specifically[3,9], have been inconclusive[21], or have been relatively small.[22-24] Standard emergency medicine and orthopedic textbooks either imply that radiographs should be performed routinely or suggest criteria that are not referenced.[25-29] Without the support of recognized or validated guidelines, emergency physicians tend to follow the expedient route of ordering a radiograph for most knee-injury patients. This practice parallels the use of radiographs in patients with ankle injuries and is fostered by the nature of emergency medicine—high case volumes, brief physician-patient contact, uncertain follow-up, and fear of medicolegal repercussions.[6,30,31]

The objective of this study was to derive a decision rule for the use of radiography in acute knee injuries. To be clinically useful for emergency physicians, such a rule should have a sensitivity of 1.0 for identifying fractures, and should be reliable and easy to apply. If validated in subsequent studies, a decision rule for knee-injury patients could lead to a large reduction in the use of knee radiography and significant health care savings without compromising patient care.

MATERIALS AND METHODS

This study was conducted in the EDs of two teaching institutions affiliated with the University of Ottawa, the Ottawa Civic and Ottawa General hospitals. We included adult patients who presented with acute blunt injuries of the knee caused by any mechanism of injury. The "knee" was considered 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 without underlying soft-tissue or bone involvement (eg, superficial lacerations, abrasions, puncture wounds, burns), had been referred from outside the hospital with radiographs, had sustained knee injury more than 7 days previously, had returned for reassessment of the same injury, had an altered level of consciousness, were paraplegic, or had multiple trauma or other fractures. This study was approved, without the need for informed consent, by the institutional research ethics committee.

Patients were assessed for 23 standardized clinical variables, which had been selected by the investigators on the basis of their clinical experience, data from the literature, and the results of a 2-month pilot study. Eligible patients were entered into the study when 1 of 33 designated staff emergency physicians was on duty. These assessor physicians were certified in emergency medicine by the American Board of Emergency Medicine, the Royal College of Physicians and Surgeons, or the College of Family Physicians of Canada. The physicians were trained by means of a 1-hour lecture and practical demonstration to assess the clinical variables in a standardized fashion. Furthermore, explicit definitions of each variable were provided in a handout and on the back of the data-collection sheet. Flexion and lack of extension were measured with a goniometer. The findings were recorded on a data-collection sheet at the time of the examination and before radiography. The data-collection sheet included a figure of nine specific points of bone tenderness. To determine the interobserver reliability of the physical findings, the patients were examined, where feasible, by a second emergency physician who was blinded to the results of the first assessment.

The criterion that the decision rule was designed to identify was any fracture of the knee or patella seen on standard plain knee radiography. We also defined a clinically insignificant fracture as any avulsion fragment that was less than 5 mm in breadth and that was not associated with a complete tendon or ligament disruption. The radiographic series were interpreted by independent staff radiologists who were blinded to the contents of the data-collection sheet. Because participating physicians routinely ordered radiography for only 69% of the eligible knee-injury patients, we could not demand that all patients undergo radiography for the purposes of the study. Consequently, individual physicians followed their usual radiography ordering practices. Those patients who did not have radiography in the ED answered a structured telephone questionnaire to determine the possibility of a missed fracture. Patients were classified as having no fracture if they satisfied all five of the explicit criteria listed in Figure 1. Patients who could not fulfil the criteria were recalled for clinical reassessment and radiography.

The clinical variables were assessed for association with fracture by univariate techniques: for nominal data the χ^2 test without continuity correction, and for continuous data the unpaired two-tailed Student t test with pooled or separate variance estimates as appropriate. The continuous variables (age, flexion, and lack of extension) were dichotomized at various clinically sensible cutoff points (Table 2). Furthermore, several new variables were created by combination: mechanism of twisting or other indirect injury, inability to bear weight both immediately and in the ED, isolated tenderness of the patella, and tenderness of the patella associated with a direct blow. These variables created by cutoff point or combination also were associated by means of χ^2 analysis. The reliability of assessing each variable was measured with the κ-coefficient (the proportion of potential agreement beyond chance) and 95% confidence intervals (CIs).[32,33] Agreement for patient age was assumed to be good and was not measured. Those variables found to be both reliable (highest κ-values) and strongly associated with a fracture (P<.05) were analyzed by means of a χ^2 recursive-partitioning technique.[34-37] The statistical

Table 1.
Characteristics of the 1,047 knee-injury patients in the study.

