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A comparative study of collimation in bedside chest radiography for preterm infants in two teaching hospitals

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ABSTRACT

Objective: Unnecessary exposure of the abdomen, arms or head may lead to a substantial increase of the radiation dose in portable chest X-rays on the neonatal intensive care unit. The objective was to identify potential factors influencing inappropriate exposure of non-thoracic structures in two teaching hospitals.
Methods: The study analysed 200 consecutive digital chest radiographs in 20 preterm neonates (mean gestation 25 ± 1 weeks). Demographical data, tube settings and exposure parameters were recorded. To grade the collimation, we used a scoring system with a maximum of 12 exposed non-thoracic structures. Length of gestation, age, the radiographer, years of experience in performing X-rays and the number of in situ catheters or lines, were correlated with collimation quality.
Results: There was no significant difference between the rates of optimal images obtained in the two hospitals (0.32 vs 0.39, n.s.). Scores showed that most suboptimal images had only mildly reduced image quality (1.40 ± 1.38 vs 1.20 ± 1.43, n.s.). Length of gestation or presence of surgical drains, catheters and tubes had no obvious effects on the exposure of non-thoracic structures. Large intra-individual variation in optimal collimation (14–86%) was noted for the radiographers in both hospitals; this was unrelated to their respective years of experience.
Conclusion: In our study, the only identifiable factor influencing the collimation of portable chest radiographs in preterm infants was the radiographer's dedication and awareness. There were no apparent differences between the hospitals investigated. Exposure of non-thoracic structures was relatively frequent and mainly involved the proximal humeri.

1. Introduction

Chest radiography is one of the most widely used diagnostic examinations in children [1–3]. In a special care baby unit, premature neonates have serious and life-threatening diseases that may require a large number of X-rays for diagnosis and treatment [4,5]. Increased neonatal radiosensitivity and longer life expectancy increase the risk of radiation-induced cancer, which emphasises the importance of minimising the dose while maintaining a clinically satisfactory image quality [6].

The radiation dose during bedside examinations can be increased without a visible change in the final image due to incorrect (free) exposure settings. It is therefore possible that different hospitals, using different image parameters, show a substantial variation in radiation dose [7–9].

However, inappropriate irradiation may be quite obvious when it comes to the incorrect collimation of the image field or incorrect positioning of the infant on the detector or film plate. Unnecessary exposure of the abdomen, arms or head can lead to a substantial increase of radiation dose, mainly due to the irradiation of red bone marrow or abdominal viscera [10]. Effects on the cumulative dose in preterm infants may be quite severe and independent of technical parameters. Reduction of the overall image quality with respect to the radiation dose could be influenced by multiple factors. Some of them may be specific to the infant, including weight, age and disease severity. Other intrinsic factors, such as the education and

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awareness of the radiographer actually taking the X-ray on the intensive care unit, may also be relevant [10,11].

The aim of the present study was to compare radiation exposure and image quality, in terms of the collimation, in two teaching hospitals. Our goal was to identify potential factors influencing inappropriate exposure of non-thoracic structures in portable chest X-rays on the intensive care unit.

2. Materials and methods

The study consisted of a retrospective analysis of 200 mobile digital AP chest X-rays (stored on phosphor plates) carried out on 20 preterm neonates at two different hospitals, including patients with multiple X-rays (performed on separate occasions). One hundred images were acquired from a university hospital (site 1) and another 100 images were obtain from a community teaching hospital (site 2). We extracted demographical data from the case notes, including the length of gestation (weeks) and the age of the neonate on the date of the X-ray. Tube settings and exposure parameters, including tube voltage, tube current and dose-area product (DAP) were recorded. The radiography systems used were a Philips Mobile Diagnost (Philips Healthcare, The Netherlands) at site 1, and a Siemens Mobilette (Siemens, Erlangen, Germany) at site 2. The radiographers were noted, as well as their years of experience in performing X-rays. In addition, we recorded the presence of tubes and catheters as a surrogate of disease severity. The data were anonymised before image evaluation. Radiographs used for the study were included sequentially and not preselected. We did not take the diagnosis into account. Both hospitals monitored the rate of repeat X-rays. Repeat images on neonates were not allowed without the permission of a consultant radiologist. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. For this type of study formal consent was not required. Informed consent was obtained from all individual participants included in the study.

