Original Article

A Reduction in Radiographic Exposure and Image Quality in Film Screen Postero-anterior Chest Radiography

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ABSTRACT

PURPOSE: To develop a protocol for the optimization of diagnostic chest radiography examination, the effect of radiographic exposure reduction on image quality is investigated.

PROCEDURE: Fourty-eight adult patients presenting for posterior-anterior (PA) chest radiography in a tertiary health care centre were categorized into 3 groups to assess the effects of exposure (tube current/time mAs) reduction on clinical image quality using in film screen (FS) chest radiography. Images were obtained at existing departmental exposure protocol (T1) while a record of the exposure factors was made. Test exposures obtained by reducing average mAs values by 20% (T2) and 50% (T3) were used to obtain radiographic images of patients following normal ethically based clinical practice. To make up for the reduction in mAs, a 4% increase in the T1 kVp was used. The quality of images obtained with each exposure protocol was studied by two Consultant Radiologists, using the image quality criteria of the Commission of European Communities (CEC). Assessors used the method of ranked scoring and worked independently.

RESULTS: Results showed no change in image quality following the 20% exposure (mAs) reduction. However, there was a significant change in image quality at 50% reduction of mAs values ($P < 0.05$) with higher image quality scores suggesting improved perceptibility of all assessed criteria among the observers.

CONCLUSION: Improving radiation protection of the patient while maintaining diagnostic quality of the radiographic image at reduced exposures is a clinically desirable development. This study will find application in current efforts at optimization of radiography procedures in the area of study.

KEYWORDS: Radiography, exposure reduction, image quality, chest, quality control.

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INTRODUCTION

Ionizing radiation has damaging effects. Some of these effects are non-threshold dose dependent. This accounts for the high emphasis placed on balancing dose reduction with image quality (IQ) obtained[1-2]. Radiation dose must be optimized. But this is done only with respect to acquisition of image of diagnostic quality, as insufficient dose during an examination may lead to repeated patient exposure to radiation. Dose reduction has been achieved elsewhere [3-4].

Patient dose assessment studies have identified different methods that could be used to reduce unnecessary radiation dose to patients. These include, among others, lowering the tube current-time product, (mAs) increasing tube voltage (kVp), increasing filtration, increasing the image receptor speed and improving the processing conditions[5]. Through these and other methods, dose reduction has been achieved in parts of the developed world [2-3].

Optimization of image quality includes aspects dealing with "information content" in addition to parameters pertaining to general outlook like density, contrast, sharpness and absence of artifact, which give a crisp appearance to image. While parameters for crispness are better described and defined, the image content is not an easy one to check but is vital to the diagnostic process [6].

Dose-image quality optimization studies have severally been conducted with phantoms [7-9], but the results obtained need to be applied to everyday diagnostic procedures [10]. It is the aim of this study to assess the effect of reducing patient radiation exposure, using the tube-current/time (mAs) factor, on observer visual perception of the image quality. Image quality criteria outlined by the Commission for European Communities (CEC) [11] are used for the study. The use of these criteria in image quality and dose optimization studies has been reported severally in the literature [12 - 14].

Results from this study will be useful in the current drive towards achieving optimized radiography techniques that will offer lower doses to patients while maintaining diagnostic quality images. This will impact favorably on diagnostic radiography service delivery and improve patient outcomes.

MATERIALS AND METHOD

Forty-eight patients (average age 41.5 ± 14 years, and weight 67.8 ± 15 kg) presenting for chest examination in the centre were divided randomly into three groups of sixteen each for the study. Group 1 patients were examined with the pre-study departmental protocol (T1) which consisted of an average tube potential of 74 ± 2.5 kVp and tube current/time value of 32 ± 4 mAs. Test protocols consisted of reducing T1 mAs values by 20% (T2) and 50% (T3), respectively, while increasing the tube potential (kVp) by 4% to compensate for the

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reduction in tube current. Patients in groups 2 and 3 were examined with T2 and T3 protocols, respectively. These and other parameters used in the study applying to the three categories of patients and the three protocols used are presented in Table 1.

Using a no-grid technique, exposures were made with a Listem-Phillips Corporation x-ray generator, having total tube filtration of 3.4 mm of aluminum, in an x-ray room equipped with a chest stand, 35 × 35 cm film for female and 35 × 42 cm film for male. Agfa cassettes with regular screen speed (400) were used to store the films for exposure. The mean values of the mAs and corresponding kVp were deduced and are shown in table 1 below. Film processing followed the regular clinical protocols.

