TITLE: Technical innovation changes standard radiographic protocols in veterinary medicine: is it necessary to obtain two dorsoproximal–palmarodistal oblique views of the equine foot when using computerised radiography systems?

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Technical innovation changes standard radiographic protocols in veterinary medicine: is it necessary to obtain two dorsoproximal–palmarodistal oblique views of the equine foot when using computerised radiography systems?

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Abstract

Since the 1950s, veterinary practitioners have included two separate dorsoproximal–palmarodistal oblique (DPr–PaDiO) radiographs as part of a standard series of the equine foot. One image is obtained to visualise the distal phalanx and the other to visualise the navicular bone. However, rapid development of computed radiography and digital radiography and their post-processing capabilities could mean that this practice is no longer required. The aim of this study was to determine differences in perceived image quality between DPr–PaDiO radiographs that were acquired with a computerised radiography system with exposures, centring and collimation recommended for the navicular bone versus images acquired for the distal phalanx but were subsequently manipulated post-acquisition to highlight the navicular bone. Thirty images were presented to four clinicians for quality assessment and graded using a 1–3 scale (1=textbook quality, 2=diagnostic quality, 3=non-diagnostic image). No significant difference in diagnostic quality was found between the original navicular bone images and the manipulated distal phalanx images. This finding suggests that a single DPr–PaDiO image of the distal phalanx is sufficient for an equine foot radiographic series, with appropriate post-processing and manipulation. This change in protocol will result in reduced radiographic study time and decreased patient/personnel radiation exposure.

Introduction

Over the last two decades, the transition from analogue film-screen radiography to computed radiography (CR) and, more recently, digital radiography (DR) in veterinary imaging has provided many benefits. A prime advantage of digital imaging modalities compared with analogue film-screen systems is the capacity for the operator to use image post-processing techniques to optimise image quality after acquisition.

Detective quantum efficiency (DQE) is one of the essential physical variables that effects radiographic image quality and can be defined as the efficiency of a detector in converting incident X-ray energy into an image signal. The greater DQE values of digital detectors compared with analogue combinations indicate that, as well as delivering improved image quality, digital detectors have the potential to considerably reduce patient exposure without degradation in image quality (Busch and others 2003, Seibert 2004, Korner and others 2007). Digital detectors have a wide dynamic range, which means they have a wide range of exposure values over which a diagnostic image is produced and over which images can be viewed. Post-processing allows optimisation of the image by changing multiple image parameters after acquisition (Freedman and Artz 1997, Prokop and Schaefer-Prokop 1997), including window width, window level, image sharpening, edge enhancement, noise reduction and smoothing filters.

The equine foot is the most common site of lameness in the forelimb and hence one of the most commonly radiographed areas. A standard foot series comprises several projections, including two dorsoproximal–palmarodistal oblique (DPr–PaDiO) projections (Butler and others 2008, Weaver and Barakzai 2010); one to image the navicular bone and the second to image the distal phalanx. These radiographic projections can be acquired either in the weightbearing limb, using a cassette tunnel and a dorso65°proximal–PaDiO X-ray orientation (‘high-coronary’) or with the limb non-weightbearing in an angled or grooved block (‘upright pedal') and a horizontal X-ray beam. To obtain images in the non-weightbearing limb, the dorsal surface of the hoof wall is angled at 80–90° from the ground and differing centring and collimation are applied. Using an 'upright pedal' orientation to radiograph the navicular bone, the centre of the X-ray beam is positioned 2 cm proximal to the coronet and is collimated tightly around the navicular bone to reduce scatter. To image the distal phalanx, the X-ray beam is centred on the coronet and the collimation is kept wider to include the distal phalanx and often the whole hoof. The radiograph for the navicular bone is typically obtained with higher exposure factors compared with those used for the distal phalanx to ensure sufficient X-ray penetration through the middle phalanx to outline the navicular bone.

With the use of DR and its post-processing capabilities, it is proposed that only a single DPr–PaDiO exposure is required to produce radiographs of diagnostic quality of the navicular bone and the distal phalanx.

We hypothesised that there is no significant difference in diagnostic quality between DPr–PaDiO radiographs specifically acquired for visualisation of the navicular bone and radiographs that have been acquired for the distal phalanx and manipulated post-acquisition to optimise visualisation of the navicular bone.

Materials and Methods

A sample of 30 front foot radiographs (15 pairs) from skeletally mature warmblood-type horses that had been presented to the authors' institution for radiographs of the foot conducted for clinical reasons unrelated to this study were analysed. For each foot, a DPr–PaDiO radiograph of the distal phalanx and a DPr–PaDiO radiograph of the navicular bone obtained in the non-weightbearing position ('upright pedal') were selected from a complete foot series. All radiographs were acquired with a computerised radiography system (FCR Profect CS, Fujifilm, Bedfordshire, UK) following the standard protocol for an equine foot series as described in Weaver and Barakzai (2010). Horses included were a range of breeds, sizes and ages reflecting the mixed population of riding horses seen at the authors' hospital. Exposures ranged from 50 kV/10 mAs to 65 kV/15 mAs for the distal phalanx images and from 60 kV/15 mAs to 70 kV/20 mAs for the navicular bone images with a focus–film distance of 100 cm depending on the size of the feet. Selection of images was conducted retrospectively in a random manner from the hospital's picture archiving and communication system. The study was approved by the authors' institution's ethics and welfare committee.