Age (years) [mean±SD]	36±25
Range (years)	18–90
No. of men (%)	603 (58%)
No. of study patients at each hospital (%)	
Ottawa Civic	536 (51)
Ottawa General	511 (49)
Time from injury to assessment (hours) [mean±SD]	19±29
No. of each mechanism of injury (%)	
Twisting	524 (50)
Other indirect injury	94 (9)
Direct blow (fall or object)	429 (41)
Activity at time of injury (%)	
Work	132 (13)
Sports	404 (39)
Other	511 (49)
No. of isolated knee injuries (%)	932 (89)
No. of fractures (%)	68 (6)
No. of clinically significant fractures (%)*	66 (6)
Patella	29 (3)
Proximal tibia	29 (3)
Head of fibula	8 (1)
Distal femur	3 (0)
Tibial spine	2 (0)
Tibial tuberosity	2 (0)
No. of clinically insignificant fractures (%)	2 (0)
No. with radiography (%)	
Knee	707 (68)
Patella	117 (11)
No. of telephone follow-ups in cases without radiography (%) [n=347]	
Successful	340 (98)
Fracture	0
No. with immediate management (%)	
Referred to orthopedist	100 (10)
Admitted	33 (3)
Time in ED for nonfracture cases (minutes) [mean±SD]	
Radiography	127 (50)
No radiography	83 (42)

*Some patients had fractures in more than one location.

Figure 1.
Criteria used in structured 14-day follow-up telephone questionnaire of patients who did not undergo radiography.

Patients who could not fulfill all of the following criteria were recalled for reassessment and radiography:
- Pain is better.
- Ability to walk is better.
- Does not require assistance to walk (crutches/cast/splint).
- Has returned to usual occupational activities (work, housework, or school).
- Has no plans to see a physician about knee injury.

model offering a combination of variables with a sensitivity of 1.0 and the highest possible specificity formed the basis of the decision rule.

The classification performance of the derived decision rule for identifying knee fracture was assessed by calculating sensitivity, specificity, negative predictive value, and positive predictive value with 95% CI.[38] Given the binary predictive nature of the decision rule and the desire to maintain a sensitivity of 100%, no attempt was made to construct receiver operating characteristic curves.[39]

Table 2.
Univariate correlation and κ-values of predictor variables for knee fracture.

Clinical Finding	Fracture Cases (n=68)	Other Cases (n=979)	χ^{2*}	P	κ-Value (n=127)
Age (years) [mean±SD]	47±19	35±25		<.0001	
Age, greater than or equal to (years) [%]					
55	38	12	38.3	<.0001	
65	21	6	23.8	<.0001	
75	10	2	14.4	<.0001	
Male (%)	35	59	14.7	<.0001	
Mechanism (%)					
Twisting or other indirect injury†	28	61	28.4	<.0001	.73
Any direct blow	72	39	28.4	<.0001	.78
Swelling, by history (%)	83	54	20.8	<.0001	.57
Effusion (%)					
Visible	79	29	70.6	<.0001	.59
By fluctuation	82	32	66.0	<.0001	.65
By sweep test	67	26	49.1	<.0001	.46
Flexion (degrees) [mean±SD]	63±39	101±31		<.0001	
Flexion, less than (degrees) [%]					
90†	65	21	66.1	<.0001	.59
60†	49	10	87.6	<.0001	.54
30†	21	3	52.7	<.0001	-.02
Lack of extension (degrees) [mean±SD]	9±13	5±10		<.01	
Lack of extension greater than (degrees) [%]					
5†	49	31	8.8	<.01	.35
10†	34	22	5.4	<.05	.48
15†	26	12	11.8	<.01	.52
Tenderness (%)					
Patella	52	23	28.6	<.0001	.76
Isolated patella†	25	11	12.5	<.0001	.59
Patella and direct blow†	47	18	33.3	<.0001	.78
Medial femoral condyle	30	29	.1	.78	.35
Lateral femoral condyle	22	10	8.8	<.01	.57
Medial tibia	35	25	3.4	.06	.28
Lateral tibia	40	11	43.8	<.0001	.38
Tibial tuberosity	15	7	5.3	<.05	.58
Medial joint line	32	44	3.7	.06	.50
Lateral joint line	37	17	16.3	<.0001	.45
Head of fibula	18	6	15.2	<.0001	.92
Pain with axial percussion (%)	17	8	7.0	<.01	.33
Patellar/quadriceps tendon tear (%)	15	2	33.3	<.0001	.43
Quadriceps inhibition test (%)	58	23	37.5	<.0001	.43
Quadriceps inhibition test (%)	58	23	37.5	<.0001	.22
Inability to bear weight (%)					
Immediately	54	17	54.5	<.0001	.67
In ED (four steps)	69	23	67.4	<.0001	.75
Immediately and in ED†	46	11	63.5	<.0001	.75

*Pearson χ^2 value with 1 *df*.
†Variable created by means of a cutoff point or combination of variables.

