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Improving Ottawa Knee and Ankle Rule Concordance in Emergency Department Radiography: A Closed-Loop Clinical Audit

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Abstract

Background: The Ottawa Knee and Ankle Rules are highly sensitive clinical decision rules intended to reduce unnecessary radiography following acute lower-limb injuries. An initial audit in our emergency department (ED) identified frequent radiography when Ottawa criteria were not met. This study evaluated whether a targeted departmental intervention improved Ottawa-rule concordance and documentation.

Methods: This was a single-centre, closed-loop retrospective clinical audit of knee and ankle radiography conducted in an ED in the United Kingdom. A total of 250 radiography records were randomly selected in each cycle. Following eligibility screening, 144 adult attendances were included in the baseline analysis and 95 in the re-audit. Ottawa status was assessed retrospectively from clinical documentation recorded in the electronic patient record. Between cycles, clinicians received targeted teaching, posters, and electronic reminders. Outcomes were compared using risk differences, risk ratios and Fisher's exact test, with 95% confidence intervals (CIs).

Results: Overall Ottawa-rule concordance increased from 78/144 (54.2%) at baseline to 76/95 (80.0%) at re-audit, an absolute increase of 25.8 percentage points (95% CI 13.7-36.4; P<0.001). Ankle concordance increased from 52/89 (58.4%) to 53/64 (82.8%), while knee concordance increased from 26/55 (47.3%) to 23/31 (74.2%). Documentation of radiographic investigations in discharge correspondence improved from 95/144 (66.0%) to 89/95 (93.7%). Eleven Ottawa-relevant fractures were identified in the re-audit, all among Ottawa-positive patients.

Conclusion: Targeted departmental education and reminders were associated with improved Ottawa-rule concordance among imaged patients and better documentation of radiographic investigations. Improvements were observed across both knee and ankle imaging. However, differences in cohort screening and the retrospective study design limit causal interpretation. Structured electronic prompts, continued clinician education, and prospective re-auditing may help improve adherence and sustain these findings.

Categories: Radiology, Emergency Medicine, Orthopedics
Keywords: emergency medicine, orthopaedics, ottawa ankle rules, ottawa knee rules, radiology

Introduction

Ankle and knee injuries are common emergency department (ED) presentations. Because clinical examination can be difficult after acute injury, radiographs are often obtained despite a low probability of fracture. This increases resource use, radiation exposure, waiting time, and downstream reporting workload.

The Ottawa Ankle Rules and Ottawa Knee Rule were developed and prospectively validated to identify patients who require radiography while maintaining very high sensitivity for clinically important fractures [1-3]. Implementation studies demonstrated reductions in ankle and knee radiography, waiting times, and costs without an increase in missed fractures [4-6]. Systematic reviews have confirmed high sensitivity for ankle, midfoot, and knee fractures, with the expected trade-off of modest specificity [7-9].

A recent United Kingdom district general hospital audit reported substantial improvements in Ottawa-rule concordance after a multifaceted intervention, supporting the feasibility of changing imaging practice in NHS emergency departments [10]. However, local baseline performance and implementation barriers vary, and sustained improvement requires closed-loop measurement.

The primary objective of this study was to compare Ottawa-rule concordance among patients undergoing

knee or ankle radiography before and after the departmental intervention. Secondary outcomes were discharge letter radiograph documentation, explicit recording of "Ottawa", and Ottawa-target fractures in the re-audit. The audit measured concordance among imaged patients, not overall radiography rates.

Materials And Methods

This was a single-centre, closed-loop retrospective clinical audit conducted in the ED at Southend University Hospital, Southend-on-Sea, Essex, United Kingdom, with reporting informed by SQUIRE (Standards for QUality Improvement Reporting Excellence) 2.0 [11]. Baseline data were collected in August 2025. Departmental education was delivered in November 2025, followed by re-audit radiography predominantly during November-December 2025. The study was approved by the Clinical Effectiveness Unit/ Clinical Governance Lead, Mid and South Essex NHS Foundation Trust (reference number: SEMER064R2).

Case selections

Knee and ankle radiography records were obtained from the Soliton radiology information system (Soliton IT, Hemel Hempstead, United Kingdom) of the hospital. A total of 250 radiography records were randomly selected for each audit cycle using Microsoft Excel (Microsoft Corporation, Redmond, Washington, United States). Eligibility was assessed using the inclusion and exclusion criteria in Table *1*. Patients with obvious deformity were not automatically excluded, provided the remaining eligibility criteria were met.

