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Antero-posterior (AP) pelvis x-ray imaging on a trolley: Impact of trolley design, mattress design and radiographer practice on image quality and radiation dose

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ABSTRACT

Introduction: Physical and technical differences exist between imaging on an x-ray tabletop and imaging on a trolley. This study evaluates how trolley imaging impacts image quality and radiation dose for an antero-posterior (AP) pelvis projection whilst subsequently exploring means of optimising this imaging examination.

Methods: An anthropomorphic pelvis phantom was imaged on a commercially available trolley under various conditions. Variables explored included two mattresses, two image receptor holder positions, three source to image distances (SIDs) and four mAs values. Image quality was evaluated using relative visual grading analysis with the reference image acquired on the x-ray tabletop. Contrast to noise ratio (CNR) was calculated. Effective dose was established using Monte Carlo simulation. Optimisation scores were derived as a figure of merit by dividing effective dose with visual image quality scores.

Results: Visual image quality reduced significantly ($p < 0.05$) whilst effective dose increased significantly ($p < 0.05$) for images acquired on the trolley using identical acquisition parameters to the reference image. The trolley image with the highest optimisation score was acquired using 130 cm SID, 20 mAs, the standard mattress and platform not elevated. A difference of 12.8 mm was found between the image with the lowest and highest magnification factor (18%).

Conclusion: The acquisition parameters used for AP pelvis on the x-ray tabletop are not transferable to trolley imaging and should be modified accordingly to compensate for the differences that exist. Exposure charts should be developed for trolley imaging to ensure optimal image quality at lowest possible dose.

Introduction

There are many technical and physical challenges associated with imaging on a trolley which have subsequent impact on image quality and radiation dose. These challenges include: the absence of AEC on a trolley; grid selection; geometric factors; mattress and trolley design.

An antero-posterior (AP) pelvis projection is often performed on trolley bound patients especially in trauma situations because transferring them onto the x-ray tabletop could exacerbate injuries causing further harm.[1] The AP pelvis projection irradiates radiosensitive organs including the gonads and is ranked the third highest radiation dose examination by the Health Protection Agency (HPA).[2] Lead shielding of the gonads is considered essential when imaging the pelvis *except* for the initial imaging such as for trauma since it might obscure important diagnostic information. Organ dose from a single AP pelvis projection can typically reach 2.1 mGy for the testes and 0.52 mGy for the ovaries, which are within the primary beam.[3] With the challenges associated with trolley imaging, combined with the radiation implications of AP pelvis projection, it seems to be an important area to explore and subsequently optimise.

The aims of this study were to: 1. explore whether acquisition parameters used for AP pelvis radiography on the x-ray tabletop are

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transferable to trolley imaging; 2. evaluate different acquisition parameters for trolley imaging in order to optimise image quality and radiation dose for an AP pelvis projection.

Method

This study used an experimental approach by imaging a pelvic anthropomorphic phantom under controlled conditions.

Imaging equipment and technique

A Philips Bucky Diagnost x-ray unit with an Optimus 50 kW high frequency generator was used (Philips Healthcare, Netherlands). The same 35 × 43 cm Fuji IP HR-V computed radiography image receptor (Barium Flurohalide (BaFX) phosphor) was used for all exposures. This was processed using a Fuji FCR Capsula XII with 50-micron resolution (Fujifilm Medical Systems, Japan). Quality assurance was conducted on all equipment prior to image acquisition in accordance with IPEM 91,[4] which included radiation output reproducibility and sensitometry testing. All test results fell within expected tolerances.

Images were acquired using a Rando SK250 sectional lower torso anthropomorphic pelvis phantom.[5] The phantom was positioned supine on the x-ray tabletop for the acquisition of a reference image which was subsequently used as the optimal comparison image. The acquisition parameters used to acquire the x-ray tabletop reference image were those typically employed in clinical practice and recommended in various published work.[6–11] They included a 110 cm source to image distance (SID), the outer chambers of the automatic exposure control, 75 kV, an oscillating grid mounted into the x-ray table Bucky, 3.2 mm Al equivalent total filtration and a broad focal spot size (1 mm). For all exposures, the collimation was adjusted to the region of clinical interest to include the iliac crests, greater trochanters and proximal one third of the femora.

