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The Challenges of Implementing and Documenting Ottawa Ankle Rules in the Pediatric Emergency Department: A Retrospective Study

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Cover Page Footnote

Thank you Ian G. Stiell, MD for granting us permission to use Figure 1. Thank you Brian Freeze, MD for your assistance in medical informatics.

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Original Clinical Investigations

The Challenges of Implementing and Documenting Ottawa Ankle Rules in the Pediatric Emergency Department: A Retrospective Study

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INTRODUCTION

Acute ankle sprains account for nearly 2% of visits to the pediatric emergency department (PED). The Ottawa Ankle Rules (OAR) were developed as a safe and effective clinical decision-making tool for detecting the need for radiographs in adults with acute ankle pain. OAR state radiographs are required with at least one of the following:

1. Inability to bear weight immediately following the injury and for four steps in the ED
2. Bony tenderness at the posterior edge of the lateral or medial malleolus

OBJECTIVE

Few prospective cohort studies have attempted to assess OAR pediatric populations. This study investigates the validity and documentation of OAR within a single academic institution's PED.

METHODS

This retrospective chart review included previously healthy patients aged 2-19 years who presented to the PED with a traumatic ankle injury between 2019 and 2021. Exclusion criteria were met with documented parental insistence for imaging studies. We compared calculated OAR predictive values to those in literature using Chi-squared tests and WINPEPI.

RESULTS

A total of 295 subjects were included. When only considering clinically significant fractures in the data analysis, 247 patients received X-rays and 42 clinically significant fractures were found. OAR were 100% sensitive (95% confidence interval 93.1–100.0), 12.2% specific (95% CI 8.2–17.2), with a positive predictive value (PPV) of 18.9% (95% CI 16.6–26.5), and negative predictive value (NPV) of 100% (95% CI 88.7–100.0). When comparing this study's findings to those with similar design protocol, specificity was lower ($p<0.05$) and there was no significant difference in sensitivity, PPV, or NPV.

CONCLUSION

Implementing the highly sensitive OAR yielded zero missed fractures. Their poor specificity results in unnecessary radiation exposure, which also increases expense and wait time. Excess imaging may be attributed to ambiguous OAR criteria, their dependence on pediatric cooperation, and parental expectations for imaging studies.

a MS4

b MS2

INTRODUCTION

Acute ankle sprain is the most common lower limb injury in athletes and accounts for 16-40% of sports-related injuries. Pediatric acute ankle and mid-foot injuries account for nearly 2% of visits to the pediatric emergency department (PED).[1]

A 2013 Australian prospective study consisting of 174 adult and pediatric subjects found that 90% of acute ankle injury patients received an X-ray as part of the initial assessment in the emergency department (ED). Despite large volumes of imaging, only 15% of patients were diagnosed with a clinically significant fracture.[2] Radiographs expose patients to radiation, induce healthcare costs, and increase wait times.[3]

The Ottawa Ankle Rules (OAR) developed by Stiell et al.[4] provide ED physicians with clinical decision rules regarding acute ankle or mid-foot injuries. These criteria aim to expedite patient care and reduce unnecessary radiation exposure.[5] The sensitivity of OAR for predicting fractures in the adult population (⩾18 years) is 100%.[6] OAR were initially precluded from use in those under 18 years presumably due to the concern for missed epiphyseal injuries and the difficulties in assessing very young children.[7]

Prospective studies have attempted to assess the validity of OAR in pediatric populations but with varying inclusion criteria. Clark et al.[8] reported 83% OAR sensitivity in 203 children, Libetta et al.[7] reported 100% sensitivity in 761 children, and Plint et al.[9] reported 100% sensitivity in 670 children. In contrast to Plint et al.[9] and Libetta et al.,[7] Clark et al.[8] prospectively considered all fractures to be clinically important, including data from Salter-Harris type I fractures (SH1F) and "tiny" (measuring less than 3 mm) avulsion fractures. These pediatric OAR studies were chosen for comparison to our study because of their simple objective, statistical power, and generalizable population.

