Vertical or horizontal orientation of foot radiographs does not affect image interpretation

Nicholas Antonio Ferran[1],
Luke Ball[2],
Nicola Maffulli[3]

[1] Department of Trauma & Orthopaedics, Leicester Royal Infirmary, UK
[2] Royal Cornwall Hospital
[3] Centre for Sports and Exercise Medicine Queen Mary University of London, Barts and The London School of Medicine and Dentistry, Mile End Hospital, London, UK

Corresponding author:
Nicholas Antonio Ferran
Department of Trauma & Orthopaedics,
Leicester Royal Infirmary
LE1 5WW, Leicester, UK
e-mail: nferran@uku.co.uk

Summary

This study determined whether the orientation of dorsoplantar and oblique foot radiographs has an effect on radiograph interpretation. A test set of 50 consecutive foot radiographs were selected (25 with fractures, and 25 normal), and duplicated in the horizontal orientation. The images were randomly arranged, numbered 1 through 100, and analysed by six image interpreters. Vertical and horizontal area under the ROC curve, accuracy, sensitivity and specificity were calculated for each image interpreter. There was no significant difference in the area under the ROC curve, accuracy, sensitivity or specificity of image interpretation between images viewed in the vertical or horizontal orientation. While conventions for display of radiographs may help to improve the development of an efficient visual search strategy in trainees, and allow for standardisation of publication of radiographic images, variation from the convention in clinical practice does not appear to affect the sensitivity or specificity of image interpretation.

Key words: foot radiograph, horizontal orientation, image interpretation, vertical orientation.

Introduction

Plain radiographs are an essential tool in the assessment of foot trauma. Analysis of foot radiographs is difficult. Junior doctors make more errors in radiograph interpretation but tend to see a greater proportion of patients in the Emergency Department setting than their senior counterparts[1]. Dorsoplantar and oblique foot radiographs are conventionally displayed in a vertical orientation with the toes pointing upward (Fig. 1). Conventions for displaying radiographs, however, tend to reflect unwritten customs handed down from trainer to trainee[2].

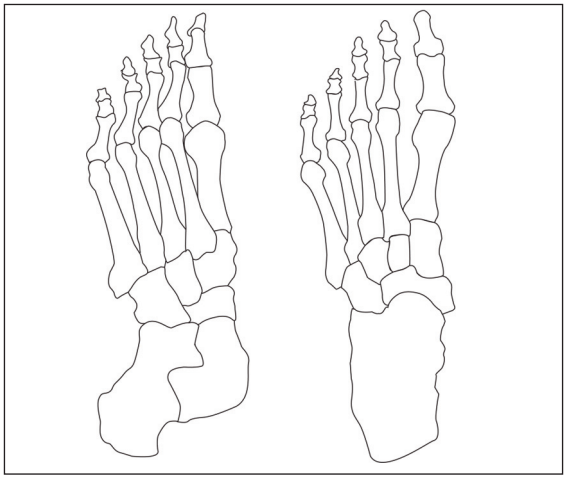

Figure 1. Schematic of anteroposterior and oblique foot radiograph in the conventional vertical orientation.

Lou & Lou have noted that, with the introduction of computed and digital radiography, image orientation is an issue, as images may be sent to the picture archiving and communication system (PACS) with the incorrect orientation. They propose that variation from the preferred convention may affect image processing and analysis[3]. We set out to determine whether vertical or horizontal (Fig. 2) orientation of foot radiographs has an effect on radiograph interpretation.

Subjects and methods

A test set of 50 foot radiographs of patients presenting to the Fracture Clinic was selected from the PACS. All 50 radiographs selected were non-weight bearing films of the dorsoplantar and oblique views. Lateral views were not included in the study, as they are only performed on request, and are not part of the standard foot trauma series at our institution.
A Consultant Musculoskeletal Radiologist reviewed the radiographs prior to selection, and provided a reference standard. Twenty-five radiographs contained fractures of the forefoot, and 25 were normal. The 50 radiographs

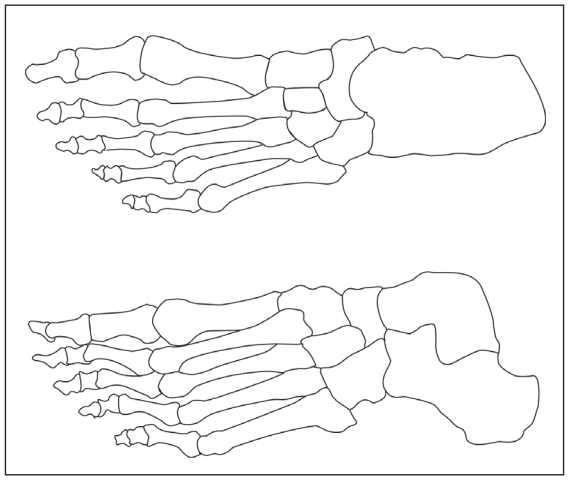

Figure 2. Schematic of anteroposterior and oblique foot radiograph in the horizontal orientation.

were saved as JPEG images, with all patient identifiers removed. The 50 radiographs were then duplicated in the horizontal orientation (rotated 90º anticlockwise) (Fig. 2) to produce a total of 100 images. The images were then randomly arranged into a slideshow, and numbered 1 through 100. The slideshow was displayed on a hospital computer with a 15 inch full colour monitor used for image analysis.