RESULTS

During the 14 months of the study (September 1992 through October 1993), 1,054 of 1,212 (87%) eligible knee-injury patients were enrolled in the study. Telephone follow-up was achieved in 340 of 347 (98%) patients who did not have ED radiography. None of these patients proved to have a fracture. The seven patients who could not be reached in follow-up to have their fracture status confirmed were excluded from further analysis. The 1,047 study patients (Table 1) were young, on average, but the age range extended to 90 years; slightly more men (58%) were represented, and half of the patients had sustained twisting injury. Of the 68 (6%) patients with fractures, 66 had clinically significant fractures, and most of these were in the patella or proximal tibia. Two of the fractures were classified as being clinically insignificant and required neither a cast nor surgery. ED radiography was performed for 707 (68%) patients. The 127 patients examined independently by two physicians were similar in characteristics to the overall study group except for a slightly higher prevalence of fracture (9%). Another 158 eligible patients who did not have data sheets completed were very similar to the overall study group but had a higher prevalence of fracture (9%) and were less likely to have isolated injuries of the knee (76%).

Figure 2.
χ^2 Recursive partitioning of cases for knee fracture.

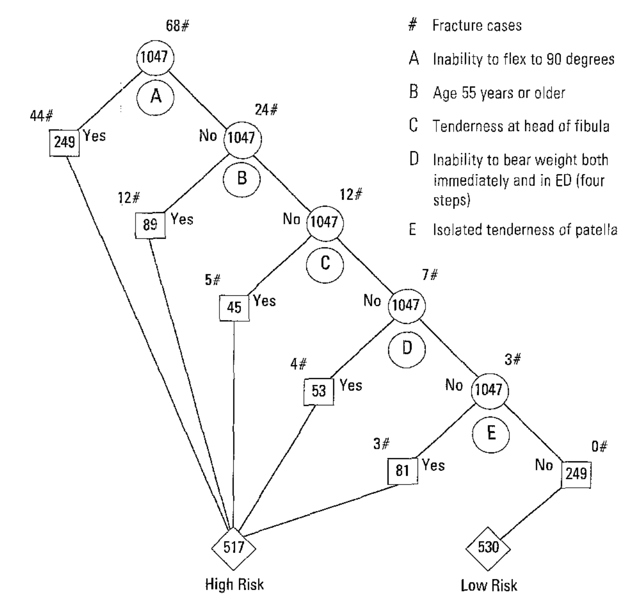

Table 2 lists the proportions of patients with and without knee fractures who were positive for the clinical variables, including those created by means of a cutoff point or combination. Most associations were statistically significant; χ^2 values with 1 *df*, the basis of the recursive-partitioning splits, are given for dichotomous variables. Interobserver agreement, however, exceeded .5 for only 18 of the variables. The following variables did not show sufficient interobserver agreement to be included in the multivariate analyses: effusion by sweep test; flexion less than 30 degrees; lack of extension greater than 5 or 10 degrees; tenderness of the medial femoral condyle, the medial tibia, the lateral tibia, or the lateral joint line; axial percussion, quadriceps inhibition test. Other assessed clinical findings pertinent to soft-tissue injury also were not included in the statistical modeling: audible pop, apprehension test[44], Lachman test, valgus stress test, and varus stress test.

χ^2 Recursive-partitioning techniques (Figure 2) yielded a model encompassing five variables, including the created variable, isolated patellar tenderness. This model, one of many possibilities achieving 100% sensitivity, was chosen because it offered the highest specificity and the smallest number of variables. The κ-values of the component variables ranged from .59 to .75, suggesting substantial interobserver agreement (interobserver agreement for age was not tested). The derived statistical model forms the basis for the decision rule that describes which knee-injury patients do not require radiography (Figure 3). The presence of one or more of the findings related to age, tenderness, or function suggests the need for radiography.