We set out to retrospectively calculate the diagnostic test values of sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of OAR within our institution's PED. We identified how often the OAR were appropriately utilized and documented. We compared our findings to those of three prospective studies when adjusting for their respective inclusion criteria. The findings of this study may be used to address the challenges associated with applying OAR in the pediatric population, in particular, the controversy of detecting SH1F.

METHODS

This is a retrospective study carried out in the PED of an academic Level II Pediatric Trauma Center. The institutional review board granted exemption according to the criteria 45 CFR 46.104 on November 2, 2022.

STUDY POPULATION

Patients aged 2 to 19 years presenting between January 2019 and December 2021 with acute traumatic injuries of the ankle were eligible. We excluded patients younger than 2 years due to their limited ability to cooperate, older than 19 years due to potential for adult injury patterns, those with chronic genetic or metabolic disease resulting in weakened or compromised bone structure (i.e. rickets disease or osteogenesis imperfecta), those with a physical disability that limits mobility (i.e. dependence on mechanical assistance), atraumatic presentations, presentation following an urgent care recommendation, documented parental insistence for imaging studies, mid-foot pathologies, suspected child abuse, and recent history (within 1 year) of ipsilateral ankle injury.

SAMPLE SIZE

A sample size of 300 patients was chosen prior to the study with the goal of collecting data across three years of PED visits following the protocol of Clark et al.[8] A 25% incidence of fractures was assumed based on previous discharge diagnoses under the chief complaint of "ankle injury" or "ankle pain". We calculated a study size of 300 patients would have 75 fractures with a 95% confidence interval (CI) of 90% to 100% for sensitivity and 225 non-fractures with a 95% CI of 32 to 48% for specificity based on calculations reported by Stiell et al.[4]

OTTAWA ANKLE RULES (OAR)

The ankle is defined as the malleolar area, distal 6 cm of tibia, distal 6 cm of fibula, and talus. OAR state that ankle radiographs are required only if the patient has pain in the malleolar zone and one or both of the following:

1. Inability to bear weight immediately after the injury and for four steps in the emergency department
2. Bone tenderness at the posterior edge or tip of the medial or lateral malleolus (Figure 1).[4]

We collected the data points stated in the OAR criteria from the history and physical examination documentation. Incomplete or ambiguous documentation of OAR criteria excluded the subject from the study. We stratified each subject's Ottawa ankle score as 'positive' or 'negative' and used this data to create a 2x2 table of diagnostic test predictive values.

The following was collected from the PED physician's note: diagnostic imaging ordered (if any), presence or omission of documenting OAR in the assessment, and final impression and diagnosis prior to discharge. The following was collected from the radiology report: presence of fracture, size, location, and classification.

ADDRESSING CLINICALLY SIGNIFICANT FRACTURES

A pediatric radiologist interpreted the ankle radiographic series. Our primary findings and comparisons excluded clinically insignificant fractures (SH1F and tiny avulsion fractures measuring less than 3 mm across) based on the study design of Stiell et al.[4], SH1F were diagnosed by point tenderness at the growth plate on physical examination by the PED physician with an absence of radiologic fracture or with radiological concern for SH1F. Subtle radiological changes are more standardized than concerning physical

