ORIGINAL ARTICLE

Reappraisal of the Use of X-Rays in Acute Ankle and Midfoot Injuries. A Prospective Evaluation of the Ottawa Ankle Rules (OAR) in a Single Tertiary Trauma Centre

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ABSTRACT

INTRODUCTION: Acute ankle and foot injuries commonly present to the emergency departments, often resulting in routine radiography referrals, despite the fact that less than 15% of cases exhibit clinically significant fractures. The OAR has been designed to reduce the number of unnecessary radiographs ordered for these patients. We evaluated the OAR for predicting ankle and midfoot fractures in a cohort of patients treated in a single tertiary trauma centre. **MATERIALS AND METHOD:** A prospective study was conducted in the emergency department and orthopaedic clinics of a tertiary trauma centre. 73 patients aged 18 years and older were recruited during a 12-month study period. Radiographs were performed for all patients after clinical evaluation findings were recorded. The main outcomes measured were sensitivity, specificity, positive predictive value, negative predictive value, and likelihood ratios (positive and negative) of the OAR. **RESULTS:** 41 patients had ankle injuries, 21 around the midfoot, and 11 within both areas. In detecting ankle fractures, OAR had a sensitivity of 100%, a specificity of 73.68%, and a negative predictive value of 100% compared to the detection of midfoot fractures (100%, 84.61%, and 100%, respectively). The OAR had the potential of reducing radiographs by 42.47%. **CONCLUSION:** OAR is an accurate and highly sensitive tool to detect ankle and midfoot fractures. The implementation would lead to a significant reduction in the request for radiographs without missing any clinically significant fractures, thus, reducing costs, radiation exposures, and waiting times.

INTRODUCTION

Acute ankle and foot injuries are the most common joint injuries presented to the emergency department.[1,2] Most patients undergo radiography but less than 10% to 15% have actual fractures.[1,2,3,4] Thus, the costs associated with the management of ankle trauma are substantial and consequential. To reduce the need for radiography in patients with acute ankle and foot trauma, various prediction rules have been developed.[5,6,7,8] The Ottawa Ankle Rules (OAR) is one of the internationally recognized prediction tools developed to evaluate these injuries in deciding on the need for radiographs. It is well-validated and has been included in many clinical practice guidelines worldwide.[1,6,9,10,11,12,13,14] According to the OAR, a series of ankle radiographs is necessary (OAR positive) only if there is any pain in the malleolar region or the midfoot zone, with at least one of the specific clinical findings.[8] OAR negative is when the decision rules are not fulfilled to indicate the necessity for radiographic examination. Figure 1 depicts the overall clinical decision rules.

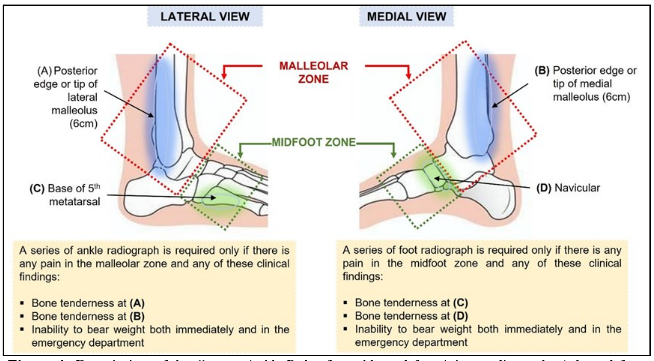

Figure 1: Description of the Ottawa Ankle Rules for ankle and foot injury radiographs (adapted from Stiell et al. 1994).[8]

The rules were developed to reduce the number of unnecessary radiographs requested, resulting in less radiation exposure, shorter the waiting times in the emergency department, and cost reduction for the medical institution without the risk of missing clinically significant fractures.[2,15] Therefore, evaluation and application of OAR in the local population are needed since currently there is no standard practice used for assessing acute ankle and foot injuries in local hospitals.

The current study aimed to validate the OAR's effectiveness in predicting clinically significant ankle and midfoot fractures within a cohort of patients receiving treatment at a single tertiary trauma centre. We aimed to determine the prevalence of ankle and midfoot fractures in the cohort of patients and calculate the OAR's sensitivity, specificity, positive and negative predictive values, and likelihood ratios in predicting the fractures. Furthermore, we aimed to determine the potential number of reductions in the request for radiography among patients with acute ankle or midfoot injuries.