If applied to the study population, the decision rule would have had a sensitivity of 1.0 (95% CI, .95 to 1.0) and a specificity of .54 (95% CI, .51 to .57) for identifying fractures of the knee (Table 3). Furthermore, application of the rule would have led to a 28.0% relative reduction in use of radiography from a baseline rate of 68.6% to a potential rate of 49.4%.

Figure 3.
Decision rule for radiography in acute knee injury.

A knee radiograph is required only for acute knee-injury patients with one 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 degrees
- Inability to bear weight both immediately and in the ED (four steps)

DISCUSSION

This study has derived a clinical decision rule, which offers physicians an opportunity to use clinical judgment to screen patients with acute knee injuries for the need for radiography. This study was, to our knowledge, the largest prospective evaluation of such patients and the first to evaluate the interobserver agreement of many of the clinical variables used to evaluate knee injuries. We found that the rapid application of a few simple clinical findings indicates which patients are at a negligible risk for a fracture and, therefore, need not undergo radiography. We previously have shown that experienced physicians have the ability, using clinical judgment, to determine accurately which knee-injury patients have fractures. However, often they are reluctant to use this skill.[40] Our decision rule should give physicians the confidence to use clinical findings to manage patients without radiography. This approach has the potential to decrease significantly the use of radiography and thereby diminish health care costs without jeopardizing patient care.

In recent years, the methodological standards for the development and testing of clinical prediction or decision rules have become established.[41,42] We believe that this study has followed these standards rigorously as described by Wasson et al and Feinstein. The outcome identified by the rule, knee fracture, was defined clearly and assessed without knowledge of the predictor variables. These predictor clinical variables were assessed prospectively in a standardized fashion without knowledge of the outcome. Furthermore, the reliability or reproducibility of these variables was shown. The patients were selected without bias and represented a spectrum of clinical and demographic characteristics. The statistical techniques were described and the classification performance of the decision rule was estimated. The sample size was large enough to allow the estimation of classification performance characteristics within narrow confidence limits.

Table 3.
Classification performance of decision rule for identifying knee fractures.

	Knee Fracture	
Decision Rule Positive	**Yes**	**No**
Yes	68	449
No	0	530

Sensitivity, 1.0 (95% CI, .95 to 1.0); specificity, .54 (95% CI, .51 to .57); negative predictive value, 1.0 (95% CI, .99 to 1.0); positive predictive value, .13 (95% CI, .10 to .16).

We believe that one of the greatest strengths of this study is that the derived decision rule may be considered sensible for clinical use. This may be because the rule was developed by experienced emergency physicians, was designed to have a sensitivity of 1.0, gives a simple yes/no answer, and is easy to apply. The few previous studies to develop guidelines for knee radiography have had one or more methodological weaknesses.[21,23,24,43]

The major limitations of this study are that the decision rule has not been validated prospectively and has not undergone an implementation trial. No decision rule should be considered for clinical use until it has been validated prospectively.[41] Many guidelines or decision rules do not perform well when tested in a new patient population.[44] We currently are conducting a validation study in 1,000 knee-injury patients and would encourage others to do the same in their own settings. We then plan to conduct an implementation trial to demonstrate the true effect of the decision rule on clinical practice. Very few decision rules have undergone field trials to test their effectiveness in altering patient care.[41,45] We have shown previously that a stepwise approach to developing and testing a decision rule for ankle radiography can lead to valid and reliable guidelines that effectively improve practice in a large variety of settings.[16-18,20]

A methodological concern in this study is that not all patients underwent radiography. This would not have been ethical or feasible, because we know that physicians in our setting routinely perform radiography for only 69% of the eligible knee-injury patients. Allowing physicians to enter only those patients whom they chose to send for radiography would have introduced selection bias into the study. Furthermore, this would have denied us a clear and consistent patient definition that could be transported to other settings.[46,47] We are fully confident that our explicit structured telephone follow-up questionnaire most likely would have identified any patients harboring a missed fracture. The eight patients who could not be reached in follow-up were excluded from the analysis. We have used this technique successfully to identify missed fractures in previous studies.[18,20]

Another potential concern in this study is the relatively low specificity (.54) and low positive predictive value (.13) of the decision rule. We could have improved the specificity and further reduced the use of radiography, but only at the expense of reducing sensitivity below 1.0. For example, if the last variable to enter the model was dropped (isolated patellar tenderness), the specificity would have increased to .62 and the potential relative reduction in radiography to 39.4%. However, this would have led to a sensitivity of only .96 and to missing patients' fractures. We believe that, in the context of current North American practice, physicians are unlikely to embrace guidelines that lead to missed fractures even if the morbidity for patients is minimal.