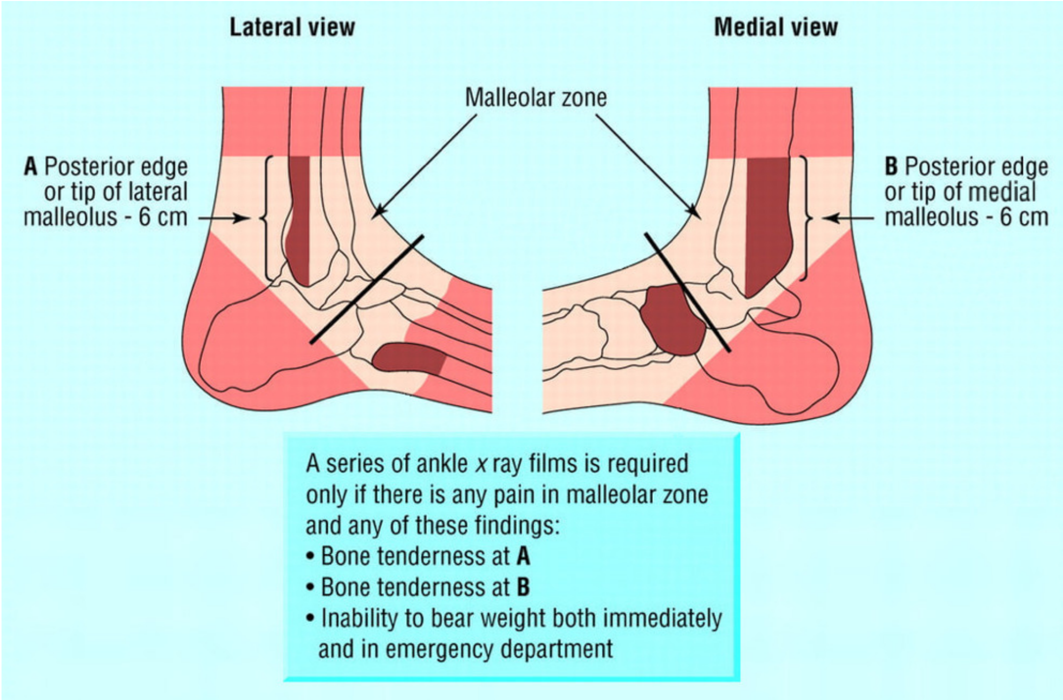

Figure 1. Ottawa Ankle Rules (adapted from Stiell et al.[4] with permission).

exam findings of swelling or tenderness and so the radiologist's concern for SH1F alone classified it as such. Tiny avulsion fractures were measured and diagnosed by the official radiology report. Our secondary findings included data from all fractures, significant and insignificant, based on the study design of Clark et al.[8] Stratifying the data into primary and secondary datasets allowed us to compare to studies with differing inclusion criteria.

Table 1. Demographics of the study population.

Demographics (N = 295)	
Average age (years) ± SD	13.5 ± 4.0
Males (%)	58.6
Females (%)	41.4

CLINICAL EVALUATION

Patients were evaluated by an emergency medicine or pediatric resident physician overseen by a board-certified pediatric emergency medicine or emergency medicine attending physician.

STATISTICAL ANALYSIS

Categorical variables are presented as frequencies and percentages. Continuous variables are presented as means with standard deviations (SD). The evaluation of a diagnostic test includes sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV), which were calculated with their respective 95% CI. Chi-squared tests compared the diagnostic test properties between our institution's findings and data from the literature.[7-9] Data analysis was completed using WINPEPI.[10]

RESULTS

During the study time, a total of 295 charts were included. When only considering clinically significant fractures in the data analysis, 247 patients received X-rays and 42 clinically significant fractures were found. When considering all fractures in the data analysis, significant and insignificant, 284 patients received X-rays and 79 fractures were found. The study population's demographics are presented in Table 1. Classification of all fractures is presented in Table 2.

PRIMARY OUTCOMES

We calculated OAR sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) from 247 patients who received X-rays when considering only clinically significant fractures as "positive fractures" (Table 3).

ONLY CONSIDERING CLINICALLY SIGNIFICANT FRACTURES

Chi-squared tests with confidence intervals compared our hospital's findings to the combined findings of two similarly designed studies, Libetta et al.[7] and Plint et al.[9] (Table 4). We found OAR specificity was lower ($p < 0.05$) and no significant difference in sensitivity, PPV, or NPV (Table 4).

CONSIDERING ALL FRACTURES AS SIGNIFICANT

We calculated OAR sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) from

Table 2. Types of fractures.

Fracture	Quantity
Salter-Harris Type I*	29
Salter-Harris Type II	16
Salter-Harris Type III	5
Salter-Harris Type IV	8
Avulsion fracture ≤ 3 mm*	8
Bimalleolar	1
Trimalleolar	3
Lateral malleolus, unspecified	2
Chip of malleolus	1
Comminuted angulated of distal tibia and fibula	1
Oblique of distal tibia	1
Spiral of tibia	1
Buckle of distal fibula	1
Oblique of distal fibula	1
Transverse of fibula	1
Total fractures	79

* indicates clinically insignificant fracture

Table 3. 2 × 2 contingency table when considering only clinically significant fractures (N = 247).