MATERIALS AND METHODS

The prospective study was conducted in the emergency department and orthopaedic clinics of a tertiary trauma centre. Over a 12-month period, 73 patients aged 18 years and older were enrolled using a purposive sampling method. These patients had sustained acute ankle or foot injuries within 48 hours of hospital presentation. Pregnant individuals and those with open fractures, which have a fracture already visible, gross deformities, multiple traumas (at least one other organ injury), underlying neuropathy over the ankle or foot (e.g., diabetic patients), altered sensorium (Glasgow Coma Scale less than 15), or referrals from other institutions for radiographic evaluation of the same injury were excluded.

Sample size calculations were based on the study's primary outcomes, including the sensitivity, specificity, positive and negative predictive values, and likelihood ratios (positive and negative) of the OAR. This entailed the following steps:

Step 1: a) Specify the width (W) of the 95% confidence interval (CI)
b) Estimating the prevalence (P)
c) Specifying expected sensitivity (SN)
d) Specify expected specificity (SP)

Step 2: Calculating True Positive (TP) + False Negative (FN) = 27.31804

Step 3: Calculating sample size for sensitivity, N1 = 72.26996

Step 4: Calculating False Positive (FP) + True Negative (TN) = 40.80206

Step 5: Calculating sample size for specificity, N2 = 65.59817

True Positive (TP) signifies cases where the OAR accurately identifies patients with fractures, while False Positive (FP) occurs when the OAR incorrectly suggests radiographic examination for non-fractured individuals. False Negative (FN) denotes cases where the OAR fails to identify the need for radiography in patients with fractures, and True Negative (TN) indicates accurate test results showing the absence of fractures.

Data collection was commenced following approval by the Human Research Ethics Committee of the institution. Two examining medical specialists, one from the emergency department and one from the orthopaedic department, participated in the data collection. Informed consent was obtained from all participants via pre-printed consent forms. Patients' data, including age, gender, and injury mechanism, were recorded in a patient datasheet. Clinical findings related to the OAR were determined and documented on the same datasheet. This allowed for easy classification of patient injuries as OAR positive or negative, indicating the need for radiographs.

Subsequently, all patients underwent a series of radiographs of the malleolar or midfoot zones, or both, based on tenderness localization. The series of radiographs included standard anteroposterior (AP) and lateral views for the ankle, and AP and oblique views for the foot. Radiographs were evaluated using the diagnostic workstation (Pathspeed 8.1, GE Medical Systems, and

Milwaukee, USA) with 3-megapixel grey-scale monitor by a single qualified radiologist and a single orthopaedic surgeon independently, both blinded to the clinical findings. Fracture presence or absence was determined based on the agreement between both experts.

Statistical Analysis

Table I presents the relationship between OAR-based findings and plain radiographs in determining the prevalence, primary outcome parameters, and the potential reduction in radiography requests in patients with acute ankle or midfoot injuries.

Table I: Correlation between the findings based on the OAR and the plain radiographs.

OAR	X-ray noted fracture	
	Positive	**Negative**
Positive	True Positive (TP)	False Positive (FP)
Negative	False Negative (FN)	True Negative (TN)

Prevalence = (TP+FN)/ (TP+FP+FN+TN)
Sensitivity (SENS) = TP/ (TP+FN)
Specificity (SPEC) = TN/ (FP+TN)
Positive predictive value = TP/ (TP+FP)
Negative Predictive Value = TN/ (FN+TN)
Positive Likelihood = SENS/ (1-SPEC)
Negative Likelihood = (1-SENS)/ SPEC
Overall Accuracy = (TP+TN)/ (TP+FP+FN+TN)
Number of reductions in the request for radiography=TN

RESULTS

A total of 73 patients were enrolled in the study, consisting of 40 males (54.8%) and 33 females (45.2%). The mean age of the cohort was 37.01 years (SD=16.11), with ages ranging between 18 to 72 years. Among these patients, 41 (56.2%) sustained injuries solely in the malleolar zone, 21 (28.8%) in the midfoot zone, and 11 (15.0%) in both areas. A significant majority (88.9%) sought medical attention within 24 hours of injury, with road traffic accidents (n=45, 61.6%), being the primary cause of injury, followed by torsional injuries (n=16, 22.0%) and falls (n=12, 16.4%).

A total of 34 patients experienced fractures following the injuries. Out of the 73 patients, 42(57.5%) were tested OAR positive. A total of 168 radiographs were ordered for the entire patient cohort, with 104 ankle series and 64 foot series conducted. Table II summarizes the distribution of fractures according to the anatomical sites. The distal end of the tibia was the most common site of fracture. Notably, none of the patients had a cuboid fracture.

