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The need for the development of an adjustable radiolucent apparatus to address sub-optimal images in terms of poor collimation on neonatal chest radiographs

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Abstract

Background. Chest radiographs are commonly used by neonatal ICU nurses and physicians to diagnose and manage neonates. Despite numerous recommendations from studies investigating radiographic techniques in neonatal imaging, collimation practices of these radiographs remain poor, increasing the risk of including radiosensitive anatomical structures such as the thyroid and humeri. The practice of collimation amongst radiographers is explored in terms of resultant radiographic contrast after continuous professional development (CPD) training.

Aim. To determine whether the literature recommendations of CPD training would improve the quality of neonatal imaging at a large academic hospital.

Methods. Collimation and image contrast in 100 pre-processed digital neonatal chest images were measured and analysed following CPD training of radiographers. The scale for collimation was: optimal collimation = 1 cm; over-collimation = < 1 cm; under-collimation = > 1 cm. Radiographic contrast was assessed subjectively.

Findings. Of the 100 images, 77% were under-collimated, and included non-essential thoracic structures; 2% were over-collimated resulting in clipping of essential thoracic structures; and 26% exhibited significantly reduced contrast. The results indicate that the images were still of sub-optimal quality following CPD training.

Conclusion. Both incorrect centring and anatomical positioning contributed to improper collimation, resulting in sub-optimal images of the neonatal chests. The intervention of CPD training appeared to be have been unsuccessful: the images remained of poor diagnostic quality. There is a need to explore the use of an adjustable radiolucent apparatus, which can be placed under the area of interest, whereby the beam can be visibly collimated. This should enable a radiographer to confidently and accurately collimate the beam to consistently produce images of optimal quality.

Keywords neonate, digital radiography, radiosensitive

INTRODUCTION

The World Health Organisation (WHO) highlights the vulnerability of neonates, indicating they are at the highest risk of mortality, particularly from respiratory complications and infections.[1] This makes chest radiography one of the most common examinations included in a neonate's diagnostic work up. Many may require as much as 10 radiographs to ensure effective treatment and management,[2-3] particularly with regards to identifying placement of lines, catheters and nasogastric feeding tubes.[4-5] The use of chest radiographs to aid diagnosis is not limited to specialist radiologists. They are often used by health professionals involved in neonatal care such as nurses and medical officers.[6] Radiographic images of neonates must be of optimal quality, to limit the margin for misinterpretation due to incorrect radiographic technique. To achieve this radiographers are guided by digital imaging considerations: collimation, accurate centring, exposure factors, post-processing evaluation of exposure indicator and grid use.[7] Radiographic techniques for neonatal imaging have been well documented; many studies globally investigated the cause and effect of poor radiographic technique on image quality,[2,8-9] Some of these factors include improper positioning and under-collimation. The transition from analogue to digital imaging is presumed to be a contributing factor for the decrease in the standard of radiography performed by radiographers, particularly with regards to collimation.[8] Karami explains that radiographers tend to rely on post-processing techniques to crop an image.[10] Although this form of 'masking' may be perceived as aesthetically appealing, the diagnostic value of an image considerably decreases.[10] This is further evidenced by the fact that reject rates have not been eliminated in digital imaging because as much as 77% of images are rejected and repeated due to improper positioning techniques.[11] This rate is alarming. Neonates should be subjected to minimal handling by a radiographer, as they take longer to recover from being moved in an incubator.[12] To address poor quality neonatal imaging in the digital era, further training on imaging techniques, clinical audits, and adherence to safety guidelines, are recommended in the literature.[2,9,13]

In the context of this study poor paediatric image quality, in a radiology department of a large training hospital in South Africa, was noted as an area that needed to be addressed. Continuous professional development (CPD) was implemented. This involved hands on training for all staff and student radiographers who rotate through the paediatric imaging departments. The aim of the study was therefore to explore the effectiveness of the CPD activity on radiographers' collimation practices for neonatal chest radiographs.

METHOD

Ethics approval was granted by the university's Faculty of Health Sciences Research Ethics Committee (402/2017). Permission to conduct the study, within the hospital, and to access patient records was granted by the chief executive officer (CEO), and the head of the radiology department.

