Original Article

PATIENTS EXPOSURE AND IMAGING QUALITY IN CHEST RADIOGRAPHS: A CRITICAL EVALUATION*

Adelaja Otolorin Osibote[1], Ana Cecília Pedrosa de Azevedo[2], Antonio Carlos Pires Carvalho[3], Helen Jamil Khoury[4], Sergio Ricardo de Oliveira[5], Marcos Otaviano da Silva[6], Carla Marchon[7]

Abstract **OBJECTIVE: Entrance skin dose, effective dose, and imaging quality in chest radiographs of adult patients have been evaluated. MATERIALS AND METHODS: The study has been developed in eight institutions — seven public hospitals (two of them philanthropic institutions) and one private — in the cities of Agra dos Reis, Cabo Frio, Campos dos Goytacazes, Itaperuna, Niterói, Recife and Rio de Janeiro. Entrance skin dose and effective dose have been evaluated in 735 chest radiographs obtained in posteroanterior/anteroposterior and lateral projections. As regards imaging criteria, 44 radiographs have been evaluated. RESULTS: Variations of up to nine times in entrance skin dose, and six times in effective dose have been detected for a same type of projection. Also, significant discrepancies have been found in values resulting from radiographic techniques employed. Besides, imaging quality has not been good since the rate of compliance with imaging criteria was only 55%. CONCLUSION: There is a pressing need for improvement/standardization of procedures in conventional radiology; this can be achieved by implementing a quality control and assurance program in the department of radiology, including training of technicians, x-ray equipment calibration, and sensitometric control of films processors.**
Keywords: Chest x-ray; Quality control; Dosimetry.

Resumo *Exposição de pacientes e qualidade da imagem em radiografias de tórax: uma avaliação crítica.*
OBJETIVO: Foi realizada avaliação da dose de entrada na pele, da dose efetiva e da qualidade da imagem em radiografias de tórax de pacientes adultos. MATERIAIS E MÉTODOS: O estudo realizou-se em oito hospitais, sendo sete públicos (dois filantrópicos) e um particular nos municípios de Angra dos Reis, Cabo Frio, Campos dos Goytacazes, Itaperuna, Niterói, Recife e Rio de Janeiro. Foram avaliadas a dose de entrada na pele e a dose efetiva de 735 radiografias de tórax nas incidências póstero-anterior/ântero-posterior e perfil. No que se refere aos critérios de imagem, foram avaliadas 44 radiografias. RESULTADOS: Constatou-se variação de até nove vezes nos valores da dose de entrada na pele e de até seis vezes na dose efetiva para um mesmo tipo de projeção. Os valores das técnicas radiográficas também apresentaram grandes discrepâncias. A qualidade das imagens também não é boa, pois foi obtido valor médio de presença dos critérios de apenas 55%. CONCLUSÃO: Há necessidade de melhoria/padronização de procedimentos em radiologia convencional, o que pode ser atingido se for implantado um programa de controle e garantia de qualidade no setor de radiologia, incluindo o treinamento dos técnicos, a aferição do desempenho dos equipamentos emissores de radiação e o controle sensitométrico do sistema de processamento radiográfico.
Unitermos: Radiografia torácica; Controle de qualidade; Dosimetria.

INTRODUCTION

Medical clinics and hospitals which utilize ionizing radiation have been searching to be in compliance with the radiological protection and quality control requirements of the Order (Portaria) No. 453/98 "Diretrizes de proteção radiológica em radiodiagnóstico médico e odontológico" ("Radiological protection guidelines in medical and odontological radiodiagnosis"), published in 1998 by the Ministry of the Health – National Sanitary Vigilance Agency[(1)].

In the states of Rio de Janeiro and Pernambuco, several hospitals and clinics have been the target of academic researches in the field of radiological protection and quality control in diagnostic radiology. These studies are coordinated by the Group of Radiological Protection and Quality Control of Fundação Oswaldo Cruz – Escola Nacional de Saúde Pública Sergio Arouca – CESTEH, and Group of Dosimetry and Instrumentation of Universidade Federal de Pernambuco Department of Nuclear Energy.