Table II: Distribution of fractures according to the anatomical site

Fracture detected on radiograph	Site of fracture	Frequency (n)	Percentage (%)
Yes	First (1st) metatarsal bone	1	1.4
	Second (2nd) metatarsal bone	1	1.4
	2nd and third (3rd) metatarsal bones	2	2.7
	3rd, fourth (4th), and fifth (5th) metatarsal bones	1	1.4
	5th metatarsal bone	3	4.1
	Distal end of the tibia	8	11.0
	Distal end of the fibula	6	8.2
	Distal ends of tibia and fibula	6	8.2
	Calcaneum	3	4.1
	Navicular	2	2.7
	Talus	1	1.4
No	None	39	53.4
Total		**73**	**100**

Among the 41 patients with injuries confined to the malleolar zone, 27 tested OAR positive, with 22 of them having fractures. In the case of 21 patients with midfoot zone injuries, the OAR was positive in 10 cases, with 8 of them showing fractures. For the 11 patients with injuries spanning both malleolar and midfoot zones, five tested OAR positive, and 4 of them had fractures. All patients classified as OAR negative, which included 14 with malleolar zone injuries only, 11 with midfoot zone injuries only, and 6 with injuries in both zones, did not sustain any fractures following their injuries (Table III). In total, 31 out of 73 patients were OAR negative and had no fractures. Applying these rules could potentially reduce the number of radiograph requests by 42.47%.

Table III: The frequency of injuries in accordance with the OAR results

Presence of fracture	Malleolar zone only injury		Midfoot zone only injury		Both zones injury		Total	
	OAR +ve	OAR -ve	OAR +ve	OAR -ve	OAR +ve	OAR -ve	OAR +ve	OAR -ve
Yes	22	0	8	0	4	0	34	0
No	5	14	2	11	1	6	8	31
Total	27	14	10	11	5	6	42	31

Sensitivity, Specificity, Predictive Value, and Likelihood Ratios of the OAR

Table IV provides a summary of the statistical characteristics of the OAR. Sensitivity for detecting fractures was 100% (95% CI: 81.50-100%) for isolated malleolar injuries (41 patients, 22 fractures), 100% (95% CI: 59.77-100%) for isolated midfoot injuries (21 patients, 8 fractures), and concurrent fractures of both zone (11 patients, 4 fractures). The overall sensitivity of the OAR was also calculated to be 100% (95% CI: 87.35-100%) across all evaluations (73 patients, 34 fractures).

The overall specificity for all the fractures was 79.49% (95% CI: 63.05-90.12%). The specificity for each zone was 73.68% (95% CI: 48.57-89.87%) for the malleolar zone, 84.61% (95% CI: 53.66-97.28%) for the midfoot zone, and 85.71% (95% CI: 42-99.24%) for concurrent injuries involving both zones.

Negative predictive values for fractures within the malleolar midfoot, and overall areas were 100% (95% CI:73.23-100%), 100% (95% CI:67.85-100%), and 100% (95% CI:86.27-100%), respectively. The negative likelihood ratio was 0 for all three evaluations. Positive predictive values of the OAR were 81.48% (95% CI: 61.25 -92.97%) for malleolar zone fractures, 80% (95% CI: 44.21-96.45%) for midfoot fractures, and 80.95% (95% CI: 65.37-90.85%) in the overall evaluation. The positive likelihood ratio was 3.79, 6.50, and 4.87 for the malleolar zone, the midfoot zone, and the overall evaluation, respectively. For concurrent injuries involving both zones, the negative predictive value, negative likelihood ratio, positive predictive value, and positive likelihood ratio were 100%, 0, 80%, and 7, respectively.