Radiographs for each exposed patient were labeled with an appropriate code that linked each with the exposure factors used in producing the image. The film processing method was standardized, as is usual for clinical work. Images obtained were reviewed by two consultant radiologists working independently, but using the same viewing conditions similar to those used for routine radiographic film reviews.

Image quality (IQ) was assessed by observer perceptibility of the image criteria, adopted from the CEC guidelines on image quality assessment, on the 48 radiographs. The assessors were not aware of the different exposure regimes used in the study but were simply asked to assess the quality of the images based on the set criteria. Criteria used are outlined with the indicating symbols used, in Table 2. Each assessor worked independently and was allowed to view the radiographs twice but in random order. Images were assessed by visual grading analysis (VGA), using the method of rank scoring which allowed the assessor to score an image criterion with a value from 0 3, with 3 being the highest and signifying maximum image performance. This method of scoring allows for qualitative assessment and is an indicator of the assessor's level of confidence in reaching the respective decision. Visual grading is the method employed in clinical practice.

Scores were interpreted as 0 - not seen; 1 - barely seen; 2 - seen but not clear; and 3 - clearly seen. From the quantification of the degree of perceptibility from the assessment, mean results for within reader and inter-reader consistencies were determined using percent coefficient of variability (COV%) and Fleiss Kappa, respectively. Differences between results obtained at T_1, (control) and the test protocols (T_2, $T_{3,}$ were compared and studied using the Mann-Whitney test of differences statistic. All statistical tests were made at the 95% confidence interval.

Table 1: Mean (± SD) of patient age, weight and exposure techniques in the study.

Parameter	Protocol used		
	T1	T2	T3
Patient weight (kg)	73 ± 13	67 ± 18	64 ± 12
Age (years)	42 ± 9.9	44 ± 18	38 ± 14
kVp	74 ± 2.5	#76	#76
mAs	32 ± 3.9	22 ± 2.9	14.8 ± 1.6

kVp = Tube potential (kilovoltage peak)
mAs = Tube current/time (millliampere/seconds)
# Actual figure was 76.9, but generator calibration reading of 76 was used.

Table 2: Assessment criteria used for subjective scoring [11].

Image quality criteria (IQC)	Code
Full inspiration (6 anterior, or 10 posterior ribs above the diaphragm)	[C1]
Symmetry of the thorax (no rotation of the patient)	[C2]
Complete medial rotation of scapulae away from the lung fields	[C3]
Sharp reproduction of the vascular pattern of the whole lung, including and in particular, the peripheral vessels	[C4]
Visualization of the spine through the heart	[C5]
Visualization of the retrocardical lung and the mediastinum	[C6]
Clear visual reproduction of the trachea and proximal bronchi	[C7]
Sharp visual reproduction of the heart borders and aorta	[C8]
Visually sharp reproduction of the diaphragm and lateral costophrenic angles	[C9]
Reproduction of the entire rib cage above the diaphragm	[C10]

RESULTS

The mean results for image quality (IQ) obtained with respective exposures employed in the different techniques (protocols) are as shown in figure 1 and 2, respectively. It is clear from the results (Figure 1) that C1 C3 assessment appeared to be independent of the technique used as they are not usually very dependent on exposure (mAs).

Average within reader variability was below 10% (8.0 ± 2.5% and 7.1 ± 5.1% for both assessors, respectively). This implied that individual assessors were consistent in their assessment of images over the two sessions. A very good agreement was found between the readers with a Fleiss Kappa value of 0.86 (Mean SE_{Fleiss} 0.10) at $P < 0.05$.

The results of image quality obtained were found to be the same for the Techniques 1 (Control) and T2, (tests with 20% mAs reduction). The overall image quality score (OIQS) of 75 ± 3.5 and 76.0 ± 3.5 percent were obtained for T1 and T2 radiographs, respectively. While the OIQS for T3 was 85.2 ± 3.2 (Figure 2). A Mann-Whitney test of differences confirmed no differences at $P = 0.87$ for image quality between T1 and T2. However, images obtained with the 50% mAs reduction (T3) were found to be significantly different ($P < 0.05$) from those of T1.