Distal phalanx images were modified using Fujifilm systems software (Fujifilm Europe GmbH) to produce images that best revealed navicular bone details ('modified distal phalanx images') (see Fig 1). Parameters adapted in this process included image collimation, window width and window level, sensitivity number (S) and latitude value (L). Navicular bone images were left unaltered ('navicular bone images').

Four equine clinicians assessed the diagnostic quality of each of the 30 images using a 1–3 grading scale (Grade 1, textbook quality; Grade 2, adequate diagnostic quality; Grade 3, non-diagnostic image). Each clinician was also asked to comment on image quality and to suggest how images could be improved, if they were deemed to not be of textbook quality.

Textbook quality was simply defined as "could this image be printed in a textbook?", "diagnostic quality: would you accept this during a routine clinical work-up?" and "non-diagnostic: would you have this repeated during a routine clinical work-up?" Further than that no criteria were specified and the decision was left to the individual observer. This was done on purpose to resemble daily clinical practice as closely as possible.

Two observers were specialists in equine surgery, and two observers were residents in equine surgery and large animal diagnostic imaging, respectively. Clinicians were unaware whether the image was originally taken for the navicular bone or a modified distal phalanx image.

An overall 'diagnostic quality score' was established for each of the 30 images by summation of the grades designated by each clinician for each image. For example, if all four observers allocated grade 2 for an image, the diagnostic imaging score would be 8, the minimum score possible would therefore be 4 and the maximum score would be 12.

Statistical analysis

Data distribution was assessed with histograms and was found to be normally distributed. The difference between overall diagnostic quality scores of the two image groups (modified distal phalanx images v navicular bone images) was assessed using a Wilcoxon rank-sum statistical test. Differences in individual grades between the two different image groups for individual observers were analysed using a Kruskal–Wallis test and differences in number of grades and number of comments with chi-squared tests. The level of agreement between clinicians was determined by calculating Fleiss' kappa coefficient and interpreted using Landis and Koch (1977) as a reference. Data were analysed using SPSS (version 22, IBM Corp. Armonk, IBM SPSS Statistics for Windows), and a P value of 0.05 was set.

Results

Diagnostic quality scores for all images ranged from 5 to 12 (median±IQR 8.0±2.0). For modified distal phalanx images, scores ranged from 5 to 12 (median±IQR 8.0±3.0) and for navicular bone images from 6 to 11 (median±IQR 8.±2.0). There was no significant difference in the overall diagnostic quality scores between modified distal phalanx images and navicular bone images (P=0.867). Individual image grades from all observers ranged from 1 to 3, with a median of 2. The median and range for the individual grades were the same for both, the modified distal phalanx images and the navicular bone images and there was no statistically significant difference (P=0.459). There was no significant difference in diagnostic quality scores between observers (P=0.244). The number of grades allocated by each of the observers for the two image groups and in total is listed in Table 1. There was no significant difference in distribution of grades between navicular bone images and modified distal phalanx images in overall diagnostic quality score (P=0.26) or for each observer (observer 1 P=0.72, observer 2 P=0.91, observer 3 P=0.63, observer 4 P=0.44).

Agreement on diagnostic image quality grade between observers was good (κ=0.73). All observers allocated the same grade in 7 feet, three observers agreed in 12 feet and two observers agreed in 11 feet. When assessing the agreement for each group of radiographs, all four observers agreed on three navicular bone images and four modified distal phalanx images, three observers agreed on six navicular bone images and six modified distal phalanx images and two observers agreed on six navicular bone images and five modified distal phalanx images. The most common comments made by observers for images that were considered suboptimal were low image contrast (29 observations in total, 16 modified distal phalanx images and 13 navicular bone images); packing defects (19 observations in total, 8 modified distal phalanx images and 11 navicular bone images); poor collimation (nine observations in total, six modified distal phalanx images and three navicular bone images); distal border superimposed over distal interphalangeal joint (four observations only, all in modified distal phalanx images) and proximal border not clearly visible (16 observations, 14 in modified distal phalanx images and 2 in navicular bone images). All images classified as 'non-diagnostic' (grade 3) had 'poor contrast' according to all observers.