Inclusion criteria	Exclusion criteria
Age 18 years or older	Age younger than 18 years
	Radiograph requested by another clinical team
Knee or ankle radiography requested by the ED team	Non-traumatic presentation
	Incomplete clinical documentation
Recent traumatic knee or ankle injury	Polytrauma or multiple painful injuries
	Infection or inflammatory presentation
Sufficient EPR clinical documentation to apply the relevant Ottawa Rule retrospectively	Previous fracture or chronic condition affecting interpretation
	Injury older than seven days

TABLE 1: Inclusion and exclusion criteria for the clinical audit

ED, emergency department; EPR, electronic patient record

For the baseline audit, 52 records were excluded because the radiographs were not requested by the ED team. The remaining 198 examination records corresponded to 195 distinct attendances after removal of three duplicate records. Following application of the recorded eligibility criteria, a further 51 attendances were excluded, leaving 144 adults in the final baseline cohort. For the re-audit, 96 of the 250 selected records were excluded because the radiographs were not requested by the ED team. The remaining 154 records underwent eligibility assessment, of which 59 were excluded, leaving 95 adults in the final re-audit cohort. Case selection and exclusion reasons for both cycles are illustrated in Figure *1*.

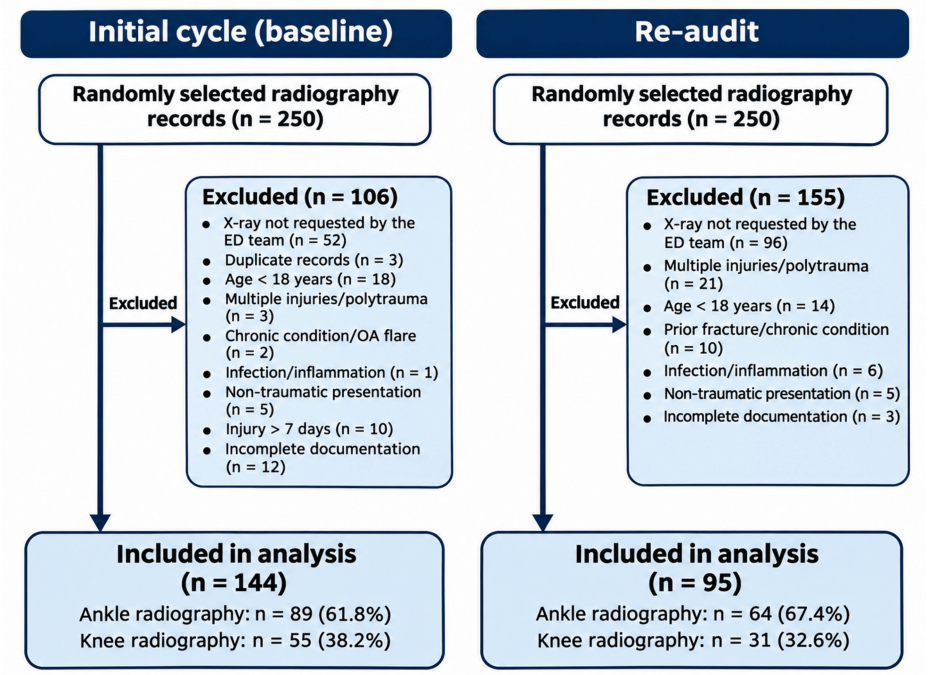


FIGURE 1: Flow diagram of case selection for the baseline and re-audit cohorts.

Radiography records were randomly selected during each audit cycle. Exclusion categories are mutually exclusive, with each record assigned one primary exclusion reason.

ED, emergency department; OA, osteoarthritis

Retrospective rule assessment and fracture classification

For each selected case, the allocated reviewer manually examined the written emergency department consultation notes available on the electronic patient record (EPR), including the clinical history and examination findings. Ottawa status was determined from these clinical records rather than the information entered on the radiography request.