This study presents the partial results of the interaction between these two institutions, with a evaluation of doses and images quality in chest x-rays performed in

* Study developed at Fundação Oswaldo Cruz (Fiocruz), Rio de Janeiro, RJ, Brazil.

1. Physicist, Doctorship Student, Fundação Oswaldo Cruz (Fiocruz), Escola Nacional de Saúde Pública Sergio Arouca-CESTEH, Rio de Janeiro, RJ, Brazil.
2. PhD in Physics, Fundação Oswaldo Cruz (Fiocruz), Escola Nacional de Saúde Pública Sergio Arouca-CESTEH, Centro de Vigilância Sanitária da Secretaria de Estado de Saúde do Rio de Janeiro, Rio de Janeiro, RJ, Brazil.
3. MD, PhD in Medicine, Department of Radiology at Faculdade de Medicina da Universidade Federal do Rio de Janeiro (UFRJ), Rio de Janeiro, RJ, Brazil.
4. PhD in Physics, Department of Nuclear Energy at Universidade Federal de Pernambuco (UFPE), Recife, PE, Brazil.
5. Physicist, Doctorship Student, Fundação Oswaldo Cruz (Fiocruz), Instituto Oswaldo Cruz, Rio de Janeiro, RJ, Brazil.
6. Physicist, Doctorship Student, Fundação Oswaldo Cruz (Fiocruz), Escola Nacional de Saúde Pública Sergio Arouca-CESTEH, Centro de Vigilância Sanitária da Secretaria de Estado de Saúde do Rio de Janeiro, Rio de Janeiro, RJ, Brazil.
7. MD, Service of Radiology at Hospital da Força Aérea do Galeão, Rio de Janeiro, RJ, Brazil.
Mailing address: Dra. Ana Cecília Pedrosa de Azevedo. Fundação Oswaldo Cruz (Fiocruz), Escola Nacional de Saúde Pública Sergio Arouca-CESTEH. Rua Leopoldo Bulhões, 1480, Manguinhos. Rio de Janeiro, RJ, Brazil, 21041-210. E-mail: acpa@ensp.fiocruz.br

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eight hospitals in seven cities in the states of Rio de Janeiro and Pernambuco.

MATERIAL AND METHODS

This study was developed in eight hospitals in the following cities: Angra dos Reis, Cabo Frio, Campos dos Goytacazes, Itaperuna, Niterói, Recife and Rio de Janeiro. These hospitals are randomly denominated A, B, C, D, E, F, G e H.

Entrance skin dose (ESD) and effective dose (ED) were evaluated in 520 posteroanterior/anteroposterior (PA/AP) and 215 lateral chest x-rays of adult patients. A parallel critical analysis of images quality was made in 44 x-ray films, adopting the European guidelines on quality criteria for diagnostic radiographic images of the Commission of European Communities[2].

1. Doses calculation

Aiming at speeding up the process of patient dose measurement a software called DoseCal, running on Windows platform was employed[3]. The DoseCal software[4] calculates the ESD, the body organ dose (BOD), and the ED, based on values of the radiographic technique employed, the x-ray tube output, and the patients' anthropometric data. The DoseCal software has been developed in the Radiological Protection Center at Hospital Saint Georges (London) and plays an essential role in the evaluation of radiation doses for a great number of patients. This software has been kindly provided for the present project in Brazil.

For a correct operation of the software, it is necessary to enter the x-ray tube output in mGy/mAs; this data may be easily obtained with a calibrated ionization chamber. In the present study, we have utilized a Nero 8000-Inovision and a Radcheck Plus 06-526. Once output values, current, kilovoltage, exposure time and focus-skin distance (FSD) are known, the following equation (1) will demonstrate the ESD.

$$ESD = Output \times \left(\frac{kV}{80}\right)^2 \times \left(\frac{100}{FSD}\right)^2 \times \times mAs \times BSF \qquad (1)$$

where: Output is the x-ray tube performance expressed in mGy/mAs, at 80 kV, and at a distance of 1 m normalized for 10 mAs; kV is the potential applied to the tubr (in kilovolts); mAs is the product from current × exposure time; FSD is expressed in centimeters (cm); and BSF is the backscatter factor. The DoseCal software utilizes the conversion factors included in tables NRPB-SR262[5] applied for ESD, BOD and ED calculations.