Discussion

Since the inception of widespread use of veterinary radiographic imaging in the UK in the 1950s, equine veterinary practitioners have obtained two separate DPr–PaDiO projections of the foot as recommended in standard textbooks (e.g. Weaver and Barakzai 2010). One image is to primarily visualise the distal phalanx and the other to visualise the navicular bone superimposed on the middle phalanx. The separate projection for the navicular bone is advised to improve the image quality and better assess the navicular bone through the use of higher exposures, tighter collimation and beam centring. For optimal evaluation of portions of the navicular bone, acquisition of radiographic projections at varying degrees of altered foot angulation to that for the distal phalanx has been advocated (Butler and others 2008). Unlike classic film-screen systems, today's CR and DR systems offer a wide range of post-processing options. In the presented study, there was no significant difference in diagnostic quality between images taken for the navicular bone and images that were originally taken for the distal phalanx and then optimised for the display of the navicular bone afterwards. The results of the present study suggest that equine practitioners with access to CR or DR systems can obtain a DPr–PaDiO single projection of the foot and alter the image post-acquisition to optimally view the different anatomical structures. The advantages of such a protocol would be a reduction in radiation exposure to the personnel involved and (less crucial in horses) the patient. In human medicine, progresses have been made in optimising the use of DR, particularly in the area of reducing radiation dose (Seibert 2008, Uffmann and Schaefer-Prokop 2009, Sun and others 2012, Vassileva and others 2013). There has been a move away from the principle of ‘image quality as good as possible’ to ‘image quality as good as needed’. Radiation dose should be as low as reasonably achievable (ALARA), while still delivering image quality sufficient to enable an accurate diagnosis (Wall 2001, Vano 2005). ALARA may not be seen to be as important a principle in veterinary imaging; however, the minimisation of exposure risk to operators would be considerable especially to equine practitioners who frequently obtain a large number of radiographs (e.g. clinicians who are involved in pre-sale or pre-purchase examinations). A common phenomenon in human medicine is the practice of ‘exposure creep’ where operators and patients are put at risk of progressively increasing radiation doses for a perceived need to continually improve image quality. Improved image quality is often associated with higher exposure levels in DR, and so radiation doses have tended to increase, resulting in an upward 'creep' of exposure values often unnecessarily (Shepard and others 2009, Gibson and Davidson 2012).

With one less projection to be performed, image acquisition time (and potentially patient sedation) required would also be reduced resulting in a cost–benefit. However, post-processing does require time and expertise. Manual adjustment of the images for optimal display of the navicular bone takes between 30 seconds and 2 minutes in the authors' experience. However, most CR and DR systems allow the creation of post-processing protocols that allow for automatisation of this process and hence do not require additional time. The full flexibility of DR was not exploited to its full potential in this study. The assessors were not enabled to modify the images themselves, with the post-processing already conducted. The navicular bone images were not altered at all, since it was assumed that images were optimised to display navicular bone details when they were used during the original clinical work-up. This does not reflect the true capability of DR or CR systems and operators in a real-life scenario. It could therefore be inferred that the quality of the images could improve even further (or not, depending on the expertise of the operator). This flexibility in post-processing would also allow the operator to change parameters when looking at different areas or structures in each image. In this study, one specific restriction identified by the grading clinicians was that the lack of ability to zoom and alter window width and window level.

There was no significant difference in the number of critical comments made for either groups of images with the exception of the superimposition of the distal border of the navicular bone over the distal interphalangeal joint. This depends on the angle of the X-ray beam to the structure and while the X-ray beam angle is standardised, the conformation of the horse is not, hence resulting in superimposition in some of the modified distal phalanx images. This was not observed in the navicular bone images and since these images were obtained during the time of the original acquisition this implies an inherent bias in this study. Less likely, this may have been because the horses moved between image acquisition altering anatomic relationships; repositioning between projections was not recorded in this study. Equally, collimation was more often critiqued in the navicular bone images group because the modified distal phalanx images were collimated after acquisition allowing a more careful collimation selection. The most common criticism was lack of contrast, which is an inherent anatomical problem due to the fact that the navicular bone is superimposed on another bony structure, the middle phalanx in this projection.

Although the study results found no significant difference in subjective diagnostic quality between the two groups of radiographs for evaluating the navicular bone, the authors acknowledge that this may not equate to comparable lesion detection in a clinical situation. Further studies are therefore warranted to compare lesion detection rates in observers blinded to the method of acquisition of the projection.

Conclusion

Comparable diagnostic quality digital DPr–PaDiO images of the navicular bone can be produced by modification and optimisation of digital DPr–PaDiO images obtained with acquisition parameters specific to the distal phalanx. This negates the necessity to obtain two DPr–PaDiO projections of the foot and will hence decrease time and patient/personnel radiation exposure. Future work should concentrate on the scrutinisation of historical radiographic protocols in light of the increasing use of CR and DR systems in veterinary practice.

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Table 1: The number of diagnostic quality grades allocated by each observer (1=textbook quality, 2=diagnostic quality, 3=non-diagnostic image)

	Grade 1	Grade 2	Grade 3
Observer 1			
Total	5	19	6
Navicular bone	3	10	2
Modified distal phalanx image	2	9	4
Observer 2			
Total	4	20	6
Navicular bone	3	10	2
Modified distal phalanx image	1	10	4
Observer 3			
Total	7	21	2
Navicular bone	4	10	1
Modified distal phalanx image	3	11	1
Observer 4			
Total	5	15	10
Navicular bone	2	7	6
Modified distal phalanx image	3	8	4

Figure Legends

Figure 1: The image on the left is a dorsoproximal–palmarodistal oblique (DPr–PaDiO) radiograph of the distal phalanx. The image on the right is the same image but after post-processing for the navicular bone (modified distal phalanx image)