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THE USE OF THE EXTENDED FILM-FOCUS DISTANCE TECHNIQUE FOR DOSE REDUCTION: EXAMINATION OF THE THORACIC (RIB) CAGE

Physics

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ABSTRACT

Aim: The technique of extended Film-Focal Distance (FFD) on chest radiographs was used to determine the optimum FFD and dose parameters to ensure safe radiological practices according to the ALARA principle, without compromising the image quality which is required by the Radiologists to accurately interpret and conclude the diagnosis from Chest X-Ray (CXR) films.
Materials and methods: PHILIPS MCD-105 mobile portable X-Ray machine with a maximum voltage of 105 kVp was used in this study. AGFA X-ray films were used to obtain all the chest radiographs. A perspex phantom was constructed to house the rib cage of a human adult obtained from the anatomy laboratory. The whole phantom arrangement was to simulate the chest part of an adult human. The phantom was exposed five times maintaining a constant voltage of 70 kV and tube load of 10 mAs by varying the FFDs at 110, 120, 130, 140, and 150 cm. A RaySafe Thin-X RAD dosemeter was used to determine the input and output radiation doses during each exposure at varying FFD values.
Results and Discussion: The maximum value of the absorbed dose recorded in this study was 335 µGy at FFD 110 cm and this value kept decreasing with increasing FFDs with its lowest value at FFD at 150 cm, which is 222 µGy. This confirms that FFD has a significant effect on the dose delivered according to inverse square law on chest X-ray examinations.
Conclusion: Even though the radiograph at FFD 150 cm had the best contrast of them all due to low exposure but the radiograph at FFD 140 cm is found to give the optimum image quality with a dose even lower than the internationally accepted maximum value.

KEYWORDS

Film-Focal Distance (FFD); Chest X-Ray (CXR); rib cage; absorbed dose; Radiology department; RaySafe Thin-X RAD Dosemeter.

INTRODUCTION

Chest X-Ray (CXR) examinations are frequently performed in many Radiology departments for the diagnosis of diseases and injuries. [1,2]. Although one of the most critical investigations for identifying many illnesses, chest radiography accounts for 30% to 40% of all undertaken radiographs. As a result, image quality and radiation dosage optimization are important topics of research [3-5]. In many countries of the world, CXR has become an essential part of routine medical examination for either admitting students into schools of higher learning and appointments of staff for jobs or normal routine medical checkups of individuals for health fitness [6]. Recently CXR has been seen as an important imaging modality alongside lung ultrasound in the diagnosis of neonatal lung diseases among others such as rib cage pain (rib cage fracture), Acute heart failure, Pneumonia, the recent Covid-19 virus etc., [7-11]

According to recent research, there is an unprecedented rise in or rising worry among patients and Radiologists that extremely high radiation levels are being supplied during routine X-ray examinations. This means that after an examination has been justified, the imaging method must be improved by ensuring that the given radiation dosage is as low as reasonably achievable (ALARA) and consistent with a high diagnostic quality image. However, doing so would accomplish the examination's clinical goal while posing the least amount of risk to the patient [12]. With the development of digital systems, there is the possibility to increase image quality while lowering radiation dose; however, to do so, technical factors must be modified to obtain high-quality X-ray images [3,13,14]. The problem is to determine the appropriate parameters to minimize the effective dose to the patient while also giving a high-quality image to make the best possible diagnosis, as outlined in the "as low as reasonably achievable" (ALARA) principle [15,16].

For many years, the dangers of ionizing radiation have been recognized, and the levels and risks associated with high doses (nuclear explosions and therapeutic usage) have been well established. The hazards from the much lower levels observed in diagnostic Radiology has been more difficult to assess. However, there is no safe amount of exposure beyond which detrimental effects cease to occur, necessitating the use of all available strategies to minimize the dose as much as possible without degrading the quality of the radiographs [12].