How important is plain radiography in the overall management of acute knee injuries? Most patients with acute knee injuries seen in an ED have soft-tissue injuries (93.5% in this series). The initial identification of major soft-tissue injuries, including ligamentous and meniscal tears, depends almost entirely on clinical assessment.[25,48] Plain radiography usually is not helpful, and more sophisticated diagnostic tools (arthroscopy, magnetic resonance imaging, computed tomography, or arthrography) are required to define the diagnosis accurately. Uncommonly, specific fractures may be associated with ligamentous disruptions—avulsions of the tibial spine and the lateral tibial condyle (Segond fracture).[49-54] Effusions may be detected radiologically and may be associated with important bone or soft tissue injuries, but such effusions usually are evident clinically.[55-57] We are conducting a parallel study to determine the most accurate and reliable clinical predictors of soft-tissue disruption in the ED assessment of acute knee injuries.

We believe that the decision rule—with the component variables related to age, tenderness, and function—should be easy for clinicians to remember and apply. The criterion of age 55 years or greater is biologically plausible, and the increased prevalence of fracture in this age group is likely associated with osteoporosis. Thirty-eight percent of the fractures were seen in patients aged 55 years or older, a group that represented only 14% of the study population. This phenomenon is similar to that observed with ankle fractures.[16]

Although most points of bone tenderness were associated with increased prevalence of fracture, only several were reliable and specific enough to contribute to the decision rule. Fractures of the head of the fibula constituted 12% of all fractures and usually could be identified by localized bone tenderness. Fractures of the patella accounted for 44% of the fractures and, likewise, usually could be identified by localized bone tenderness. We found, however, that tenderness of the patella was a relatively nonspecific finding that also was present in many patients without fractures. Isolated tenderness of the patella, defined as no other areas of bone tenderness about the knee, is a much more specific finding for predicting fracture.

Clinical findings related to function are important predictors in our decision rule. Sixty-five percent of the fracture patients were unable to actively flex the injured knee to 90 degrees. Finally, inability to bear weight proved to be one of the most reliably assessed variables. Combining the stipulation that the patient must be unable to bear weight both immediately and in the ED increases the specificity of this finding. We define weight bearing in the ED as the ability to transfer weight twice onto each leg (a total of four steps), regardless of limping. We assess ability to bear weight only after determining bone tenderness and never attempt to coerce a patient. This predictor variable also has been an extremely useful component of the Ottawa ankle rules.

Clinical judgment is paramount in patient management and should not be neglected in the application of decision rules or guidelines. The rule may not be reliable in situations where patient assessment is difficult: drug or ethanol intoxication, head injury, multiple painful injuries, or diminished sensation caused by neurologic deficit. The rule has not been developed for patients younger than 18 years.

The derived decision rule has several potential implications for clinical practice. Application of the rule could reduce the use of radiography for acute knee injuries by 28% (or more, depending on current local practice). This would decrease waiting times for patients discharged without radiography (by 44 minutes in this study). Successful use of the rule by triage nurses could improve patient flow and similarly decrease waiting times. The most important benefit, however, is the potential for more efficient and cost-effective patient management. Even a modest reduction in the use of radiography for knee-injury patients would lead to substantial cost savings for our health care system.

CONCLUSION

We have derived a practical, highly sensitive, and reliable decision rule that would permit physicians to be much more selective in their use of radiography for acute knee-injury patients. Clinical application of this rule should await a large-scale prospective validation study.

REFERENCES

1. Abrams HL: The "overutilization" of x-rays. *N Engl J Med* 1979;300:1213-1216.

2. Gleadhill DNS, Thomson JY, Simms P: Can more efficient use be made of x-ray examinations in the accident and emergency department? *BMJ* 1987;294:943-947.

3. Brand DA, Frazier WH, Kohlhepp WC, et al: A protocol for selecting patients with injured extremities who need x-rays. *N Engl J Med* 1982;306:333-339.