Experiment technique

The experimental images were acquired on one commercially available trolley (Lifeguard 50 trolley) using two different mattresses (standard 65 mm and Bi-Flex 130 mm). Images were also acquired with the image receptor holder (platform) elevated and lowered, for comparison. The Lifeguard 50 trolley platform that accommodates the image receptor should be elevated prior to an exposure to reduce object to image distance (OID). However, in clinical practice this elevation may not always be achieved.[12] All images were acquired with a commercially available stationary focused grid (focused to 105 cm ± 15 cm) with a grid ratio of 10:1 and strip density of 40 lines/cm.[13] Initially, images were to be acquired with and without a grid to explore the air gap technique however this idea was eliminated following a preliminary experiment demonstrating significant image quality deterioration without a grid. For each projection on the trolley, the mAs increment was varied from 16 mAs (which was the AEC reading derived from the acquisition parameters used to acquire the reference image) to 20 mAs, 25 mAs and 32 mAs. Three different SIDs were also used, with an initial setting of 110 cm and then two further distances of 120 cm and 130 cm. These were to compensate for the increased OID as a result of trolley design but also to reduce radiation dose as found in previous studies.[14–16] A 130 cm SID was considered the maximum practical and achievable SID to be used considering the effective range of the stationary grid and grid cut off. Both Heath et al. and Tugwell et al. also found that image quality deteriorated at higher SID values.[14,16] SID was measured manually with a tape measure by two radiographers to ensure consistency. All other acquisition parameters remained constant including the use of 75 kVp. This resulted in 48 experimental images being produced on the trolley under different conditions.

Radiation dose calculations

Entrance surface dose (ESD) was measured at the surface of the phantom at the centre of the collimation field using the Unfors Mult-O-Meter 407L ionising chamber (Unfors Equipments, Billdal, Sweden). Three repeated exposures were performed and then averaged in order to reduce random error. Effective dose was calculated using Monte Carlo dosimetry simulation software (PCXMC 2.0) (STUK, Helsinki, Finland). This software uses tissue weighting factors from ICRP Publication 103[17] to estimate effective dose in milliseverts (mSv). Dose area product (DAP) was used in this estimation along with the acquisition parameters.

Assessment of image quality

Following ethical approval from the School of Healthcare Sciences, University of Salford (HSCR14/104), relative visual grading analysis (VGA) with bespoke software to present the images and capture responses from observers.[18] Previous research has reported on the benefits of relative VGA in comparison to an absolute VGA as it allows easier detection of differences in quality as oppose to observers evaluating images utilising criteria without a comparison reference image.[19] The observers consisted of five diagnostic radiographers with more than five years clinical experience who were blinded to the parameters used to acquire all images.

The bespoke software allowed for two images to be presented simultaneously on dual side-by-side 5 megapixel monitors[4,20]; one the reference image (standard practice x-ray tabletop image) which was permanently displayed on the left monitor whilst the experimental images (acquired on the trolley) were displayed in random order in the right monitor. The display software prohibits post processing capabilities such as zooming and window adjustments and therefore differences detected between images would more likely be the result of acquisition parameters/technique change. The monitors were calibrated for Digital Imaging and Communications in Medicine (DICOM) grayscale standard display function which is to the recommended specification of the Royal College of Radiologists.[21] A visual pattern check (AAPM in report 93) was undertaken prior to each observer undertaking visual evaluation.[22] Room lighting conditions were maintained at a dimmed and consistent level (luminance of >170 cd/m^2) in accordance with the European Guidelines on Quality Criteria for Diagnostic Radiographic Images.[23]

Observers were required to score the experimental images against the reference image using a visual grading scale which consisted of 15 items[24] (Table 1). The items were scored using a 5-point Likert scale where '1' indicated much worse than the reference image, '2' slightly worse, '3' equal to, '4' better than, and '5' much better than the reference image. Image quality scores for each of the 15 items were totalled; for each image, scores ranged from 15 to 75. An image which scored 45 indicated equal quality to that of the reference image, a score of >45 was considered an improvement in image quality and anything lower than 45 considered a decrease in image quality. An additional item was also included at the end of the 15 item image criteria scale (Table 1), which involved a binary decision (yes or no answer). For this item, the observers considered the overall diagnostic quality of each experimental image, deciding whether they were acceptable or unacceptable for diagnostic purpose.

The magnification factor was derived for all images. The right femoral head diameter (FHD) was measured in millimetres by one radiographer with experience in pre-operative hip arthroplasty

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