A variety of dose-reduction strategies have been studied. Rare-earth filters, quick film-screen combinations, and low attenuation materials in cassettes are examples of these. Although research has shown the efficiency of these and other strategies for reducing exposure, there are typically economic consequences for imaging departments, and the ensuing applicability appears limited in the current atmosphere of finite resources. As a result, it's critical to think about dose-reduction strategies that don't require a lot of resources [12].

Only when the image quality of the radiograph is confirmed is a patient dose evaluation representative. Direct inspection by a Radiologist, who provides ratings to radiographs based on image quality standards described in the literature, is one method of analyzing the image. For member countries, the European Community (EC) has established image quality guidelines in diagnostic Radiology; the idea of keeping radiation doses as low as reasonably possible is observed [17]. The EC criteria also laid the groundwork for correct medical interpretation of radiographic images, and they've been used to evaluate radiological clinics and hospitals all around the world [18-21]

This research aims to ensure better service delivery through patient dose reduction in chest X-ray in the radiology department of Skane Radiodiagnostic Centre/Hospital Nig. Ltd. Jos, Plateau State, Nigeria contributing to the health of all patients coming to the department for chest X-ray examination and help globally, especially those using a similar type of X-ray machines to have a good practice through reducing patient dose and also to provide clear and qualitative radiographs for the Physician's diagnosis.

METHODS

X-ray machine: A PHILIPS MCD-105 mobile portable X-Ray

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machine with a maximum voltage of 105kVp was used in irradiating the phantom. The manufacturer of the machine is Philips Manufacturing Company in Japan with serial number 8814771. The films were AGFA films manufactured by a Belgium Company in Belgium having dimensions as 14x14cm and 17x14cm. The phantom was exposed five times maintaining a constant voltage of 70 kVp and tube load of 10 mAs varying the FFDs at 110, 120, 130, 140, and 150 cm. The exposed films were processed and dried using standard techniques.

Perspex Phantom: A rectangular perspex phantom was constructed with dimensions as 29cm x 20cm x 56cm in length, width, and height respectively. The whole arrangements were made to simulate the chest part of an adult human. The ribcage was fixed in position in the phantom and made to be stable to avoid floating because the phantom was filled with water to cover the bones completely which simulates human tissue.

Rib Cage: The specimen (rib cage) used was an adult human rib cage that was carefully selected from the Anatomy Department, Faculty of Medicine, University of Jos, Plateau State, Nigeria. It was selected out of the specimens used in teaching Medical Students.

RaySafe ThinX Dosemeter: A RaySafe ThinX dosemeter was used to measure the exposure doses. It was placed at the central point on the entrance surface corresponding with the central ray on the phantom and exposed to x-rays. It is an easy tool for fast results and has been optimized to meet the need for a basic multi-parameter instrument for simultaneous measurement of dose, dose rate, kVp, HVL, exposure time and pulses. All parameters were conveniently displayed in the large LCD.

Fig. 1. RaySafe ThinX Dosemeter

Image Quality Assessment

An evaluative panel of three-experienced clinicians (two Consultant Radiologists and one Radiographer) was used to assess the radiographs.

The image quality assessment was formulated using European Guideline on Quality criteria for Diagnostic Image for Analytical Criteria, (CEC guidelines, 1996). The anatomical criteria were based on subjective scoring by two Consultant Radiologists and one Radiographer from the Department of Radiology, Jos University Teaching Hospital (JUTH), Jos, Nigeria, Bingham University Teaching Hospital (BUTH), Jos, Nigeria, and University of Jos Health Centre respectively. The criteria were based on visually sharp reproduction of spaces between the ribs (intercostal space), spinal column, pedicles, vertebral bodies (joints), and lung fields.

A radiograph demonstrating perfect visualization was used as a reference image [22]. All images were examined using constant illuminator and ambient light conditions throughout the study, time and observer, film distance was unrestricted, and all images were assessed blindly [12].