	Fracture	No Fracture
Ottawa Positive	42	180
Ottawa Negative	0	25

284 patients who received X-rays when considering all fractures, even 28 SH1F and 8 tiny avulsion fractures, as "positive fractures" (Table 5). When including clinically insignificant fractures in the 2 × 2 contingency table, we found OAR was higher in sensitivity ($p < 0.05$) and lower in specificity ($p < 0.05$) with no significant difference in PPV or NPV compared to the findings of Clark et al.[8] (Table 6).

COMPARISON BETWEEN INCLUDING OR EXCLUDING SALTER-HARRIS I FRACTURES

Between the two datasets at our institution, considering clinically insignificant fractures in the 2 × 2 contingency table results significantly increased the calculated PPV ($p < 0.05$) while the other three predictive values were not significantly different.

POTENTIAL REDUCTION IN X-RAYS

We found that applying OAR to clinically significant fractures has the potential to reduce radiographs by 9.7%. This is greater than the 7% reported by Libetta et al.[7] but less than the 60% reported by Clark et al.[8] and 16% reduction reported by Plint et al.[9] In our study, zero clinically significant fractures would have been missed when applying OAR.

SECONDARY OUTCOMES

OAR were used to guide clinical decision making 90% (265/295) of the time despite the explicit documentation of "Ottawa Ankle Rules" only occurring in 12% (34/295) of encounters. Of the 34 OAR documentation, 27 were included in resident physician's assessment while 6 were addended in the attending physician's attestation.

DISCUSSION

We found our calculated OAR diagnostic predictive values to be generally congruent with those in previous literature. OAR are highly sensitive, not very specific, and their use results in zero missed fractures. However, our specificity was significantly lower than those in the literature both with and without excluding clinically insignificant fractures. This was likely due to the limitations of a retrospective study such as the extrapolation of OAR criteria from non-standardized documentation and the subjective nature of "tenderness" in the pediatric population. Despite systematic review findings of Bachmann et al.[11] and Dowling et al.[12] establishing pediatric OAR as a reliable tool in excluding pediatric fractures, modifications to these criteria may be able to increase the specificity and reduce overimaging.

SIGNIFICANT PEDIATRIC FRACTURES IN PREVIOUS LITERATURE

In 2001, Boutis challenged the role of OAR in detecting SH1F as clinically significant, pointing out that stringent adherence to OAR may result in a substantial number of unnecessary radiographic examinations.[13]

Table 4. Comparison of the calculated Ottawa ankle rule predictive values to those of Libetta et al.[7] and Plint et al.[9] when considering only clinically significant fractures.

	Cooper University Hospital N = 247	Libetta et al.[7] & Plint et al.[9] N = 1489	p-value
Sensitivity (95% CI)	100.0 (93.1 to 100.0)	98.9 (96.4 to 99.9)	1.000
Specificity (95% CI)	12.2 (8.2 to 17.2)	38.2 (35.6 to 40.9)	**<0.05***
PPV (95% CI)	18.9 (14.2 to 24.5)	18.0 (15.6 to 20.4)	0.732
NPV (95% CI)	100.0 (88.7 to 100)	99.6 (98.7 to 99.9)	1.000

** p < 0.05 indicates significant difference; PPV, positive predictive value; NPV, negative predictive value; CI, confidence interval*

Table 5. 2 × 2 contingency table when considering all fractures as significant (N= 284).

