AP vs PA positioning in lumbar spine computed radiography: image quality and individual organ doses

Poster No.: B-1019
Congress: ECR 2015
Type: Scientific Paper
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Keywords: Radioprotection / Radiation dose, Musculoskeletal spine, Computer applications, Conventional radiography, Computer Applications-General, Radiation safety
DOI: 10.1594/ecr2015/B-1019

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Lumbar spine radiography is classified as a relatively high dose examination which irradiates the radiosensitive reproductive organs of both males and females. Radiographic imaging of the lumbar spine accounts for 2.1% of all conventional X-ray examinations and 2.2% of the collective dose within the United Kingdom (UK) (Hart et al., 2010). One simple but effective method of radiation dose reduction is the replacement of the traditionally performed anteroposterior (AP) projection with the posteroanterior (PA) projection. Despite this it is still common practice for the majority of UK departments to perform lumbar spine examinations using the AP position.

**AIM**

The aim was to compare AP and PA projections of the lumbar spine, at various kVp increments, using computed radiography (CR), in order to establish the optimum parameters for this radiographic examination.
Methods and materials

Imaging equipment and phantom

The study was conducted in a university imaging department using a Wolverson Acroma X-Ray unit (Wolverson X-ray Ltd, Willenhall, UK) with a Varian 130 HS X-ray tube (Varian Medical Systems, Palo Alto, CA) with an inherent filtration of 3 mm aluminium. An Agfa (Agfa-Gevaert, Mortsel, Belgium) 35 x 43 cm computed radiography (CR) image receptor was used for acquisition and images were processed using an Agfa CR 35-X digitiser. All exposures included the use of a 10:1 reciprocating grid with (40 line/cm frequency) and a broad focal spot size of 1.2 mm. Equipment quality assurance testing, in line with IPEM 91 (IPEM, 2005), was performed prior to image acquisition which included an assessment of voltage accuracy, which was found to be within tolerance.

Phantom positioning

A fixed source-to-image-distance (SID) of 115 cm was used together with automatic exposure control (AEC) using the central chamber. A tube potential of 75 kVp was selected and when combined with the above factors allowed the production of a reference image that was consistent with typical clinical imaging parameters. These exposure parameters were established following a brief consultation with four local departments and after reviewing recommendations in the EC guidelines (European Commission, 1996).

For all exposures the collimated field was adjusted to include the twelfth thoracic vertebra superiorly and the sacro-iliac joints inferiorly. The use of fixed collimation was essential in order to ensure it did not impact on phantom radiation dose or image quality, as the amount of scattered radiation varies when different volumes of tissue are irradiated (Fauber, 2004).

For AP projections the phantom was positioned supine in accordance with standard radiographic technique (Sloane et al., 2010). For PA projections the phantom was positioned prone. In order to ensure the centring point was replicated, masking tape was applied to and wrapped around the torso of the phantom with its superior border directly at the level of the horizontal line of the AP centring point. The diameter to the left and right of the vertical line in the AP projection was measured using a ruler and then replicated in the PA orientation. Collimation was once again fixed and consistent with the AP projection.

Experimental technique

For each projection (AP/PA) the kVp increment was varied by 5 kVp from 75 to 110 kVp. In order to ensure continuity and minimise error the same imaging plate was used...
throughout the study. Image acquisition was repeated three times for each kVp increment and at each orientation (AP/PA).

Dosimetry

Entrance surface dose (ESD) was measured using a Mult-O-Meter 407L (Unfors Instruments, Billdal, Sweden) positioned on the phantom at the centre of the collimated field. In order to increase the accuracy of dose measurement the ESD was measured three times and an average value was calculated. ESD measurements were converted to effective dose (ED) estimations using the Monte Carlo dosimetry simulation software PCXMC 2.0 (STUK, Helsinki, Finland).

The mean effective (ICRP 103, 2007) and absorbed doses to the stomach, colon and remainder tissues were recorded, as these are classified as the three most sensitive tissues irradiated during an AP lumbar spine radiography (Wall et al., 2011). Absorbed doses to the ovaries and testes were also recorded in order to compare findings between the two projections.

Image quality assessment

The evaluative panel consisted of five final year radiography students, who at the time of the study were < 6 months away from qualification. Each of the raters had previously participated in visual grading analysis (VGA) experiments and were deemed sufficiently experienced to undertake image analysis. Images were assessed under standardised viewing conditions using two EA243WM MultiSync (NEC Corporation, Tokyo, Japan) 2.3 megapixel monitors. Ambient lighting, less than 50 lx and the distance of the chair from the monitor were kept constant. Details of how the images were acquired were blinded to all raters.