The Ottawa Knee Rule criteria included age 55 years or older, isolated patellar or fibular-head tenderness, inability to flex the knee to 90°, or inability to bear weight for four steps. The Ottawa Ankle and Midfoot Rules included the relevant anatomical tenderness and weight-bearing criteria [1,2,4]. The recorded Ottawa-positive or Ottawa-negative classification was retained for the analysis.

Cases were grouped according to the knee or ankle examination requested. Combined ankle-foot examinations were included in the ankle-region cohort; isolated foot examinations were not sampled. Duplicate examination entries were removed before the final analysis. Fracture outcomes were determined from the routine written radiology reports, predominantly reported by trainee radiologists and occasionally by reporting radiographers. Reviewers were not blinded to the audit cycle, cases were not independently double-reviewed, and no formal inter-rater agreement assessment was performed.

Intervention

The intervention consisted of short refresher teaching sessions for ED clinicians, particularly junior doctors, focusing on the Ottawa Knee and Ankle Rules and commonly missed criteria. Printed posters were displayed in clinical areas, and reminders were distributed through departmental email and WhatsApp (Meta Platforms, Inc., Menlo Park, California, United States). The intervention aimed to improve recognition and application of the clinical criteria when requesting radiography.

Measures and outcome definitions

The primary outcome was Ottawa-rule concordance, defined as the proportion of included radiographs for which the retrospectively assessed clinical findings met the relevant Ottawa criteria. Radiographs without documented positive criteria were classified as Ottawa-negative. The reference audit standard was radiography meeting the appropriate Ottawa criteria or having a clearly documented clinical justification for

deviation.

Secondary outcomes included documentation of the radiograph in the investigations section of the emergency department discharge letter, explicit recording of the term "Ottawa" in the clinical indication or radiology report, and Ottawa-relevant acute fractures identified in the re-audit.

In the discharge letter field, responses coded as "Yes" or "Billed" were classified as documented, while other responses were classified as not confirmed. Fracture outcomes were determined from the written radiology reports. Diagnostic performance was assessed within the imaged re-audit cohort.

Statistical analysis

Categorical variables were reported as counts and percentages. Wilson 95% confidence intervals (CIs) were used for proportions, Newcombe-Wilson CIs for absolute differences, and log-transformed CIs for risk ratios. Two-sided Fisher's exact tests were used to compare audit cycles. Exact Clopper-Pearson intervals were calculated for diagnostic performance measures. A P-value below 0.05 was considered statistically significant. Comparisons between cycles were observational, and subgroup analyses were exploratory. Descriptive statistical analysis was performed using Microsoft Excel.

Results

Initial cycle

A total of 250 radiography records were randomly selected for the initial audit. Fifty-two were excluded because the radiographs were not requested by the ED team. The remaining 198 records represented 195 distinct attendances after removal of three duplicate examination entries. A further 51 attendances were excluded following eligibility assessment: 18 for age younger than 18 years, three for multiple injuries or polytrauma, two for chronic conditions or osteoarthritis flare, one for infection or inflammatory presentation, five for non-traumatic presentations, 10 for injuries older than seven days, and 12 for incomplete documentation. The final baseline cohort comprised 144 adult attendances, with a median age of 49 years (interquartile range (IQR) 30-67). Of these, 89 (61.8%) underwent ankle-region radiography and 55 (38.2%) underwent knee radiography. Seventy-eight (54.2%) were Ottawa-positive, while 66 (45.8%) were Ottawa-negative.

Re-audit

A total of 250 radiography records were randomly selected for the re-audit. Ninety-six records were excluded because the radiographs were not requested by the emergency department team, leaving 154 records for eligibility assessment. Fifty-nine attendances were subsequently excluded: 21 for multiple injuries or polytrauma, 14 for age younger than 18 years, 10 for previous fractures or chronic conditions, six for infection or inflammatory presentations, five for non-traumatic presentations, and three for incomplete documentation. The final re-audit cohort comprised 95 adults, with a median age of 39 years (IQR 31.5-56). Of these, 64 (67.4%) underwent ankle-region radiography, and 31 (32.6%) underwent knee radiography. Seventy-six (80.0%) were Ottawa-positive, and 19 (20.0%) were Ottawa-negative.

Cohort characteristics for both cycles are summarised in Table *2*.