4. Lloyd S: Selective radiographic assessment of acute ankle injuries in the emergency department: barriers to implementation. *Can Med Assoc J* 1986;135:973-974.

5. Dunlop MG, Beattie TF, White GK, et al: Guidelines for selective radiological assessment of inversion ankle injuries. *BMJ* 1986;293:603-605.

6. Stiell IG, McDowell I, Nair RC, et al: Use of radiography in acute ankle injuries: Physicians' attitudes and practice. *Can Med Assoc J* 1992;147:1671-1678.

7. McCaig LF: National Hospital Ambulatory Medical Care Survey: 1992 emergency department summary. *Advance Data* 1994;245:1-12.

8. National Center for Health Statistics: *National Hospital Ambulatory Medical Care Survey 1992.* Hyattsville, Maryland, National Center for Health Statistics, 1994.

9. McConnochie KM, Roghmann KJ, Pasternack J, et al: Prediction rules for selective radiographic assessment of extremity injuries in children and adolescents. *Pediatrics* 1990;86:45-57.

10. Gratton MC, Salomone JA III, Watson WA: Clinically significant radiograph misinterpretations at an emergency medicine residency program. *Ann Emerg Med* 1990;19:497-502.

11. Pennycook AG, Rai A: Knee radiographs: A substitute for proper clinical examination within the accident and emergency department? *Injury* 1993;24:383-384.

12. Stiell IG, Wells GA, McDowell I, et al: Use of radiography in acute knee injures: need for clinical decision rules. *Acad Emerg Med,* in press.

13. Moloney TW, Rogers DE: Medical technology: A different view of the contentious debate over costs. *N Engl J Med* 1979;301:1413-1419.

14. Angell M: Cost containment and the physician. *JAMA* 1985;254:1203-1207.

15. Ontario Ministry of Health: *The Ontario Statistical Reporting System 1991-92.* Toronto: Ministry of Health, 1992.

16. Stiell IG, Greenberg GH, McKnight RD, et al: A study to develop clinical decision rules for the use of radiography in acute ankle injuries. *Ann Emerg Med* 1992;21:384-390.

17. Stiell IG, Greenberg GH, McKnight RD, et al: Decision rules for the use of radiography in acute ankle injuries: Refinement and prospective validation. *JAMA* 1993;269:1127-1132.

18. Stiell IG, McKnight RD, Greenberg GH, et al: Implementation of the Ottawa ankle rules. *JAMA* 1994;271:827-832.

19. McDonald CJ: Guidelines you can follow and can trust: an ideal and an example. *JAMA* 1994;271:872-873.

20. Stiell I, Wells G, Laupacis A, et al: A multicentre trial to introduce clinical decision rules for the use of radiography in acute ankle injuries. *BMJ,* in press.

21. Saxena AC, Norris RL, Finstuen K, et al: The role of knee radiographs in the emergency department: A prospective study (abstract). *Ann Emerg Med* 1992;21:658.

22. Seaberg DC, Jackson R: Clinical decision rule for knee radiographs. *Am J Emerg Med* 1994;12:541-543.

23. Weber JE, Peacock WF, Jackson RE, et al: Clinical indices prediction knee fractures (abstract). *Acad Emerg Med* 1994;1:A23.

24. Bauer SJ, Hollander JE, Thode HC, et al: A clinical decision rule in the evaluation of acute knee injuries (abstract). *Acad Emerg Med* 1994;1:A64-A65.

25. Simon RR, Koenigsknecht SJ: *Emergency Orthopedics: The Extremities.* Norwalk, Connecticut, Appleton & Lange, 1987.

26. Harwood-Nuss A: *The Clinical Practice Of Emergency Medicine.* Philadelphia, Lippincott, 1991.

27. Callaham ML: *Current Therapy in Emergency Medicine.* Toronto, Decker, 1987.

28. Tintinalli JE, Krome RL, Ruiz E: *Emergency Medicine: A Comprehensive Study Guide.* Montreal, McGraw-Hill, 1992.

29. Rosen P, Barkin RM, Braen GR, et al: *Emergency Medicine: Concepts and Clinical Practice.* St Louis, CV Mosby, 1992.

30. Feinstein AR: The "chagrin factor" and qualitative decision analysis. *Arch Intern Med* 1985;145:1257-1259.

31. Long AE: Radiographic decision-making by the emergency physician. *Emerg Med Clin North Am* 1985;3:437-446.

32. Kramer MS, Feinstein AR: Clinical biostatistics: LIV. The biostatistics of concordance. *Clin Pharmacol Ther* 1982;29:111-123.

