PAEDIATRIC PELVIS – CU FILTRATION

Review article – A narrative review on the reduction of effective dose to a paediatric patient by using different combinations of kVp, mAs and additional filtration whilst maintaining image quality

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KEYWORDS

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ABSTRACT

This paper reviews the literature for lowering of dose to paediatric patients through use of exposure factors and additional filtration. Dose reference levels set by The International Commission on Radiological Protection (ICRP) will be considered. Guidance was put in place in 1996 requires updating to come into line with modern imaging equipment. There is a wide range of literature that specifies that grids should not be used on paediatric patients. Although much of the literature advocates additional filtration, contrasting views on the relative benefits of using aluminium or copper filtration, and their effects on dose reduction and image quality can vary. Changing kVp and mAs has an effect on the dose to the patient and image quality. Collimation protects adjacent structures whilst reducing scattered radiation.

INTRODUCTION

It is the responsibility of the radiographer to select the correct exposure factors to produce an image that is diagnostically acceptable whilst maintaining a reasonably low dose to the patient[1]. Ionising radiation has been shown to cause cancer since early in the use of medical imaging[2]. Whilst children are developing, their cells are rapidly dividing, making them more predisposed to increased DNA damage and malignant changes later in life[3]. It has been estimated that radiation exposure in the first 10 years of life has an attributable lifetime risk[4], therefore dose is of high consideration especially in paediatric examinations. It is important to ensure dose is kept as low as reasonably achievable (ALARA)[5] as stated in the ICRP guidance[6], whilst maintaining acceptable image quality.

Due to the associated risks of ionising radiation, it is essential to try and find optimal exposure / acquisition factors and if required additional filtration to reduce dose. Research has shown that additional filtration of 0.2mm of copper (Cu) can reduce dose by up to 40%[7]. Filtration works by hardening the beam, meaning more useful X-rays reach the image receptor and the low energy X-rays are filtered out without being detrimental to image quality. Uffmann and Schaefer-Prokop state that standard tube filtration in diagnostic radiology, as required by regulations, is 2.5mm of the aluminium (Al) equivalent[5].

Diagnostically acceptable image quality does not mean as good as possible, but rather as good as is needed. Exposure factors can be manipulated to achieve a low dose with diagnostically acceptable image quality; this can be achieved by altering kVp and mAs. This review article concentrates on literature relating to analysing ionising radiation dose and diagnostic image quality in paediatric pelvis imaging.

This paper reviews evidence about cancer risks, the effects of changing acquisition parameters (eg kVp, mAs, grid, collimation and copper filteration) and the influence this has on patient dose. Visual and physical evaluation of image quality, dose estimation (Monte Carlo) and diagnostic reference level will be discussed.

The search strategy for literature was peer reviewed journal articles from PubMed. Additional material used was Grey literature, professional guidelines, and international standard documents

Key Words

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PCXMC
2AFC
ImageJ
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Cancer risks in paediatric imaging

Since the discovery of the risks of using X-ray imaging there has been a debate on optimising the image quality and minimising dose. Because of this, the concept of ALARA was developed. This is to protect the patient so that an image is obtained that is adequate for diagnostic purposes, whilst the radiation dose is kept as low as reasonably achievable[8]. In paediatric imaging there can be a higher risk of developing cancer from X-ray imaging through stochastic effects, because children are expected to live longer than adults. In addition they have a more rapid cell division, which makes them more sensitive to radiation[9]. This causes an awareness of lowering the radiation dose in X-ray imaging, especially for children. The necessity of the image needs to be higher than the risks of taking it[5,10], that is, the examination needs to be justified. The pelvis examination is a common region with high dose, compared to other radiographic exposures. One pelvis image has the same effective dose as 35 chest images[8], causing more concern in children, particularly of dose to the gonads. The pelvis area has organs and tissues that are highly radio-sensitive[6].

Changing parameters to lower the dose – kVp, mAs and grid

Radiographers can change a number of exposure factors, including kVp and mAs; these regulate the X-ray beam quantity, thereby affecting the patient dose and quantity of radiation received by the image receptor[1]. Changes in these factors must be performed cautiously because it is important to perform examinations according to the philosophy of ALARA. Therefore optimisation is a balance between the risk of the ionising radiation exposure and the advantage of the diagnostic imaging to the patient[10]. The increase of kVp and mAs result in an overall increase of patient dose and also result in more signal reaching the detector that should reduce the noise in the image and improve the SNR[10]. According to European Guidelines the parameters advised for paediatric pelvis X-ray in AP projection are 60 – 70 kV and < 10ms[11]. The anti-scatter grid is used to filter out the scattered photons, thereby improving the quality of the image by increasing the contrast. However, the dose to the patient can be increased by a factor of two compared with not using a grid[10,12]. In paediatrics, the use of a grid is not recommended, the proportion of diffused radiation is much lower and therefore has no impact on the quality of the image[12]. In cases where high voltages are used then a grid must be used; it is suggested the grid be composed of materials with low attenuation such as carbon fibre or non-metallic materials[11]. In practice, the proportion of diffused radiation is so small that the grid is not used for paediatric patients, as dose increases unnecessarily[10].