Two experienced radiologists (JCS and IK-S) evaluated the image quality, based on the exposure of non-thoracic structures. They determined the most superior and inferior parts of the body, as well as the lateral structures, which had been included within the boundaries of collimation on each chest X-ray. The readers performed their evaluations according to the European Guidelines on Quality Criteria for Diagnostic Radiographic Images in Paediatrics [12]. A grading system was used to measure image quality in terms of correct collimation. Inappropriate exposure of abdominal viscera was assumed when the caudal imaging field extended below the level of L1/2 (1 point). Exposure of the cranial structures was considered inappropriate when the collimated field included more than the tip of the mandible (1 point). Inappropriate exposure of the arms was assumed when more than the diametaphyseal junction of the proximal humerus came within the field of view: part of the diaphyseal humerus (1 point); entire humerus (2 points); part of the forearm (1 point); entire forearm (2 points); hand (1 point). The maximum score was 12 points. The image quality in terms of correct collimation was graded arbitrarily as follows: 0 points = optimal image quality; 1–2 points = slightly reduced; 3–4 = moderately reduced; 5–6 = markedly reduced; and >7 points = severely reduced (Fig. 1). Rotation and tilting were also recorded. Radiographic errors were recorded on individual tick sheets and the information was captured in an Excel spreadsheet (Microsoft, Redmond, WA). The readers resolved any differences by consensus.

The exposure of non-thoracic structures was correlated with factors potentially influencing image quality. The chi^2 test (uncorrected for continuity) was used to calculate differences between the hospitals, as well as between optimal and suboptimal images with respect to age, gestation, number of tubes and catheters, radiographer, and the number of years' experience. Student's t test was used to calculate differences between DAPs. The Spearman rank correlation coefficient was used to analyse the correlation between the radiographer's experience in performing X-rays and collimation quality. A level of $p < 0.05$ was regarded as statistically significant. Analyses were performed using SAS statistical software (version 9.1; SAS Institute, Cary, NC).

Table 1
Frequency and distribution of exposure of non-thoracic structures in two different hospitals. The number of structures and the points scored are shown for the two hospitals. There was no significant difference (*n.s.) between site 1 (university hospital) and site 2 (community teaching hospital).

Exposure of non-thoracic structures		Site 1 [n (points)]	Site 2 [n (points)]
Head		5/5	7/7
Right upper limb	Part of upper arm	32 (32)	24 (24)
	Entire upper arm	20 (40)	12 (24)
	Part of forearm	7 (7)	4 (4)
	Entire forearm	0 (0)	1 (2)
	Hand	1 (1)	0 (0)
Left upper limb	Part of upper arm	17 (17)	28 (28)
	Entire upper arm	19 (38)	12 (24)
	Part of forearm	4 (4)	4 (4)
	Entire forearm	1 (2)	2 (4)
	Hand	1 (1)	2 (2)
Abdomen		7 (7)	8 (8)
Total		114 (154)*	104 (131)*

Table 2
Comparison of image quality at the two institutions in terms of collimation. The chi^2 test showed no statistically significant difference in the number of correctly collimated images (*n.s.). The number of exposed non-thoracic parts (head, abdomen, arms and hands) in the suboptimal images is also given as a semiquantitative measure of image quality.

Image quality (collimation)		Site 1 (%)	Site 2 (%)
Optimal		0.32*	0.39*
Sub-optimal		0.68	0.61
1–2 parts exposed	Slightly reduced	0.48	0.49
3–4 parts exposed	Moderately reduced	0.17	0.08
5–6 parts exposed	Markedly reduced	0.02	0.04
>7 parts exposed	Severely reduced	0.01	0.00

3. Results

All images were obtained with the neonate in a supine position. Imaging parameters were 60 (60–62) kVp and 1.96 (1.6–2.5) mAs at the university hospital, and 72 (70–77) kVp and 0.71 (0.56–0.80) mAs at the community hospital, with no grid and a 20×25 cm image plate. The DAPs were 0.08 ± 0.04 cGy cm^2 and 0.10 ± 0.05 cGy cm^2, respectively (n.s.). The monitored repeat rates were low at both units. Only one repeat X-ray was recorded at site 2 and none at site 1.

Table 1 shows all exposed non-thoracic structures in both hospitals. The upper arm was most commonly observed, while exposure of all other parts was relatively infrequent. The overall frequency and distribution were quite similar in the two hospitals (154 vs 131 points, n.s.). Table 2 presents the number of images with optimal and suboptimal collimation. Evaluation shows a comparable rate of optimal images in the two hospitals with no significant difference (32% vs 39% for site 1 and 2, respectively). The majority of suboptimal radiographs demonstrated only 1–2 errors per film, accounting for 48% and 49% of the X-rays evaluated at sites 1 and 2, respectively.