Clinical information was not provided, and reviewers controlled the progression of images. An answer sheet was designed with lines numbered 1 through 100. A group of six Orthopaedic Trainee clinicians of Specialist Registrar level volunteered to participate as image interpreters. None of the authors took part in image interpretation. Participants were instructed to indicate on the answer sheets "yes" if they identified a fracture, and "no" if they considered the radiograph to be normal.

Data from the answer sheets were entered into a database, and the answers were separated out into 50 vertical answers and 50 horizontal answers. Receiver operating characteristic (ROC) analysis was performed using a web based calculator, and the area under the curve, accuracy, sensitivity and specificity were recorded for each observer in both the vertical and horizontal orientation[4].

The area under the ROC curve was regarded as the primary outcome measure. Sensitivity was defined as the proportion of fracture positive cases correctly called, and was expressed as a percentage. Specificity was defined as the proportion of normal cases correctly called, and was expressed as a percentage. Sample size estimation tables estimate that, for six observers with moderate variability, high accuracy, and a ratio of normal to abnormal of 1:1, a sample size of 39 images is required to achieve 80% power[5]. Our sample size of 50 exceeded this.

Data were entered into a commercially available statistical software package. Descriptive statistics were calculated. Mann-Whitney Rank Sum test was used to compare the difference between the mean area under the curve (A_z), sensitivity, specificity, and accuracy, of the observers between vertical and horizontal orientations.

Results

All six reviewers complied with the test conditions, and all their answers were included in the study and analysed. All data tested showed normal distribution and equal variance. The mean area under the curve (A_z) was 0.872 for vertical images and 0.973 for horizontal images, with no statistical difference between vertical and horizontal images ($p = 0.24$) (Tab. 1).

For both vertical and horizontal images mean accuracy was greater than 83%, mean sensitivity was greater than 87% and mean specificity was greater than 79%. The mean accuracy, sensitivity, and specificity, were greater for the horizontal (unconventional) images. There was no statistically significant differences in accuracy, sensitivity, and specificity between vertical and horizontal images ($p>0.5$) (Tab. 2).

Discussion

This study demonstrated no difference in the area under the curve (A_z), accuracy, sensitivity, or specificity of radiograph interpretation between horizontal and vertical images.

A slideshow was used in this study and tested only the

Table 1. Difference in area under curve (A_z) between vertical and horizontal images (Mann-Whitney Rank Sum Test).

	A_z Vertical	A_z Horizontal	P value
Reviewer 1	0.929	0.930	
Reviewer 2	0.862	0.925	
Reviewer 3	0.774	0.940	
Reviewer 4	0.929	0.966	
Reviewer 5	0.880	0.958	
Reviewer 6	0.860	0.799	
Average (Mean ± SD)	0.872 ± 0.057	0.903 ± 0.072	0.240

Table 2. Difference in accuracy, sensitivity and specificity between vertical and horizontal images (Mann-Whitney Rank Sum Test).

	Vertical Mean (95% CI)	Horizontal Mean (95% CI)	P value
Accuracy (%)	83.3 (79.3 – 87.3)	88.0 (83.8 – 92.2)	0.180
Sensitivity (%)	87.3 (78.8 – 95.8)	94.0 (92.2 – 95.8)	0.394
Specificity (%)	79.3 (71.4 – 87.2)	82.0 (72.8 – 91.2)	0.699

variables of image orientation. The slideshow allowed us to deliver the test to the image interpreters in a format similar to PACS, thereby making this a representative estimation of image interpretation. Lamb et al. also used a slideshow of digital images as this allowed standardised viewing conditions between image interpreters[6].

In this study, one experienced Consultant Musculoskeletal Radiologist defined the reference standard (presence or absence of a fracture) of each radiograph. This was justified as the presence or absence of a fracture was clear cut, i.e. there was no grading of disease that was likely to cause controversy amongst experts. The estimated image sample size necessary for a power of 80%[6] was exceeded, but the study could have been further strengthened by recruiting 10 image reviewers, and increasing the number of images beyond 50. However it is not known if detecting such a small difference would be clinically relevant.