In previous studies, a steep increase in dose was observed in a group of children aged 3-7 years due to the use of the grid[4]. However, for children over 15 a significant increase in image quality is seen when a grid is used. ***On younger children***, the quality of ***images without grid is considered to be of an acceptable diagnostic level[13].***

Collimation

Collimation restricts the X-ray beam to the body part that is to be examined, protecting the adjacent structures from being exposed unnecessarily. It also reduces the scattered radiation that arrives to the detector contributing to an improved contrast resolution and image quality. As the collimation field is reduced so too is the tissue volume irradiated and, as a result, the overall integral dose reduces at the same time as the radiation risks[14-15].

Diagnostic reference level and dose lowering

To keep the radiation dose under a maximum level, The ICRP has developed a diagnostic reference level (DRL). There are difficulties developing these levels because all patients are different. Even though the patients´ age, gender and thickness of the anatomy being X-rayed is the same, there can be other variations that need to be considered. Furthermore, a child will have tissue with a higher water content than an adult, therefore radiation is absorbed differently. A higher kVp is needed to penetrate an adult for the same thickness[12].

Considering these factors, a scale was devised showing that for a 5 year old child in an AP pelvis examination, there is a maximum of 0.9 mGy expressed in entrance surface dose per image. Some of the factors that can be alternated in lowering the dose is kVp, mAs and filters[6].

Filtration – Copper 0.1mm and 0.2mm

In most radiological facilities found in practice, there is a recommended filtration of at least 2.5mm of aluminium inside the tube[11]. Adding an additional filtration can harden the photon beam and reduce the proportion of lower energy radiation. Part of the low-energy radiation is completely absorbed by the patient and is not used for the production of the X-ray image whilst also increasing the dose to the patient unnecessarily. This is why thin sheets of metal such as copper or aluminium are used as additional filtration[7,11]. Several authors recommend the use of additional filtration rather than decreasing the kVp to reduce patient dose[5].

Using thin layers of copper can reduce the dose at the entrance to the patients by up to 40% following the body part that is considered[7]. Using 0.1 and 0.2mm copper is suggested and is commonly used in practice for radiographs in paediatric departments[5]. The use of copper is recommended compared to the aluminium because it can absorb a larger proportion of lower energy radiation. However, the disadvantage of the use of copper is the need to increase kVp to compensate for the additional attenuation produced by the filter[7]. According to a previous study, the use of copper provides additional filtration to reduce the dose at the entrance of the skin of the patient, without reducing the image quality. However, the SNR and CNR are affected by the additional copper filtration[16]. Yet Brosi et al state that the potential consequences due to reduced contrast from the use of copper filtration are minor in digital imaging systems as contrast can be changed in post-processing[17].

Evaluation of image quality

The ALARA principle states that although dose needs to be kept low, it is important to maintain an image quality that is diagnostically acceptable. Image quality is based on the sharpness of the details, the contrast, the presence or not of noise, the luminance, the distortion, the presence of artefacts or not and most importantly whether the pathology can be seen. Some of these factors can be measured physically and others visually. One of the most commonly used measurable indicators is SNR[5] which, aside positioning the region of interest, is not dependent on human observer[3]. Although the SNR is quite basic, it is useful as it includes the noise level, which gives an indication of image quality. High noise indicates a low quality image and a large SNR indicates an image of high quality. In the literature, the SNR is one of the most used factors[5].

It is written in the literature that for the comparison of a pelvis X-ray, the most common method is achieved by asking questions about the visibility of a part of an images, such as femoral neck, sacral foramina, sacro-iliac joint and more[13,18]. The answers often use a Likert scale from 1 to 5: much worse, worse, same, better, much better[7,13]. It is also possible to rate the image from -2 to + 2, in much the same way as the 1 to 5 scale[18]. Every image can be evaluated one by one asking every question on each image or to get a reference image and compare each image to it. That last option is adapted to evaluate a large range of images and showing the differences between the two[19].

Estimating dose

Monte Carlo simulations can provide estimates of organ and effective dose (E) for a range of radiographic examinations. Such simulations calculates the patients' organ doses by using the acquisition parameters – tube potential, filtration, focus skin distance, geometry of the X-ray beam – and also the air kerma at the point where the central axis of the X-ray beam enters the patient[20]. One example is PCXMC software; this provides an accurate estimation of the effective dose to the patient and their potential risks of cancer[17].

Measuring image quality

ImageJ is a program that can display, edit, analyse, process, save and print 8–bit, 16–bit and 32–bit images. This program can calculate area and pixel value statistics of user-defined selections. It can measure distance, angle, create density histograms and line profile plots. It also supports standard image processing functions, such as contrast manipulation, sharpening, smoothing, edge detection and median filtering. ImageJ can also calculate SNR or CNR by choosing one or more specific regions of interest (ROI) in the image. The program uses one ROI for calculating the SNR and two ROIs to measure the CNR[21].

CONCLUSION

Because of the relative high dose in a paediatric pelvis exam, and the stochastically high risk of developing cancer, this is an important area of interest in research. In radiographic imaging, there will always be an ionising radiation dose, but the goal is to keep this as low as reasonably achievable. With a combination of kVp, mAs, collimation and additional copper filtration, this can be achieved. It is shown in previous studies that when adding copper filtration, the image quality remains the same or better, with a lower dose. This is a reason to test dose and image quality in paediatric pelvis exams. To prove that the image quality remains acceptable, it is important to do a visual and physical evaluation.

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