A quantitative research design with a descriptive approach was used as the aim of the study was to explore the practice of collimation practices among radiographers in a training institute following CPD training. Data were collected at a large training hospital in the Gauteng province of South Africa.

CPD training

CPD training was provided to all the radiographers who rotated through the paediatric imaging department in September 2017. The CPD training covered a practical session for radiographers to practice on an anatomical paediatric dummy. The practical session focused on essential neonatal chest radiographic technique. This included the following.

- Communication – family/other health professionals
- Clinical history
- Patient preparation
- Centre point
- Positioning
- SID (subject image distance)
- Mobilisation
- Markers
- Collimation.
- Radiation shielding

In this paper we focus on the collimation training. As stated above the training entailed using an anatomical paediatric dummy. The use of four-sided collimation, which only includes essential thoracic structures, was demonstrated. The focus was primarily on positioning and technique. In October 2017 data were collected to determine whether the training had achieved a reduction in reject rates and improved collimation, using a data collection sheet formulated by the researchers. A randomised sampling strategy was used to obtain a sample of 100 pre-processed neonatal chest images that were viewed directly from two mobile machines. The images were also stored on the PACS system. We only wanted to access the raw data thus opted to view the images directly from the mobile machines. The rationale was that we wanted to gain a true reflection of the collimation practices prior to post-processing. Anterior posterior (AP) supine chest radiographs of neonates between the ages day 0 and 28 days were included in the study. The date of birth and examination selection details of neonates were the inclusion criteria. The same ruler was used to measure the collimation on each image. Each image display was 100% view to represent the true image captured. Measurements were taken from the soft tissue of the lateral chest wall to the visible collimation boundary line laterally. Vertical measurements were made from the third cervical vertebrae to the level of the costophrenic angles.[7] A data collection sheet was categorised into two sections: collimation, and image contrast. Collimation was measured based on that of the International Atomic Energy Association (IAEA),[14] which states that 1 cm collimation should be adopted in paediatric imaging. The data were therefore categorised as follows:

a. < 1 cm = essential thoracic anatomy clipped off (Figure 1 a);
b. 1 cm = all essential thoracic structures thus optimal collimation (Figure 1 b);
c. > 1 cm = inclusion of non-essential thoracic structures such as the humerus, mandible, c-spine and upper abdomen (Figure 1 c).

Image contrast was subdivided into optimal, suboptimal but passable, and suboptimal thus repeat examination should have been done. Image contrast was assessed subjectively by the authors.

Descriptive statistics were used to analyse the continuous and categorised data as means and frequencies, respectively.

RESULTS

One month after radiographers had undergone practical CPD collimation training on an anatomical paediatric dummy 100 pre-processed neonatal chest images were analysed for collimation and image contrast.

The results were: 21% of the 100 images were optimally collimated with 1 cm four-sided collimation; 2% were over collimated (< 1 cm); 77% were under-collimated (> 1 cm). Figures 2a to c, show unwanted anatomy (e.g abdomen, humerus, c-spine). Figure 2d shows that essential chest structures were cut-off due to < 1 cm collimation. The evaluation of radiographic contrast pertained to the optimal shades of grey to visualise lung tissue. The results were: 21% of images were of optimal quality in line with results of the percentage of optimal collimation; 53% were of sub-optimal quality, however diagnostic information was not significantly comprised due to reduced image contrast hence were considered to not require a repeat examination; 26% exhibited significantly reduced contrast and should have