Studies have been undertaken to test the accuracy of radiograph interpretation with varying levels of experience [7-9], and conventional versus digital display[7]. Sherief et al. found that the overall accuracy of diagnosing injuries on foot radiographs was 87% among radiologists, orthopaedic surgeons, and emergency physicians[9]. These findings closely match the findings in this study.

Visual perception research has also demonstrated that humans process information at or near the vertical or horizontal meridians more efficiently than information projected onto the retina at oblique angles, a phenomenon known as the 'oblique effect'. Orientation selectivity is believed to be influenced by experiences during the early developmental stages of the visual system[10].

There is an accepted convention for displaying radiographs. Researchers have focussed efforts toward developing algorithms that can allow PACS software to recognise and orient images to conform to this convention[3].

Lamb et al. studied the effect of changing the orientation of veterinary chest radiographs on accuracy of diagnosis of rib fractures. In a methodology similar to this study, the authors found no difference in accuracy when images were rotated 90º clockwise[6]. The authors' findings did not support anecdotal evidence that rotating a chest radiograph improved the diagnostic accuracy with respect to rib fractures.

Studies of the accuracy of interpretation of radiographs in the emergency department have reported errors in interpretation of foot radiographs of 9.7%[1] and 3.16% [11]. We experienced a much higher rate of errors in this study (mean vertical accuracy of 83% and horizontal accuracy of 88%), possibly because our image reviewers did not have the benefit of clinical information.

Eng et al. studied the issue of interpretation of radiographs by Emergency Physicians and Radiologists of varying levels of experience, and compared accuracy with conventional and digital radiology. They found a significant association between training level and accuracy of radiography interpretation, with more experienced clinicians having higher accuracy. They did admit, however, to allowing spectrum bias to magnify any differences by purposely selecting difficult images to interpret[7]. Kundel and La Follette[8] proposed that the increased accuracy of image interpretation with experience resulted from the evolution of fixation patterns and visual search strategies with increased exposure to radiographs.

While conventions for display of radiographs may help to improve the development of an efficient visual search strategy in trainees, and allow for standardisation of publication of radiographic images, variation from the convention in clinical practice does not appear to affect image interpretation.

The authors acknowledge, however, that our findings can be limited to simple foot fractures, and may not be applicable to other body segments, or to more complicated, or more subtle, injury patterns in the foot.

Acknowledgement

The authors wish to acknowledge the assistance of Dr. Peter Mullaney, Consultant Musculoskeletal Radiologist, who provided a reference standard for the images used in this study. We would also like to thank Ms. Janice Sharpe of the Medical Illustration Department of University Hospital of Wales for assistance in preparing schematic diagrams for this paper.

References

1. Wardrope J, Chennells PM. Should all casualty radiographs be reviewed? Br Med J (Clin Res Ed) 1985; 290:1638-1640.
2. Hall FM. Viewing the lateral radiograph. AJR Am J Roentgenol 1982; 139:1235.
3. Luo H, Luo J. Robust online orientation correction for radiographs in PACS environments. IEEE Trans Med Imaging 2006; 25:1370-1379.
4. Eng J. ROC analysis: web-based calculator for ROC curves. Baltimore: Johns Hopkins University (updated 2006 May 17; cited 2008 Jul 6). Available from: http://www.jrocfit.org.
5. Obuchowski NA. Sample size tables for receiver op-

erating characteristic studies. AJR Am J Roentgenol 2000; 175:603-608.
6. Lamb CR, Parry AT, Baines EA, Chang YM. Does changing the orientation of a thoracic radiograph aid diagnosis of rib fractures? Vet Radiol Ultrasound 2011; 52:75-78.
7. Eng J, Mysko WK, Weller GE, Renard R, Gitlin JN, Bluemke DA, Magid D, Kelen GD, Scott WW Jr. Interpretation of Emergency Department radiographs: a comparison of emergency medicine physicians with radiologists, residents with faculty, and film with digital display. AJR Am J Roentgenol 2000; 175: 1233-1238.
8. Kundel HL, La Follette PS Jr. Visual search patterns and experience with radiological images. Radiology 1972; 103:523-528.
9. Sherief TI, Mucci B, Greiss M. Lisfranc injury: how frequently does it get missed? And how can we improve? Injury 2007; 38:856-860.
10. Coppola DM, Purves HR, McCoy AN, Purves D. The distribution of oriented contours in the real world. Proc Natl Acad Sci U S A 1998; 95:4002-4006.
11. Brunswick JE, Ilkhanipour K, Seaberg DC, McGill L. Radiographic interpretation in the emergency department. Am J Emerg Med 1996;14:346-348.