	Fracture	No Fracture
Ottawa Positive	77	180
Ottawa Negative	2	25

In 1999, Plint et al.[9] excluded fractures in which the avulsion fragment was 3 mm or smaller, which is likely based on the 1992 design protocol of Stiell et al.,[4] and clarified that these patients are not usually treated with plaster immobilization. Additionally, Plint et al.[9] excluded SH1F diagnosed clinically or by radiographic changes such as widening of the growth plate for the purpose of analysis despite these patients receiving plaster immobilization at their institution. Plint et al.[9] also excluded patients who returned to normal physical activity within five to seven days of ED discharge. Sensitivity was originally found to be 100% but after a large percentage of SH1F (119/237, 50%) were excluded, the sensitivity decreased to 91%.[9]

Libetta et al.[7] did not set numerical measurements for classifying a significant fracture. They assumed that an Ottawa negative subject who did not return to the emergency department within five to seven days of ED discharge had an insignificant fracture and recovered without treatment and so detection of such fractures would not change management. Libetta et al.[7] found no significant difference in missed fractures between the historical control group and the study group to which OAR were applied.

Due to the unclear clinical significance of SH1F and tiny avulsion fractures in children, the 2003 prospective Clark et al.[8] study included all fractures as significant when calculating the predictive values of OAR. They cite that all fractures have the potential for growth arrest or deformity.[14] Although one week follow-up evaluations were attempted for all SH1F to determine the final diagnosis, patients lost to follow-up radiographs may have missed fracture diagnoses. Clark et al.[8] concluded that OAR cannot be applied to children with the same sensitivity as adults.

QUESTIONING THE SALTER-HARRIS TYPE I FRACTURE

In 1963, Salter and Harris proposed a physeal fracture classification that stated physeal cartilage is weaker than the surrounding ligaments and so children are more likely to sustain a physeal or growth plate injury than a ligament injury. For over 50 years SH1F have been diagnosed either by subtle changes on X-ray (such as widening of the growth plate) or presumptive, based on soft tissue swelling overlying the physis.[9,13] This fracture is believed to be the most common ankle fracture in children.[15] In the case of a normal radiograph, detecting SH1F with imaging adds little to the clinical diagnosis, although X-rays are frequently ordered to exclude a more serious fracture.

Dowling et al.[12] argues that OAR will always detect SH1F because both are characterized by maximal tenderness and swelling over the growth plate, which is within 6 cm of the posterior edge of either malleolus. They also point out the considerable variation in management of SH1F, which ranges from symptomatic treatment only to below knee casting and follow-up with an orthopedic surgeon.[12] Based on widely held beliefs of pediatric physeal cartilage vulnerability, what would be a simple ankle sprain in adults is managed with immobilization (usually by casting), follow-up imaging, and an orthopedic referral in pediatric patients.[16]

In 2016, Boutis et al.[17] conducted the largest study to date in attempts to simplify the treatment of lateral ankle injuries and safely minimize the cost of overtreatment. They utilized MRI to prove the low frequency, only 3%, of SH1F of the distal fibula in skeletally immature patients as well as the excellent prognosis using a removable device and allowing return to activities as tolerated. This undermines the conventional teaching about the relative weakness of the pediatric physeal cartilage compared with the adjacent ligaments.[18] While the Boutis and colleagues[17] study had a thorough design protocol, adequate power, and a generalizable study population, long-term follow-up beyond three months is needed to confirm that no growth arrest occurs in displaced SH1F of the distal fibula.[19]

SH1F and tiny avulsion fractures detected at our institution's PED are often managed with plaster or immobilization and so we excluded them in our primary outcomes due to the uncertainty of their clinical significance and based on recent literature.

DOCUMENTATION OF OAR

Utilization of OAR was prevalent in this institution's PED regardless of documentation. A standardized smart phrase containing the three binary criteria of OAR may help providers discern true bony tenderness (a criteria of OAR) from diffuse tenderness over the ankle as documented in

Table 6. Comparison of the calculated Ottawa ankle rule predictive values to those of Clark et al.[8] when considering all fractures as significant.