Measure	Baseline	Re-audit
Radiography records randomly selected, n	250	250
Excluded: not requested by ED team, n	52	96
Duplicate examination records, n	3	0
Excluded following clinical eligibility screening, n	51	59
Final analysis cohort, n	144	95
Age (years), median (IQR)	49 (30–67)	39 (31.5–56)
Ankle-region radiography, n (%)	89 (61.8%)	64 (67.4%)
Knee radiography, n (%)	55 (38.2%)	31 (32.6%)

TABLE 2: Cohort construction and characteristics

Primary outcome

Overall Ottawa rule concordance increased from 78/144 (54.2%) at baseline to 76/95 (80.0%) at re-audit, representing an absolute increase of 25.8 percentage points (95% CI 13.7-36.4; risk ratio 1.48, 95% CI 1.23-1.77; Fisher's exact P<0.001). Nineteen re-audit patients (20.0%) underwent radiography despite having no documented positive Ottawa criterion.

In the exploratory subgroup analysis, ankle-region concordance increased from 52/89 (58.4%) to 53/64 (82.8%), an absolute increase of 24.4 percentage points (95% CI 9.7-37.1; P=0.001). Knee concordance increased from 26/55 (47.3%) to 23/31 (74.2%), an increase of 26.9 percentage points (95% CI 5.2-44.4; P=0.023). These results are summarised in Table *3*.

Outcome	Baseline, n (%)	Re-audit, n (%)	Difference (95% CI); P-value
Overall Ottawa concordance	78/144 (54.2%)	76/95 (80.0%)	+25.8 pp (13.7–36.4); P<0.001
Ankle-region concordance	52/89 (58.4%)	53/64 (82.8%)	+24.4 pp (9.7–37.1); P=0.001
Knee concordance	26/55 (47.3%)	23/31 (74.2%)	+26.9 pp (5.2–44.4); P=0.023
Discharge letter radiograph documentation	95/144 (66.0%)	89/95 (93.7%)	+27.7 pp (17.8–36.5); P<0.001

TABLE 3: Ottawa Rule concordance and documentation outcomes

CI, confidence interval; pp, percentage points.

Fractures and diagnostic performance

Eleven of the 95 eligible re-audit patients (11.6%; 95% CI 6.6-19.6) had an acute Ottawa-relevant fracture according to the radiology report: eight in the ankle-region cohort and three in the knee cohort. All 11 fractures occurred among Ottawa-positive patients. No Ottawa-relevant fracture was identified among the 19 imaged Ottawa-negative patients.

One combined ankle-foot examination identified third- and fourth-metatarsal fractures outside the predefined Ottawa-target fracture endpoint. Diagnostic performance estimates for the imaged re-audit cohort are presented separately for ankle-region and knee examinations in Table *4*.

Measure	Ankle-region (n=64), n (%); 95% CI	Knee (n=31), n (%); 95% CI	Combined (n=95), n (%); 95% CI
Sensitivity	100% (8/8); CI 63.1–100%	100% (3/3); CI 29.2–100%	100% (11/11); CI 71.5–100%
Specificity	19.6% (11/56); CI 10.2–32.4%	28.6% (8/28); CI 13.2–48.7%	22.6% (19/84); CI 14.2–33.0%
Positive predictive value	15.1% (8/53); CI 6.7–27.6%	13.0% (3/23); CI 2.8–33.6%	14.5% (11/76); CI 7.5–24.4%
Negative predictive value	100% (11/11); CI 71.5–100%	100% (8/8); CI 63.1–100%	100% (19/19); CI 82.4–100%

TABLE 4: Diagnostic performance in the imaged re-audit cohort

95% CIs are exact Clopper–Pearson intervals. Estimates apply only to radiographed patients.

Discharge documentation

Documentation of radiographic investigations in the ED discharge letter increased from 95/144 (66.0%) at baseline to 89/95 (93.7%) at re-audit, representing an absolute increase of 27.7 percentage points (95% CI 17.8-36.5; P<0.001). The term "Ottawa" was not explicitly recorded in the reviewed clinical indications or radiology reports in either cycle (0/144 at baseline and 0/95 at re-audit). Documentation outcomes are summarised in Table *3*.