33. Landis JR, Koch GG: The measurement of observer agreement for categorical data. *Biometrics* 1977;33:159-174.

34. Ciampi A, Hogg SA, McKinney S, et al: RECPAM: A computer program for recursive partition and amalgamation for censored survival data and other situations frequently occurring in biostatistics. I. Methods and program features. *Comput Meth Prog Biomed* 1988;26:239-256.

35. Ciampi A, Chang CH, Hogg S, et al: Recursive partition: A versatile method for exploratory data analysis in biostatistics, in MacNeill IB, Umphrey GJ (eds): *Time Series and Econometric Modelling, Biostatistics Vol V.* Boston, D Reidel Publishing Company, 1987;23-50.

36. Friedman JH: A recursive partitioning decision rule for nonparametric classification. *IEEE Trans Comput* 1977;16:404-408.

37. Ciampi A, Thiffault J, Nakache J, et al: Stratification by stepwise regression, correspondence analysis and recursive partition: a comparison of three methods of analysis for survival data with covariates. *Comput Stat Data Anal* 1986;4:185-204.

38. Diamond GA: Limited assurances. *Am J Cardiol* 1989;63:99-100.

39. Hanley JA, McNeil BJ: The meaning and use of the area under a receiver operating characteristic (ROC) curve. *Radiology* 1982;143:29-36.

40. Stiell IG, Wells GA, Greenberg GH, et al: Physicians' judgment in the use of radiography in acute knee injuries (abstract). *Acad Emerg Med* 1994;1:A66.

41. Wasson JH, Sox HC, Neff RK, et al: Clinical prediction rules: application and methodological standards. *N Engl J Med* 1985;313:793-799.

42. Feinstein AR: *Clinimetrics.* New Haven, Connecticut, Yale University Press, 1987.

43. Seaberg DC, Jackson R: Clinical decision rule for knee radiographs (abstract). *Ann Emerg Med* 1993;22:903.

44. Charlson ME, Ales KL, Simon R, et al: Why predictive indexes perform less well in validation studies. *Arch Intern Med* 1987;147:2155-2161.

45. Lee TH: Evaluating decision aids: the next painful step. *J Gen Intern Med* 1990;5:528-529.

46. Poses RM, Cebul RD, Collins M, et al: The importance of disease prevalence in transporting clinical prediction rules: The case of streptococcal pharyngitis. *Ann Intern Med* 1986;105:586-591.

47. Wigton RS, Connor JL, Centor RM: Transportability of a decision rule for the diagnosis of streptococcal pharyngitis. *Arch Intern Med* 1986;146:81-83.

48. Baugher WH, White GM: Primary evaluation and management of knee injuries. *Emerg Med Clin North Am* 1984;2:347-359.

49. Fairclough JA, Johnson SR: Ski injuries, the significance of flake fractures. *Injury* 1988;19:79-80.

50. Kannus P, Järvinen M: Routine radiographs in acute knee distortions. *Orthopedics* 1988;11:1591-1593.

51. Goldman AB, Pavlov H, Rubenstein D: The Segond fracture of the proximal tibia: A small avulsion that reflects major ligamentous damage. *AJR Am J Roentgenol* 1988;151:1163-1167.

52. Woods GW, Stanley RF, Tullos HS: Lateral capsular sign: X-ray clue to a significant knee instability. *Am J Sports Med* 1979;7:27-33.

53. Pavlov H: The radiographic diagnosis of the anterior cruciate ligament deficient knee. *Clin Orthop Rel Res* 1983;57-64.

54. Dietz GW, Wilcox DM, Montgomery JB: Segond tibial condyle fracture: lateral capsular ligament avulsion. *Radiology* 1986;159:467-469.

55. Maskell TW, Finlay DB: The prognostic significance of radiologically detected knee joint effusions in the absence of associated fracture. *Br J Radiol* 1990;63:940-941.

56. Singer AM, Naimark A, Felson D, et al: Comparison of overhead and cross-table lateral views for detection of knee-joint effusion. *AJR Am J Roentgenol* 1985;144:973-975.

57. Kaye JJ, Nance EP Jr: Pain in the athlete's knee. *Clin Sports Med* 1987;6:873-883.

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