SHORT REPORT

The tuning fork test—a useful tool for improving specificity in “Ottawa positive” patients after ankle inversion injury

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The Ottawa ankle rules are a clinical instrument calibrated towards a high sensitivity in order not to miss any fractures of the ankle or mid-foot. This is at the cost of a mean specificity of around only 32%. The aim of this study was to determine the suitability of tuning fork testing in combination with existing Ottawa guidance for increasing the specificity in detecting fractures of the lateral malleolus. A prospective pilot study was carried out, in which a single trained investigator examined all patients with already “Ottawa positive” findings for possible lateral malleolus injury by applying a tuning fork (C° 128 Hz). The tuning fork test findings were compared with formal reports of plain ankle radiographs using simple cross-table analysis. The observed prevalence of ankle fractures was 5 of 49 (10%). Sensitivity and specificity were calculated as 100% and 61%, respectively, for tuning fork testing on the tip of the lateral malleolus (TLM), and as 100% and 95%, respectively, for testing on the distal fibula shaft (DFS). The associated positive and negative likelihood ratios were 2.59 and 0 (TLM), and 22 and 0 (DFS), respectively. The data were significant, with $p=0.014$ (TLM) and $p<0.001$ (DFS). This study suggests that additional tuning fork testing of “Ottawa positive” patients may lead to a marked reduction in ankle radiographs, with consequently reduced radiation exposure and journey time. This may be particularly relevant in situations where radiological facilities are not readily available (expedition medicine) or where access to these has to be prioritised (major incidents, natural catastrophes).

The James Cook University Hospital, Middlesbrough, is a major trauma centre based in the northeast of the UK, serving a mostly urban population of 1.5 million. The number of annual new attendances to the emergency department exceeds 90 000, with an average case mix and an admission rate of around 20%. Ankle injuries account for up to 8% of minor injuries seen in the emergency department, with most of these being inversion injuries. Current UK practice follows the Ottawa ankle rules in determining the need for radiographic investigations.¹ A recent review of the literature has highlighted a mean specificity of only 32% for this clinical tool, leading to a high number of unnecessary x rays.² In addition, it has been shown that average journey times increase by up to 31 min in “see and treat” patients who are sent for radiographic investigations.³

Tuning fork tests have a role in assessing the need for bone scintigraphy in military recruits with suspected stress fractures of the tibia.⁴ Historically, clinical fracture auscultation has been used for detecting femoral neck fractures and identifying patients who need further radiographic imaging.⁵ The use of tuning fork testing as a screening tool for fractures of the lateral malleolus after inversion injury, however, has not been described so far.

The aim of this pilot study was therefore to determine the suitability of tuning fork testing for increasing the specificity of detecting a fracture of the lateral malleolus in patients with “Ottawa positive” findings after inversion injury.

METHODS

Study design

The study was conducted prospectively over a 6-week period in February and March 2005. A single investigator examined all patients with inversion ankle injury who presented to the “see and treat” area of our emergency department between 9:00 and 17:00 h on weekdays and between 10:00 and 18:00 h on weekends when on duty during these periods. Patients who had tenderness along the posterior aspect of the lateral malleolus or were unable to bear weight for more than four consecutive steps—that is, with “Ottawa positive” findings—were included in the study. Exclusion criteria were as follows: age < 12 years, non-traumatic ankle swelling, mechanism of injury other than inversion, extensive soft-tissue swelling with inability to palpate any bony prominences and presence of diminished or altered sensation to the lower leg.

The base of a vibrating tuning fork (C 128 Hz) was placed on to the tip of the lateral malleolus (TLM; fig 1) and then on to the distal fibula shaft (DFS) 5–10 cm proximal to the point of maximal tenderness (fig 2), ensuring that good contact was achieved with the underlying bone. Any sensation of discomfort or pain was recorded as an abnormal test result for either of the test positions.

After clinical examination, all patients had anterior–posterior and lateral x rays of the ankle joint. These were reported independently of this study, by consultant radiologists or reporting radiographers, and were considered the “reference standard”.

Statistical analysis

We aimed at a sample size of about 50 patients. A formal power calculation was not carried out, as no previous data were available to allow this.

Cross-tables (tables 1 and 2) were designed comparing the tuning fork test results with the findings on “reference standard” ankle radiographs. Given the small sample size of the study, Fisher’s exact test was used to check for independence of the variables. A level of $p<0.05$ was considered to be significant. Sensitivity, specificity and accuracy, as well as diagnostic positive and negative likelihood ratios, were subsequently calculated for each of the tuning fork test positions. In addition, 95% confidence intervals (CIs) were calculated for these parameters by using the Wilson test.

No data on patient number or fracture prevalence were collected for patients who were excluded from this study.

Abbreviations: DFS, distal fibula shaft; TLM, tip of lateral malleolus

Figure 1 Application of the tuning fork on the tip of the lateral malleolus.

Figure 2 Application of the tuning fork on the distal fibula shaft 5–10 cm proximal to the point of maximum tenderness.

RESULTS

During the 6-week trial period, 49 patients aged 12–84 years (27 men and 22 women) were examined by the single investigator working in the “see and treat” area of our department. Only five (10%) patients had a fracture of the lateral malleolus proved on ankle radiographs compared with an average prevalence of 13% (9–20%) reported in the literature.²

Fisher’s exact test yielded Pearson’s coefficients of 9.5 and 36.7, with two-sided *p* values of 0.014 and <0.001 for tuning fork testing on the TLM and the DFS, respectively.