	Cooper University Hospital N = 284	**Clark et al.[8]** N = 195	**p-value**
Sensitivity (95% CI)	97.5 (91.9 to 99.6)	82.5 (68.4 to 92.0)	**<0.05***
Specificity (95% CI)	12.2 (8.2 to 17.2)	50.3 (42.5 to 58.2)	**<0.05***
PPV (95% CI)	30.0 (24.6 to 35.8)	30.0 (22.0 to 39.0)	0.994
NPV (95% CI)	92.6 (77.6 to 98.7)	91.8 (84.4 to 96.3)	1.000

* *p < 0.05 indicates significant difference; PPV, positive predictive value; NPV, negative predictive value; CI, confidence interval*

the physical exam. This standardization of documentation and reminder of the criteria could improve the calculated specificity of OAR if a future prospective study was to be performed.

LIMITATIONS

There were several limitations in this study. Retrospective collection of data did not allow for standardized documentation of OAR criteria and so potentially eligible subjects were eliminated. Some physical exam documentation noted specific measurements of pain while others reported "tender to palpation lateral malleolus" without specific borders. Not all patients had adequate follow-up examinations at the orthopedic clinic or primary care clinic. It is not sufficient to exclude "no shows" as clinically insignificant fractures. Even among patients who received a repeat radiograph, potential fractures may have been missed.

YOUNG CHILDREN

Clinical experience suggests that the younger patients are more difficult to assess with their limited willingness to ambulate on command, especially while in pain, nor are they always able to coherently verbalize how they feel or may be limited by stranger anxiety.[8] The 2009 systematic review conducted by Dowling et al.[12] recommends caution when applying the OAR in those younger than six years. Pediatric OAR studies such as Boutis et al.,[13] Clark et al.,[8] Libetta et al.,[7] and Plint et al.[9] excluded children under the age of 3, 0, 1, and 2 years old, respectively. Since OAR were originally created using an adult population, a standardized inclusion criteria for age should be determined in future pediatric studies.

PARENTAL EXPECTATIONS VERSUS CLINICAL ALGORITHMS

Parental expectations may contribute to pressure for imaging studies after an acute injury with persistent pain. Documented parental insistence or urgent care transfers for further imaging were excluded from the study, but it is unknown if there were undocumented confounding variables present for each case. Furthermore, socioeconomic factors of the surrounding population may dictate the likelihood of stratifying fracture risk using a tool such as OAR. In a resource-rich area, X-rays may be readily available as opposed to a resource-poor area where imaging adds increased wait time and cost to the family, especially if underinsured.

Societal or patient satisfaction and expectations, especially in borderline cases, may limit the application of clinical algorithms. These expectations may supersede or be equally important to clinical-based algorithms when determining treatment of simple traumatic ankle injuries. Current literature has explored other areas of imaging overutilization such as the need for lumbar radiographs for low back pain in the emergency department[20] and the recommendations for a head CT in pediatric patients following a minor head injury compared to PECARN criteria.[21]

FUTURE STUDIES

Future studies should refine application of OAR in the pediatric population and address unique challenges of this age group such as the ambiguity surrounding the exclusion and management of SH1F and tiny avulsion fractures. This may be achieved by analyzing the follow-up X-rays of the SH1F diagnosed in the ED since healing fracture lines may be more obvious after 7 to 10 days than the fracture itself.[22]

It is unknown whether certain mechanisms of injury (i.e., eversion or inversion injury) are more likely to result in an occult fracture and warrant proactive management. The number of SH1F needed to splint to prevent worsening of a fracture injury and growth plate damage could be deduced by such studies.

It is possible that in addition to parental expectations for imaging, clinicians consider improvements in X-ray technology that minimize harmful radiation, which contributes to overimagining of simple traumatic injuries. Survey studies of ED physician perceptions of the harms of radiographic imaging may be conducted to determine these unconscious biases.

CONCLUSION

We conclude that our institution's PED practices evidence-based medicine by utilizing OAR to limit missed fractures, even when OAR are not documented. Like previous studies, the OAR were found to be highly sensitive but not very specific and so their role in decreasing radiographs in the pediatric population can be improved. This study points out the lack of guidelines for OAR application exclusively in the pediatric population. Refinement of OAR must consider the challenges of pediatric ankle injuries such as the high prevalence of SH1F and uncertainty in potential growth plate complications, patients' limited communication and motor coordination, and parental expectations for imaging in the pediatric emergency department.

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