2. Images criteria

Based on the premise that "the best image will provide a better diagnosis" the European Union has formed a commission to develop quality criteria for diagnostic radiographic images. Other criteria such as general principles associated with good imaging performance and guidelines on radiation dose to the patient have been included. The most recent version of this document[2] was published in 1996 (EUR 16260 EN-European Guidelines on Quality Criteria for Diagnostic Radiographic Images), including criteria for imaging the chest, skull, lumbar spine, pelvis, urinary tract, and breast. These criteria were basically defined considering or not the presence of anatomical structures of the focused region, as well as their visualization degree. The criteria are the following: visualization — anatomical characteristics are detected but are not totally reproduced; reproduction — anatomical detials are identified, but are not clearly defined; visually sharp reproduction — anatomical details are clearly defined.

The images criteria for chest in PA/AP and lateral projections, according to the European Communities, are shown on Table 1.

RESULTS

The Table 2 includes the statistics (mean, first and second quartiles) of ESD (in mGy) in PA/AP and lateral chest x-rays. It may be oserved that, on PA/AP projections, mean values range between 0.07 mGy (hospitals E and H) and 0.64 mGy (hospital C) (mean value, 0.24 mGy). Values on lateral projection ranged between 0.14 mGy and 1.02 mGy (mean value, 0.47 mGy). As regards ED, values ranged between 0.01 mSv (hospitals B, D, E and H) and 0.06 mSv (hospital C) (mean value, 0.03 mSv) for PA/AP projections, and between 0.01 mSv and 0.7 mSv (mean value, 0.2 mSv) on lateral projections.

Table 3 and Figure 1 show values of radiographic techniques employed and patients' anthropometric data. Mean kilovoltage values ranged between 70 kV (hospitals B and C) and 93 kV (hospital E) (mean value, 78 kV) on PA/AP projections. On

Table 1 European Commission images criteria for diagnostic radiographic chest images in PA/AP and lateral projections.

Chest – PA/AP
1 – Performed at full inspiration (ten posterior ribs) and under apnea
2 – Symmetrical reproduction of the chest, without rotation or basculation
3 – Medial border of the scapulae to be outside the lung fields
4 – Reproduction of the whole rib cage above the diaphragm
5 – Visually sharp reproduction of the pulmonary vascularization (mainly the pheripheral vessels)
6 – Visually sharp reproduction of the trachea and proximal portion of bronchi
7 – Visually sharp reproduction of the diaphragm and lateral costo-phrenic angles
8 – Visually sharp reproduction of the heart and aorta
9 – Visualization of the retrocardiac lung and the mediastinum
10 – Visualization of the spine through the heart shadow
Chest – Lateral
1 – Performed at full inspiration and under apnea
2 – Arms should be raised clear of the chest
3 – Overlapping of the posterior lung borders
4 – Reproduction of the trachea
5 – Reproduction of the costo-phrenic angles
6 – Visually sharp reproduction of the posterior border of the heart, aorta and mediastinum
7 – Visually sharp reproduction of the diaphragm, sternum and thoracic spine

Table 2 Statistics (mean, first and second quartiles) of ESD and ED on PA/AP and lateral projections, for the eight hospitals.