DISCUSSION

The OAR has been used worldwide for over than three decades since their introduction by Steill et al. in 1992.[2] It is crucial to emphasize that the OAR is primarily applied in acute settings assessments generally conducted within 7 to 10 days of injury.[6,9,10,11] Systematic reviews reported high sensitivities ranging from 90% to 100% but with varying specificities (ranging from 10% to 80%) in the adult population.[4,6,9,15,16] Bachmann et al. hypothesised that the accuracy of the OAR may vary due to differences in the assessors' clinical skills, experience in detecting and interpreting the findings, and the timing of assessments.[16] A delay in the assessment of the injury was also addressed as one of the influencing factors of the accuracy. Higher sensitivities were often recorded when the rules were applied within the first 48 hours after injury,[16] which prompted the inclusion of this criterion in our study. Differences should be anticipated considering the polarity of population, patient selection, and level of users, which is why validation studies were recommended.[1]

The findings from the current study were consistent with the previous validation studies, confirming the OAR's reliability[3,6,8,9,12,13,15,16] Sensitivities were consistently 100% across all evaluations, involving the malleolar zone, the midfoot zone, and concurrent fractures (Table IV). In a review of 66 studies, it was found that the OAR had a higher specificity for the midfoot compared to the ankle rules.[15] Although the current study also reported higher specificities compared to the pooled specificity from the review, it is important to note that a higher specificity decreases the likelihood of false positives.[9,12] This is a critical aspect, as avoiding unnecessary radiographs is a key goal of the OAR.

The overall positive likelihood ratio calculated in the current study indicated that a positive finding using the OAR increased the odds of having a fracture by 4.87 times. This aligns with previous research and suggests that a positive OAR is a valuable indicator for potential fractures. Gomes et al. reported a pooled positive likelihood ratio of 1.47.[9] The negative likelihood ratio

Table IV: Statistical characteristics of the OAR

Performance indicator	SENS (%)	SPEC (%)	PPV (%)	NPV (%)	PLR	NLR	Prevalence (%)	Overall accuracy (%)
Isolated malleolar injury	100	73.68	81.48	100	3.79	0	38.09	90.47
Isolated midfoot injury	100	84.61	80.00	100	6.50	0	53.65	87.80
Both zone injury	100	85.71	80.00	100	7.00	0	36.36	90.90
Overall	100	79.49	80.95	100	4.87	0	46.58	89.04

SENS: sensitivity, SPEC: specificity, PPV: positive predictive value, NPV: negative predictive value, PLR: positive likelihood ratio, NLR: negative likelihood ratio indicates the odds of ruling out a fracture when a negative finding is obtained. The current study scored 0 for all three and the overall evaluations, indicating that when the OAR is negative, the odds of ruling out a fracture are high. This is a promising feature, especially considering that previous studies reported similar results. However, some studies reported lower sensitivity rates when modifications to the prediction rules were made, emphasizing the importance of adhering to the established OAR criteria.[7] A pooled overall negative likelihood ratio of 0.15 was calculated in the systematic review by Gomes et al.,[9] whereas Bachman et al. recorded 0.09, 0.07, and 0.21 for ankle fractures, midfoot fractures, and concurrent fractures in both zones, respectively.[16] Wang et al. suggested that physicians adhere to the 6cm area to palpate as spiral fractures may be missed if palpation is limited to the lateral malleolus only.[4] When attempting to use the ability to weight bear as the sole criterion compared to the OAR, Amiri et al. recorded lower accuracy and sensitivity in the outcomes. The risk of missing fractures was also reported to be higher.[17]

Patient selection and population characteristics can influence the outcomes of the validation studies.[9,14,18] The current study focused solely on adult patients, although various studies include paediatric populations as well. The OAR can be used on paediatric cases with some caveats, with most studies recommending the selection of patients aged 5 years and above.[15,16,19] Mechanisms of injuries vary, but we found that road traffic accidents were the most common, followed by torsional injuries and falls. This pattern aligns with most previous reports. Yazdani et al. reported a similar mechanism of injuries with a higher volume of cases contributed by falls.[1]

The preponderance of male patients (54.8%) may be attributed to their higher pain tolerance due to increased opioid activity and baroreceptor-regulated pain systems.[20] This might affect the response to palpation in assessing tenderness. A female patient who has a lower pain threshold would have a higher chance of getting a radiograph for her injury. The preponderance of males in this study did not reflect the lower threshold of pain in females which makes them more susceptible to extra radiographs. In addition to the expression of pain, cultural and geographical factors may also play a role in influencing the interpretation of the test.[6,16] African Americans rated cutaneous pain stimuli as more atrocious and tended to rate it as more profound than whites.[20] These differences in pain response between ethnic and races can influence the OAR assessment of tenderness on palpation. Previous studies of OAR in the Asian region have Chinese as the majority.[12,21] In Canada, the United Kingdom, and New Zealand, there was whites' preponderance in their study.[2,13,22] Best to our knowledge, no validation study of the OAR had been conducted in Malaysia. Akhmar et al. conducted a retrospective study to explore the compliance of emergency physicians with the OAR in planning for their imaging requests back in 2004. Stressing that the research was not a validation study, they reported that most physicians did not incorporate OAR in their routine clinical practice.[23]