Sensitivity and specificity were calculated from the cross-tables as 100% (CI 46% to 100%) and 61% (CI 46% to 75%) for tuning fork testing on the TLM, and as 100% (CI 46% to 100%) and 95% (CI 83% to 99%) for testing on the DFS, respectively (table 3). Diagnostic accuracy was recorded as 65% (CI 50% to 78%) and 96% (CI 85% to 99%), respectively.

The associated positive likelihood ratios were 2.59 (CI 1.78 to 3.76) for the TLM and 22 (CI 5.68 to 85.21) for the DFS, with negative likelihood ratios of 0 and 0, respectively; 95% CIs for the negative likelihood ratios could not be calculated from the study data.

CONCLUSION

The Ottawa ankle rules are a clinical instrument calibrated towards a high sensitivity in order not to miss any fractures of the ankle or mid-foot.¹ This is at the cost of a pooled specificity of around only 32% (19–77%), depending on the prevalence of fractures in the different study groups and probably on the clinical experience of the investigators.²

This pilot study suggests that tuning fork testing on the DFS in addition to applying Ottawa ankle rules may yield a threefold increase in specificity, without any reduction in sensitivity for the detection of fractures of the lateral malleolus complex. This is also expressed by the associated strong positive and negative likelihood ratios. Tuning fork testing on the TLM seems to increase the specificity only twofold when compared with the use of Ottawa ankle rules alone. Reasons for this may lie in the close anatomical proximity of the lateral ligamentous complex, which in the injured state (ie, simple ankle sprain) may in itself produce a sensation of discomfort, leading to a higher number of false-positive tests. This could be caused either by direct pressure on application of the tuning fork or by the transmission of sound waves through the injured ligaments.

A limitation of our study is that all the patients were examined by the same investigator. This did not allow for the

Table 1 Cross-table comparing the data for tuning fork testing on the tip of the lateral malleolus with outcomes reported on standard ankle radiographs

“TLM” position	Fracture on radiographs	No fracture on radiographs	Total
Abnormal tuning fork test	5	17	22
Normal tuning fork test	0	27	27
Total	5	44	49

TLM, tip of lateral malleolus.

Table 2 Cross-table comparing test results for tuning fork testing on the distal fibula shaft with outcomes reported on standard ankle radiographs

“DFS” position	Fracture on radiographs	No fracture on radiographs	Total
Abnormal tuning fork test	5	2	7
Normal tuning fork test	0	42	42
Total	5	44	49

DFS, distal fibula shaft.

fact that different clinicians examine patients in a different and subjective way, and led to a lack of interobserver variation. As only patients presenting to the “see and treat” area during “office hours” were included, it is possible that noticeable sample bias has been introduced due to non-consecutive recruitment. The fact that patients with excessive soft-tissue swelling were excluded for technical reasons has introduced spectrum bias as it may have lowered the prevalence of ankle fractures in the study sample. Owing to the specific inclusion criteria, it is not clear whether tuning fork testing would have detected any additional ankle fractures in patients presenting with “Ottawa negative” findings.

We compared tuning fork test results with findings on a single set of ankle radiographs as a “reference standard”, which may have led to some “radiologically” undetected fractures or “over-reporting” of fractures. Likewise, reporting radiographers and consultant radiologists are of different seniority levels and make it difficult to justify a one-off

Table 3 Sensitivity, specificity, accuracy, positive likelihood ratio and negative likelihood ratio calculated from the cross-tables and the fracture prevalence described in the literature

Tuning fork position	Sensitivity	Specificity	Accuracy	Positive likelihood ratio	Negative likelihood ratio
TLM	1.00	0.61	0.65	2.59	0
DFS	1.00	0.95	0.96	22	0

DFS, distal fibula shaft; TLM, tip of lateral malleolus.

Results are presented separately for tuning fork testing on the TLM and on the DFS.

“reference standard”. For future studies, it may therefore be necessary to follow up all study patients for a period of 2 months and use a combination of final outcome and radiological opinion as a “gold standard”.

Finally, the relatively small sample size resulted in large CIs for calculated sensitivities (46% to 100%). This questions the ability of a “negative” tuning fork test to sufficiently exclude a lateral malleolus fracture in patients with “Ottawa positive” findings.

Despite the above limitations, tuning fork testing may lead to a marked reduction in ankle radiographs, with consequently reduced radiation exposure and journey times in patients who have “Ottawa positive” findings for lateral malleolus injury after traumatic ankle inversion (ie, Ottawa test positive, but tuning fork test negative). In addition to this, the tuning fork test may be a valuable tool in risk-stratifying patients who have already tested “Ottawa positive” for further radiographic investigations in situations where radiological facilities are not readily available (expedition medicine), or where there is a need for prioritisation (major incidents, natural catastrophes).

Therefore, a larger and adequately powered prospective trial including multiple investigators of varying clinical seniority needs to be conducted to confirm the preliminary findings of this study.

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Ethical approval: Not sought.

Declaration: The photographs displayed in figs 1 and 2 display body parts of staff of the Accident and Emergency Department at The James Cook University Hospital. They have been taken for demonstration purposes only. Written consent of the staff involved has been obtained and is available on request.

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