Projection	PA/AP	Lateral
	Hospital A	
Mean (ESD [mGy])	0.36	—
First quartile	0.20	—
Second quartile	0.54	—
Number of x-ray films	55	—
ED (mSv)	0.04	—
	Hospital B	
Mean (ESD [mGy])	0.13	—
First quartile	0.06	—
Second quartile	0.18	—
Number of x-ray films	79	—
ED (mSv)	0.01	—
	Hospital C	
Mean (ESD [mGy])	0.64	—
First quartile	0.38	—
Second quartile	0.86	—
Number of x-ray films	8	—
ED (mSv)	0.06	—
	Hospital D	
Mean (ESD [mGy])	0.09	—
First quartile	0.08	—
Second quartile	0,10	—
Number of x-ray films	58	—
ED (mSv)	0.01	—
	Hospital E	
Mean (ESD [mGy])	0.07	0.14
First quartile	0.04	0.11
Second quartile	0.06	0.15
Number of x-ray films	17	13
ED (mSv)	0.01	0.01
	Hospital F	
Mean (ESD [mGy])	0.37	1.02
First quartile	0.27	0.77
Second quartile	0.45	1.20
Number of x-ray films	142	61
ED (mSv)	0.04	0.70
	Hospital G	
Mean (ESD [mGy])	0.19	0.54
First quartile	0.15	0.43
Second quartile	0.21	0.61
Number of x-ray films	66	61
ED (mSv)	0.02	0.05
	Hospital H	
Mean (ESD [mGy])	0.07	0.18
First quartile	0.02	0.08
Second quartile	0.10	0.20
Number of x-ray films	95	80
ED (mSv)	0.01	0.02

Table 3 Mean values for radiographic techniques employed in the eight hospitals, and average anthropometric data of patients.

Projection	PA/AP	Lateral
	Hospital A	
kV	80	—
mAs	12	—
Focus-film distance (cm)	121	—
Patient's age (years)	44	—
Patient's weight (kg)	66	—
	Hospital B	
kV	70	—
mAs	15	—
Focus-film distance (cm)	124	—
Patient's age (years)	44	—
Patient's weight (kg)	67	—
	Hospital C	
kV	70	—
mAs	36	—
Focus-film distance (cm)	120	—
Patient's age (years)	46	—
Patient's weight (kg)	62	—
	Hospital D	
kV	79	—
mAs	5	—
Focus-film distance (cm)	160	—
Patient's age (years)	51	—
Patient's weight (kg)	76	—
	Hospital E	
kV	93	95
mAs	3	7
Focus-film distance (cm)	150	144
Patient's age (years)	51	50
Patient's weight (kg)	65	65
	Hospital F	
kV	73	85
mAs	15	24
Focus-film distance (cm)	121	109
Patient's age (years)	47	47
Patient's weight (kg)	66	66
	Hospital G	
kV	83	95
mAs	8	16
Focus-film distance (cm)	162	157
Patient's age (years)	52	53
Patient's weight (kg)	63	63
	Hospital H	
kV	75	85
mAs	5	11
Focus-film distance (cm)	151	153
Patient's age (years)	46	46
Patient's weight (kg)	68	68

lateral projections, values ranged between 85 kV and 95 kV (mean value, 90 kV). As regards milliamperage, values ranged between 3 mAs (hospital E) and 36 mAs (hospital C) (mean value, 12 mAs) on PA/AP projections. On lateral projections, the values ranged between 7 mAs and 24 mAs (mean value, 15 mAs). The FSD ranged between 120 cm (hospital C) and 162 cm (hospital G) (mean value, 139 cm) on PA/AP projections. On the lateral projections, values ranged between 109 cm and 157 cm. Patients' mean age was 48 years for PA/AP projections, and 49 years for lateral projections. Mean weight was 67 kf for PA/AP and lateral projections.

As regards image criteria, the results are shown on the Table 4 and Figura 2. The criteria with highest compliance rates were criterion 8 present in 97% of x-ray studies, and criterion 9, in 94%, both for PA/AP projections. On the other hand, criterion 6 (for both projections), and criterion 7 (for lateral projection) were absent in all the images.

DISCUSSION

ESD values demonstrate high variation among the hospitals evaluation. A difference of more than nive times was found in ESD values, and more than six times in ED values. These differences reflect the disparity of radiographic techniques employed in each institution. It is possible to observe that hospital C, with highest ESD value (0.64 mGy), was the one utilizing the lowest mean kilovoltage (70 kV) and highest

Table 4 Rate of presence of imaging criteria in PA/AP and lateral projections.