The OAR has shown flexibility in application, involving various levels of healthcare providers. During the development of the OAR, the initial study in 1992 only involved emergency physicians.[2] A more diverse involvement of physicians and multiple clinical settings was conducted in the subsequent multicentre study to introduce the OAR.[25] In the Asian region, there were two validation studies of OAR conducted in Hong Kong and Singapore, where the latter involved various levels of healthcare providers.[12,21] The study by Yuen et al. only evaluated the application of OAR by emergency physicians.[12] The current study only evaluated the application of OAR involving orthopaedic surgeon and emergency physician considering that one of the study criteria used was assessment within the first 48 hours of injury. Most of these patients will be treated by physicians in the emergency and orthopaedic departments. On the other hand, there are other studies on OAR evaluating its application by nurses. In some regions, emergency department nurses were able to use OAR accurately, leading to a reduction in radiograph requests. Training nurses and medical assistants in OAR application can not only reduce waiting times but also enhance nursing practices and job satisfaction.[25,26] Allerston and Justham reported a significant difference in the request rates of radiography between physicians who did not apply the OAR compared to practicing nurses who did.[27] In

Malaysia, however, nurses have no role in requesting radiographs. With the better implementation of the OAR application, medical institutions can train nurses and medical assistants in using the OAR during triage. Apart from reducing the waiting time in the emergency department as the physicians can spend more time reviewing the radiograph if the OAR is positive, or reassessing the need for a radiograph if it is negative during triage, higher nurse job satisfaction can be achieved through the empowerment of nursing practices.[27] Despite the spectrum of diversities reported in previous studies, numerous studies involving different levels of assessors and fields had been producing similarities in the sensitivity of the OAR.[15,25] However, a high false positive rate was recorded when OAR was applied by physiotherapists in a rehabilitation centre.[28] A possible explanation would probably be that physiotherapists are more involved during the later phase in managing ankle and foot fractures, hence, the assessment may not be as accurate as in the acute setting.

The current study demonstrated a significant reduction (42.47%) in unnecessary radiographs, which is in line with previous findings. A higher percentage of reduction (51.0%) was reported in another study.[10] Bachmann et al. calculated a possible reduction of about 30% to 40% of radiograph requests with the proper application and implementation of the OAR.[16] Similar results were recorded in other previous studies.[8,11,12,22] The cost-effectiveness of the OAR lies in its potential to lower medical costs, improve efficiency, and reduce patient and staff radiation exposure, without the increased risk of missing significant fractures.[9,12,24,29] It is paramount to consider that multiple plain radiographs, although viewed as a low-cost assessment tool, conceivably a financial impediment to the healthcare system as the advanced, high-priced, but less-frequently used interventions such as magnetic resonance (MR) imaging and computed tomography (CT) scans.[1] Inevitably, the implementation of OAR is not without challenges. Despite the potential benefits, there are challenges to implementation, including resistance from healthcare providers driven by concerns such as fear of litigation and the practice of defensive medicine. Immediate access to radiography, physicians' obsessiveness, and anxiety, as well as pressure given by the patients and their relatives, were among the contributing factors.[9,10,16] Requesting for a radiograph lavishly may not be considered a significant ethical issue despite the subsequent hazards of radiation exposure since it is what most physicians do.[1] Without awareness, neither extensive training nor active dissemination of its benefits was adequate to influence them in reducing radiograph requests.[1,6,30]

Despite the study's contribution to validating the OAR in the Malaysian context, it has some limitations. Future studies should include healthcare providers at various levels and assess local medical practitioners' awareness and attitudes towards OAR. Patient acceptance and satisfaction should also be explored. Additionally, the study had no cuboid fractures and only one case of talar involvement, limiting the generalizability of our results to all midfoot fractures.

CONCLUSION

The current study reaffirms the OAR as a precise and highly sensitive tool for detecting ankle and midfoot fractures, consistent with the original study and numerous previous research. The OAR remains a valuable asset in reducing unnecessary radiographs and enhancing the efficiency and cost-effectiveness of managing ankle and midfoot injuries. Future efforts should focus on wider implementation and continued education to further optimize its utilization within the healthcare system. Its application can significantly reduce the volume of requests for radiographs without missing any clinically significant fractures, thus, reducing costs, radiation exposures, and waiting times in the emergency departments.

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