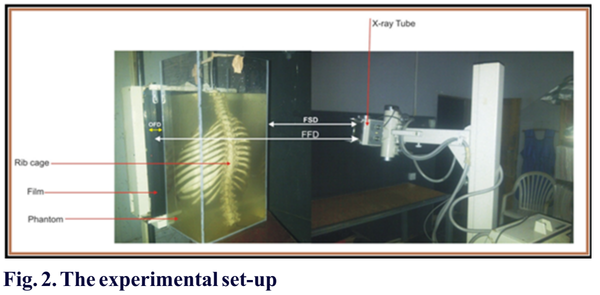

Fig. 2. The experimental set-up

Calculation of the doses absorbed by the thoracic cage

The absorbed dose was simply obtained through the absorbed dose definition as done by [23].

Absorbed dose = input dose – output dose (i.e., differences between the input and output dose)

$A_d = I_d - O_d$

Where:

A_d = Absorbed dose

I_d = Input dose

O_d = Output dose

RESULTS

The three expert's assessments indicated that the radiographs at FFD 110, 120 and 130 cm appeared darker, and it was because of very high exposures which translated to much penetration of the images of the rib cage. While the radiograph at FFD 150 cm had the best contrast which is due to low exposure. However, according to the experts, the radiograph at FFD 140 cm gave the optimum image quality. That showed that the quality of the film was perfect indicating that all the bones of anatomical interest were seen and present.

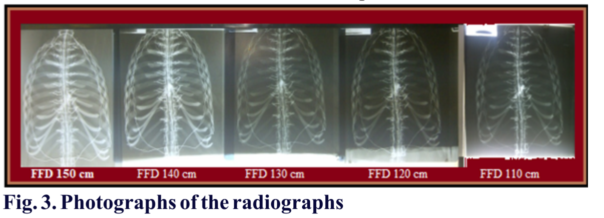

Fig. 3. Photographs of the radiographs

Table 1 shows the results obtained for input and output doses of the phantom at constant kVp and mAs of 70 and 10 respectively. The result showed a decrease in both the input and output doses with an increase in FFD.

The maximum values were recorded for the input and output doses at 558 and 223 µGy respectively and the lowest values obtained are consistent with the inverse square law.

Table 2 shows the relationship between the absorbed dose and increasing FFD. The maximum value of absorbed dose recorded in this work is 335 µGy at FFD 110 cm and this value kept decreasing with an increase in FFD with its lowest value at FFD 150 cm which is 222 µGy. Now checking the columns for absorbed dose and FFDs, it is seen that lower doses are obtained with an increase in FFD. This indicated the importance of increasing FFD on the overall dose absorbed by patients.

Table 1: Reduction In Dose Due To Increase In Film-focus Distance (ffd)

FFD (cm)	Input Dose (µGy)	Output Dose (µGy)
110	558	223
120	458	175
130	365	95
140	317	79
150	253	31

Table 2: Reduction In Absorbed Dose Due To Increase In Film-focus Distance (ffd)

FFD (cm)	Input Dose (µGy)	Output Dose (µGy)	Absorbed Dose (µGy)
110	558	223	335
120	458	175	283
130	365	95	270
140	317	79	238
150	253	31	222

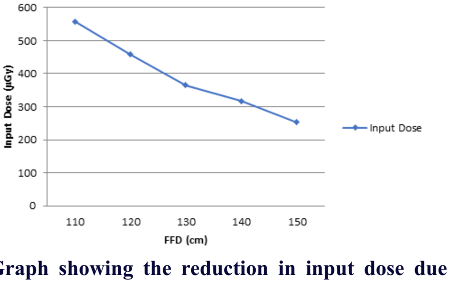

Fig. 4. Graph showing the reduction in input dose due to an increase in Film-Focus Distance (FFD)