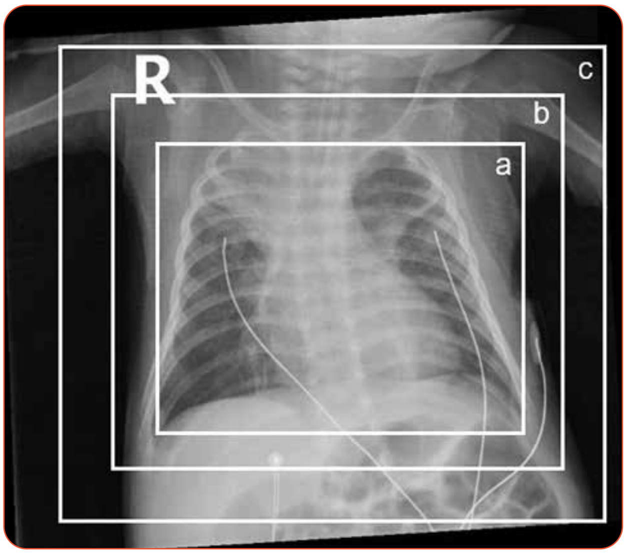

Figure 1. Example of measurement parameters used to record collimation: a) collimation less than 1cm resulting in essential thoracic anatomy clipped of; b) optimal collimation of 1cm including all essential thoracic anatomy within the field of view; c) collimation of more than 1cm resulting in the inclusion on non-essential thoracic structures.

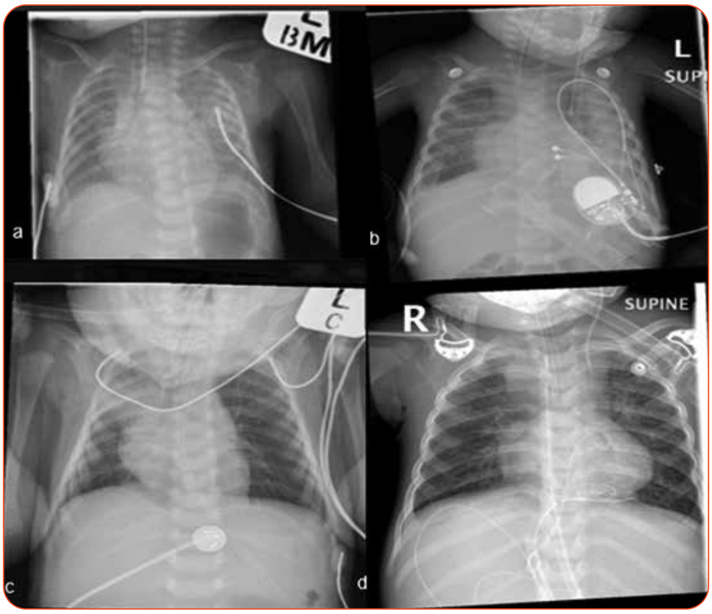

Figure 2. Examples from raw data on collimation practices of neonatal chest x-rays: a) improper centering resulting in uneven collimation and inclusion of non essential thoracic structures; b) under collimation resulting in inclusion of non-essential thoracic structures; c) improper positioning resulitng in under collimation and overlapping of soft tissue on essentail thoracic structures; d) over-collimation resulting in clipping of essential anatomic structures.

been repeated. In view of departmental protocol that aims at keeping paediatric radiation dose to a minimum, repeat exposures are avoided if some diagnostic information can be derived from an image.

DISCUSSION

Based on the results it is evident that collimation practices are aligned with results from other studies conducted both globally and in South Africa. With regards to proper collimation techniques 21% of the 100 chests were optimally collimated at 1 cm, with optimal quality, in terms of image contrast. These results can be viewed in a positive light. Stringent measurements of 1 cm were used to assess the images, in comparison to other studies that used 2 cm as an acceptable measurement.[8] These results also exceeded those found in a study conducted by Karami in Iran; there was satisfactory collimation in 15,5% chest images.[8] Only 2% of the images were over-collimated, and these results align with views of Stollfuss, Schneider and Stollfuss. They explain that radiographers tend to open the collimation field to avoid the risk of clipping of important anatomy due to motion, resulting in an examination having to be repeated.[2] The majority (77%) of the images were that collimation exceeded 1 cm, on all four sides and included non-thoracic structures. The aim of the study was to determine the collimation practices and image quality in terms of radiographers contrast, but we noted that a large number of images were incorrectly centred, and the chest anatomy was improperly positioned. This resulted in uneven collimation, whereby one side was over-collimated and the other side under-collimated as seen in Figure 2a. Incorrect positioning of a neonatal chest may result in inclusion of the mandible and humerus, which should be moved away from the area of interest and immobilised, with the assistance of a neonatal nurse. These results greatly exceed those of Stollfuss, Schneider and Stolfuss's comparative study of collimation practices in two teaching hospitals in Germany.[2] Their results revealed that only 32% and 39% images from each respective hospital were sub-optimally collimated. Pedersen et al.[15] assessed the degree of neonatal chest collimation at a training hospital in the United Kingdom (UK); their results revealed that 21% of the images had sub-optimal collimation in the transverse plane. Studies undertaken in South Africa revealed higher values of lack of collimation in comparison to those conducted across the globe. A study conducted in three hospitals in South Africa showed that 74.9% of chest images were sub-optimally collimated, and 64.9% were incorrectly centred.[9] The findings in this study did not differ substantially from the cited South African study.