	Projection	
Criterion	PA/AP	Lateral
Criterion 1	72	87
Criterion 2	39	87
Criterion 3	30	37
Criterion 4	61	87
Criterion 5	75	25
Criterion 6	0	0
Criterion 7	75	0
Criterion 8	97	—
Criterion 9	94	—
Criterion 10	89	—
Number of x-ray films	36	8

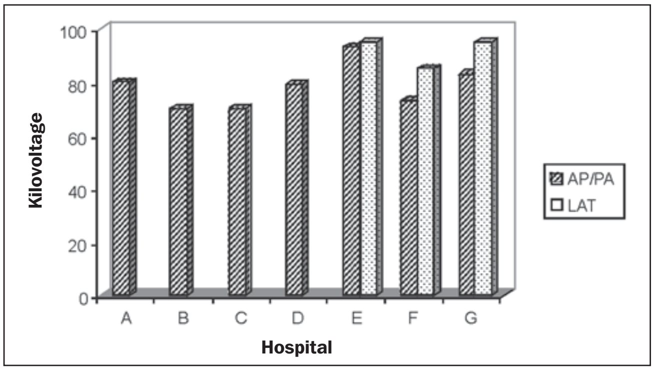

Figure1. Mean kilovoltage employed in the studied hospitals for PA/AP and lateral chest x-rays.

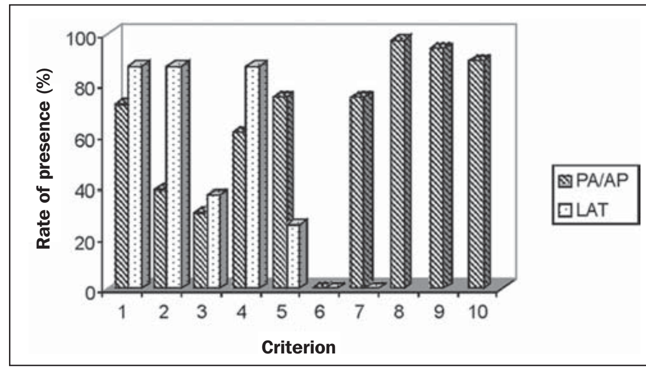

Figure 2. Rate of presence of image quality criteria on the evaluated x-ray films.

milliamperage (36 mAs). Additionally, hospital C employs an extremely low focus-film distance (120 cm). These factors contribute for an increase in the radiation dose to patient.

Several factors also contribute for the variation of doses; the most significant are: technicians training, system of radiographic films processing, the luminance of the negatoscope utilized for images evaluation and x-ray beam filtration.

As regards images quality criteria, the criterion 6 in PA/AP projections ("Visually sharp reproduction of trachea and proximal portion of bronchi") was absent in all of the images, indicating the impossibility of a visally sharp reproduction of this region in these projections. Also, criterion 6 in lateral projection ("Visually sharp reproduction of the llposteiror border of the heart, aorta and the mediastinum") could not be detected in any of the images. The criterion 7 ("Visually sharp reproduction of the diaphragm, sternum and thoracic spine"), for lateral projection, also was not present in any of the images analyzed. The mean rate ofpresence of criteria was 55% (63% for PA/AP projections, and 46% for lateral projection).

Also, based on data, it could be observed that on PA/AP chest x-rays, the criteria 2 and 3 presented the lowest rate of presence. These criteria refer to the symmetrical reproduction of the chest and medial border of the scapulae to be outside of the lung fields, and therefore, to the patient positioning. This reuslt demonstrate the relevance of the necessity of technicians qualifying.

CONCLUSION

The doses standardization/reduction may be achieved by means of easy-to-implement (almost always very simple) measures. These measures should be included in a program of quality control and assurance to be implemente in every service of diagnostic radiology. The appropriate training of technicians, the x-ray equipment and automatic films processor performance, as well as the employment of high kilovoltage techniques may be extremely useful for reduction of radiation dose to patients and obtention of high quality images.

As regards the quality criteria established by the European Communities, certainly a x-ray in compliance with all the criteria will result in a better diagnosis. Basically, a good x-ray film depends on an adequate training of the technician, who, in the absence of a radiologist, must be able to decide whether the image is adequate or not. This will be easier if the image criteria are known. The mean rate of presence of the European criteria on the images in the present study (55%) demonstrates that maybe such images have not the quality required for a more reliable and adequate diagnosis.

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