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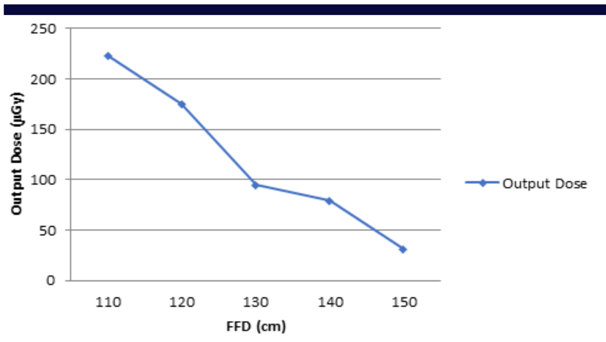

Fig. 5. Graph showing the reduction in Output dose due to increase in Film-Focus Distance (FFD)

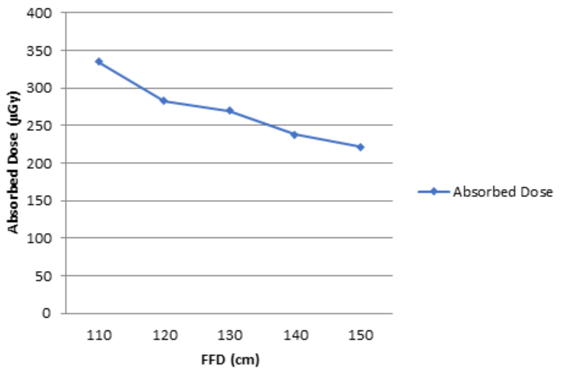

Fig. 6. Graph showing the reduction in Absorbed dose due to an increase in Film-Focus Distance (FFD)

DISCUSSION

Figure 4 clearly shows the reduction in input dose due to the increase in Film-Focus Distance (FFD). The input dose has its maximum value as 558 μGy corresponding to the least FFD of 110 cm and its minimum value as 253 μGy corresponding to the maximum FFD of 150 cm, meaning that distance has a significant effect on the dose delivered to any patient on x-ray examination.

Figure 5 also shows the reduction in output dose due to the increase in Film-Focus Distance (FFD). The output dose has its maximum value as 223 μGy corresponding to the minimum FFD value of 110 cm with its minimum value as 31 μGy corresponding to the maximum FFD of 150 cm which means that distance has a significant effect on the dose delivered to any patient on x-ray examination.

Figure 6 shows the reduction in absorbed dose due to the increase in Film-Focus Distance (FFD), as the FFD was being increased, the corresponding absorbed doses were seen to be decreasing, with maximum absorbed dose as 335 μGy corresponding to the least FFD of 110 cm meaning that distance has a tremendous effect on the dose delivered to any patient on x-ray examination.

From the analysis of the three figures (figures 4, 5, and 6) distance has been seen as a tremendous factor affecting the doses delivered to anyone on X-ray examination which has its prove on the radiation protection principles as time, distance and shielding. Time, distance, and shielding actions minimize your exposure to radiation in much the same way as they would protect you against overexposure to the sun. Just as the heat from a fire reduces as you move further away, the dose of radiation decreases dramatically as you increase your distance from the source.

CONCLUSION

The assessors reported that the radiographs of FFD 110, 120 and 130 cm appeared darker, and it was because of very high exposures which translated to much penetration of the images of the rib cage. While the radiograph at FFD 150 cm had the best contrast it is due to low exposure. However, the best radiograph according to them is that of FFD 140 cm which showed clearly all the bones of anatomical interest. Converting the absorbed dose of FFD 140 cm which is 238 μGy to mGy is 0.238 mGy.

The standard value by [24, 25, 26] and the British Journal of Radiology, 1997, is 0.300 mGy, which shows that the result is valid since the absorbed dose for the FFD 140 cm is lower than the standard value. This means that lesser doses will be delivered to patients with good image quality if 140 cm FFD is maintained and setting the voltage to 70 kVp and tube load to 10 mAs.

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