Discussion

Statement of principal findings

The initial cycle showed that 78/144 (54.2%) knee and ankle radiographs met Ottawa criteria, while 66/144

(45.8%) did not. Baseline concordance was lower for knee than for ankle imaging (47.3% versus 58.4%). Following targeted teaching, review of commonly missed criteria, posters, and electronic reminders, overall concordance increased by 25.8 percentage points, from 54.2% to 80.0%. Documentation of radiographic investigations in discharge correspondence also improved by 27.7 percentage points, from 66.0% to 93.7%. Improvements were observed across both examination types, with ankle concordance increasing by 24.4 percentage points and knee concordance by 26.9 percentage points.

In the re-audit, all 11 acute Ottawa-relevant fractures occurred among Ottawa-positive patients. No Ottawa-relevant fractures were identified among the 19 imaged Ottawa-negative patients. However, the confidence intervals around diagnostic sensitivity were wide because of the small number of fractures. These findings are encouraging but do not independently establish the diagnostic accuracy or safety of the rules.

Interpretation within the context of the wider literature

The observed improvement is consistent with previous studies demonstrating that targeted education and implementation of the Ottawa Rules can improve clinical decision-making and reduce unnecessary radiography [5-7]. Similar findings were reported in a recent United Kingdom audit by Dalla Ali et al., where knee-rule concordance increased from 74.6% to 89.9% and ankle-rule concordance from 33.1% to 75.8% following intervention [10]. Our study additionally reports changes in discharge documentation and examination-specific concordance with confidence intervals.

Despite these improvements, 20.0% of radiographs in the re-audit remained Ottawa-negative, indicating further opportunities to improve imaging requests. The low specificity observed in the imaged cohort may partly reflect retrospective assessment from clinical notes and the selection of patients who had already undergone radiography. Previous systematic reviews and meta-analyses have demonstrated the high sensitivity and comparatively limited specificity of the Ottawa Knee and Ankle Rules [6,8,9,12,13].

An important finding was the difference between documentation of radiographic investigations and explicit recording of the Ottawa Rules. Although discharge letter documentation improved from 66.0% to 93.7%, none of the 95 re-audit patients had the term "Ottawa" explicitly documented in the reviewed indications or reports. This highlights the importance of structured clinical documentation to support transparent decision-making and future auditing.

Implications for policy, practice and research

Future improvement work should incorporate a brief structured Ottawa checklist into radiography requests or electronic clinical records, allowing clinicians to document the relevant positive criteria or reasons for justified deviation. Refresher teaching during junior doctor induction and regular departmental feedback may further improve adherence [14,15].

A future prospective audit should apply consistent eligibility criteria, include both imaged and non-imaged patients, and assess re-attendance or delayed fracture diagnoses. Repeated audit cycles over a longer period would also help establish whether the observed improvements are sustained.

Strengths and limitations

Strengths of this study include completion of a closed audit loop, random case selection, removal of duplicate attendance records, retrospective assessment of clinical documentation, and reporting of effect sizes with confidence intervals. The audit also assessed discharge documentation and reported diagnostic performance separately for knee and ankle imaging.

This was a single-centre retrospective audit, and Ottawa status was determined from existing EPR clinical documentation rather than prospective assessment. Reviewers were not blinded to the audit cycle, cases were not independently double-reviewed, and no formal inter-rater agreement assessment was performed. Improvements in documented examination findings may therefore have contributed to the observed increase in concordance. Although patients younger than 18 years were excluded from both cohorts, differences in the recorded eligibility screening, including injury-duration exclusions, may have influenced the comparison.

Differences in age distribution, injury patterns, seasonal presentation and clinician experience may also have contributed to the observed improvement. The baseline audit coincided with the August junior doctor rotation, whereas the re-audit was conducted several months later. The short interval between teaching and re-audit raises the possibility of a Hawthorne effect [16], and longer-term sustainability was not assessed. Furthermore, only patients undergoing radiography were included, preventing assessment of overall imaging rates or delayed fracture diagnoses among non-imaged patients.

Conclusions

Departmental education and targeted reminders were associated with improved Ottawa-rule concordance

among patients undergoing knee and ankle radiography for acute lower-limb injuries. Improvements were observed across both examination types, alongside better documentation of radiographic investigations in discharge correspondence. However, differences in eligibility screening and the retrospective study design limit causal interpretation. Further improvements should focus on integrating structured Ottawa-rule documentation into electronic clinical records, reinforcing clinician education, and conducting prospective re-audits to assess the sustainability of these findings.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

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Disclosures

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