Literature recommends further training for radiographers, specific to paediatric technique to hopefully lead to a reduction of sub-optimal neonate images being produced. It is evident that despite the radiographers having undergone CPD training in this study the majority of pre-processed images showed unacceptable beam collimation. Literature proffers some possible reason for this: lack of dedication of radiographers; lack of awareness of the implications of under-collimation; fear of repeating due to over collimation.[2,16] In the general context of radiographic imaging, qualitative data suggest that in the digital era newly qualified radiographers focus on work load and less on quality, resulting in them neglecting to collimate.[17]

Pederson et al.[15] hold contrasting views regarding radiographers' attitude towards collimation. They suggest that sub-optimal collimation may be attributed to radiographers being doubtful of the visible surface anatomical landmarks and boundaries. According to them there is a gap in this research area; surface landmarks for neonatal chest imaging have not been clearly established.[15]

Radiographic imaging text books refer to collimation as the 'area of interest'.[7,18-19] In view of this gap in the literature, and the findings of this study, it is recommended that there should be a robust approach to address the ongoing issue of poor collimation practices, and resultant sub-optimal image quality in neonatal imaging. An example of this approach is the possibility of a radiolucent apparatus, which can be placed under an infant, and physically adjusted to include essential structures of the thoracic cavity at the discretion of a radiographer. The beam could subsequently be collimated to visible borders of the apparatus. The concept of external anatomical land marking is not new to the field of medical research. It has been used in many medical procedures such as placement of intercostal drains and catheters.[20] In radiology, particularly nuclear medicine, skin marking, for example, is used to accurately demarcate the region of interest to be radiated, using surface land marks. These markings include the field centre and edges, similar to the collimation light found in radiographic equipment.[21] This type of external marking has also proved to be successful in fusion imaging, whereby an immobilisation device is fitted with external markers to improve localisation and accuracy of an area imaged.[22]

LIMITATIONS

The study was conducted in one academic hospital following a paediatric training CPD activity. The CPD activity was limited to radiographic technique. Future studies could include more aspects in the training such as exposure selection and brightness.

RECOMMENDATIONS

It is therefore recommended that future studies be done at other training institutes in this region to ascertain whether the results are unique to the institute in this study or can be generalised to the district. The study was limited to collimation practices and resultant radiographic contrast thus future studies could investigate other factors such as exposure techniques, density and brightness, radiation dose and artefacts.

CONCLUSION

In this study it was evident that radiographers did not employ proper collimation even after undergoing neonatal specific CPD training. More than half of the images were under-collimated and 2% over-collimated. We suggest the development of anatomical markers for neonatal chests, in the form of an adjustable radiolucent apparatus that can be placed under the area of interest for beam collimation. It is recommended that further studies be done to develop and explore the effectiveness of such a proposed apparatus to ensure radiographs consistently and accurately collimate to the region of interest to reduce radiation dose to peripheral non-essential thoracic structures.

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CONFLICT OF INTEREST

None.

CONTRIBUTIONS OF AUTHORS

ER (UP) protocol development, editing of manuscript; HE assisted supervised protocol development, data collection, write up and drafting and editing of manuscript; ER, MM, OB, SS, and FG development of protocol, data collection, analysis, and drafting of manuscript.

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