Two-alternative forced choice (2AFC) software (Hogg et al., 2012) was used to present the acquired images to the raters. This allowed the presentation of the reference image concurrently alongside the comparator images on the monitor but in a randomised order. A further advantage of this software was that it prohibited zooming and window width or level adjustments. Previous research has reported on the benefits of 2AFC in that it permits easier detection of differences in quality when compared to an absolute method where observers are asked to evaluate images utilising criteria without a comparison reference image. Finally, magnification was assessed and compared between the AP and PA projections using the software program Image J (National Institute of Health, Bethesda, MD). This was assessed in the same manner as that employed by Heriard, Terry & Arnold (1993) who determined the magnification differences between the two projections by measuring the transverse diameter of the vertebral body of L3 (Tsuno & Shu, 1990).
Results

Image quality

Total (weighted) image quality scores for both the AP and PA projections, for each kVp increment, are presented in Table 1 and Figure 1. An image quality score of 48 was considered equal to the reference image after weighting factors were applied.

| kVp | AP Projection | | | PA Projection | | |
|-----|---------------|---|---|---------------|---|
|     | Mean | SD | % change from reference | Mean | SD | % change from reference |
| 75  | 41.6 | 1.1 | -13.3 | 41.6 | 1.1 | -13.3 |
| 80  | 58.2 | 5.8 | +21.3 | 45.4 | 5.8 | -5.4 |
| 85  | 52.4 | 7.7 | +9.2 | 40.2 | 3.5 | -16.3 |
| 90  | 51.0 | 5.7 | +6.3 | 38.2 | 5.0 | -20.4 |
| 95  | 46.0 | 4.3 | -4.2 | 37.2 | 0.8 | -22.5 |
| 100 | 42.2 | 5.9 | -12.1 | 34.8 | 3.3 | -27.5 |
| 105 | 33.2 | 0.8 | -30.8 | 28.0 | 2.1 | -41.7 |
| 110 | 28.2 | 3.1 | -41.3 | 25.4 | 2.6 | -47.1 |

SD, standard deviation. A score of 48 is equivocal to the reference image (AP 75 kVp)

The reliability of individual image quality scores between raters must be considered. The ICC value for the five students was 0.85 (95% confidence interval, 0.72 to 0.94). An ICC value of 0.85, according to Rosner (2011), indicates very good reproducibility.

Magnification

The transverse diameter of the L3 vertebral body was 25 mm and 27 mm for AP and PA projections, respectively. As a result the PA projection demonstrated a magnification factor of 1.08 times greater than the AP.

Dosimetry

From an evaluation of the dosimetry calculations (Figures 2 - 5) it is evident that the PA projection results in a significantly reduced effective dose for all tube potentials.
studied. The mean ED reduction was 19.8% (range, 17.9 to 22.8%). As expected a trend was noted where kVp increases the ED for both orientations was seen to progressively decrease.

Individual organ/tissue doses were compared by kVp and between the AP and PA projections. It was evident (Figure 3A) that the PA projection reduced the absorbed dose to the stomach by a maximum 74.0% at 75 kVp and a minimum of 66.9% at 110 kVp. It was also clear that the PA projection reduced the absorbed dose to the colon (Figure 3B). The maximum dose reduction (68.3%) was seen at 70 kVp with a minimum dose reduction of 56.6% seen at 110 kVp. The PA projection also reduced the absorbed dose to the remainder tissues (Figure 3C). The maximum reduction in absorbed dose was again experienced at 75 kVp (36.0%) with a minimum reduction of 29.3% at 110 kVp.

With respect to gonadal dose, the PA projection also reduced the absorbed dose to the testes by a maximum of 24.7% at 70 kVp a minimum of 8.7% at 80 kVp. The absorbed dose to the testes appears to increase with an increase in tube potential (Figure 4A). The PA projection resulted in a reduction in the absorbed dose to the ovaries of 22.8% at 70 kVp (maximum) and 3.7% at 110 kVp (minimum) (Figure 4B).

Figure 5 demonstrates the relative (percentage) absorbed dose reduction to the stomach, colon, remainder tissues, ovaries and testes across each kVp. Figure 5 clearly indicates that the most significant dose reduction is to the stomach, followed by the colon and remainder tissues.
Fig. 1: Mean image quality scores for AP and PA projections across a range of tube potentials. Error bars demonstrate the standard deviation for the image quality scores.

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Fig. 2: An illustration of the entrance surface dose (A) and effective dose (B), for each kVp increment, across both AP and PA projections. Error bars denote the standard error for each measurement.

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Fig. 3: An illustration of the absorbed doses for the stomach (A), colon (B) and remainder tissues (C), for each kVp increment, across both AP and PA projections. Error bars denote the standard error for each measurement.

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Fig. 4: An illustration of the absorbed doses for the testes (A) and ovaries (B), for each kVp increment, across both AP and PA projections. Error bars denote the standard error for each measurement.

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**Fig. 5:** An illustration of the percentage change in absorbed dose for each organ, for each kVp increment, across both AP and PA projections.

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Conclusion

Results obtained in this investigation demonstrate that the PA projection dramatically reduces the effective dose (up to 20%), and absorbed doses to the stomach (70.4%), colon (61.1%), remainder tissues (33.2%), ovaries (7.3%) and testes (15.9%), when compared to the AP projection. This may be at the expense of a minor reduction in image quality (not statistically significant). This may further be considered acceptable when balanced against the significant dose reduction and, therefore, despite this the PA projection may be considered as the preferred option when undertaking lumbar spine radiography. The optimum beam energy will depend on the projection, for AP projections a higher energy beam can provide a further means optimising lumbar spine imaging examinations.
Personal information

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Research was conducted has part of the University of Salford Diagnostic Imaging Research Programme (DIRP).
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