Per image criterion performance for the individual image quality criteria used in the assessment, presented in Figure 2, shows that radiographs produced with T3 protocol recorded higher image scores in all cases (C4-C10).

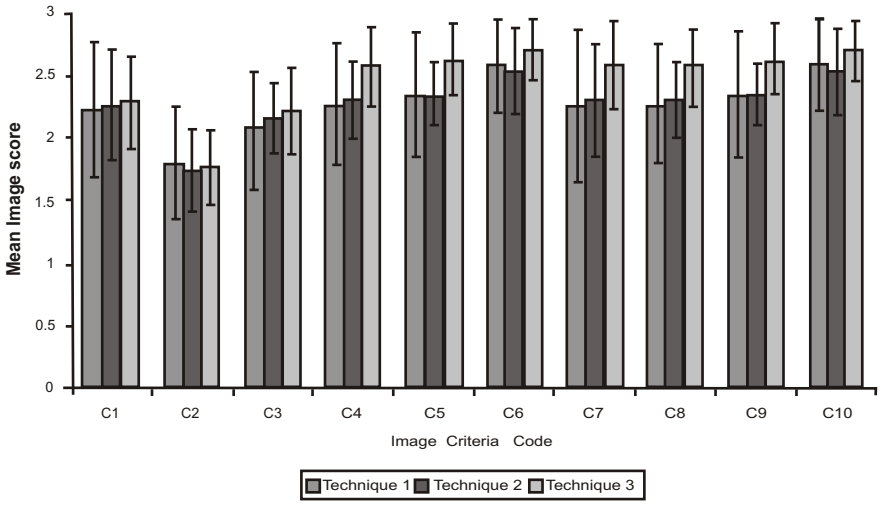

Figure 1: Mean image score per criterion assessed for the three techniques employed in the study. Error bars indicate 1 standard deviation from the mean.

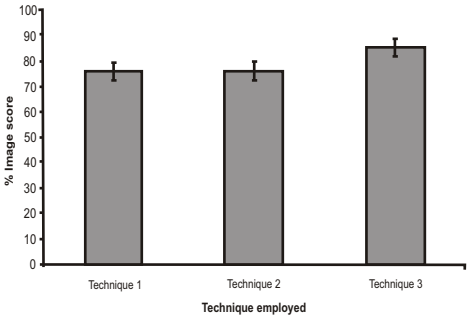

Figure 2: Percentage overall image score for the three exposure protocols used. Error bars are 1 standard deviation from the mean values.

DISCUSSION

Medical radiography doses for chest radiography have been reduced to more than fifty percent of what they were over twenty years ago in the United Kingdom [4]. Current research focus has been on means and ways of implementing internationally acceptable good practice with respect to patient dose reduction with acceptable image quality [5,8,13]. The adoption and implementation of similar research results in clinical radiography practice has not been reported in Nigeria.

Studies have revealed a pattern of poor and average results in radiology service delivery (with respect to patient doses and image quality, respectively) due largely to the lack of quality assurance (QA) programmes in many radiology centers in the country [14-16].

This is without prejudice to the efforts of regulatory bodies like the Radiographers Registration Board of Nigeria and the Nigerian Nuclear Regulatory Authority towards achieving this. It may seem that such efforts have not reached the end users of the regulations. The results obtained in this study suggest that dose-image quality optimization with dose savings for the patient is achievable in a Nigerian tertiary health institution.

Average observer result in the current study has shown that there was improved observer perceptibility of image quality criteria assessed as mAs was reduced to 50% of the T1 (control protocol) value. This result was achieved with a negligible increase in kVp values used, and may be suggestive of the fact that for the same average kVp, a 50% reduction in mAs will not produce a loss in image quality [5].

The implication of the results in this study in the radiation protection of the patient is obvious. Dose savings by mAs reduction is cost free, easy to practice and can be taken on by all operators of x-ray diagnostic facilities. However, the applicability of these results to other radiographic projections and with several x-ray facilities need to be explored.

CONCLUSION

The foregoing shows that within the limits of the study, dose reduction can be achieved without loss in image quality in PA chest radiography when the exposure factor of tube current and time (mAs) are reduced by 50% of their original value. These results illustrate a cost free dose, saving technique which can be easily employed for patient dose reduction in Nigerian radiology centers.

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