Optimization of pediatric chest radiographic images using optical densities ratio

Otimização de imagens radiográficas de tórax pediátrico utilizando a razão de densidades ópticas

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Abstract

The aim of this study is the optimization of radiographic images for the pediatric patients in the age range between 0 and 1 years old, through Optical Density Ratio (ODR), considering that pediatric patients are overexposed to radiation in the repeated attempts to obtain radiographic images considered of good quality. The optimization of radiographic techniques was carried out with the RAP-PEPP (Realistic Analytical Phantom coupled to homogeneous Phantom Equivalent to Pediatric Patient) phantom in two incubators and one cradle. The data show that the clinical routine radiographic techniques generate low-quality images at up to 18.8% when evaluated by the ODRs, and increases in doses up to 60% when compared to the optimized techniques doses.

Keywords: optimization, phantom, dosimetry, image quality, pediatrics.

Resumo

O objetivo deste estudo é a otimização das imagens radiográficas para pacientes pediátricos na faixa etária de 0 a 1 anos de idade, através da razão de densidade óptica, considerando que pacientes pediátricos são superexpostos à radiação nas repetidas tentativas de se obter imagens radiográficas consideradas de boa qualidade. A otimização das técnicas radiográficas foi realizada com o fantoma RAP-PEPP (fantoma analítico realístico acoplado a um fantoma homogêneo equivalente ao paciente pediátrico), em duas incubadoras e um berço. Os dados mostram que as técnicas radiográficas de rotina clínica criam imagens de qualidade inferior em até 18,8%, quando avaliadas por razões de densidade óptica, e aumentam em doses de até 60% ao serem comparadas às doses das técnicas otimizadas.

Palavras-chave: otimização, fantoma, dosimetria, qualidade da imagem, pediatria.

Introduction

The process of optimization of pediatric radiographic images is part of an effective quality control program, which must be implemented in every institution that makes use of ionizing radiation[1,2].

This process have a great importance in the radiological protection context, keeping in view that pediatric patients are subjected to a lot of X-rays, depending on the conditions under which they are, as weight (between 750 g and 2000 g), gestational age (between 6 and 9 months), respiratory problems and other intrinsic conditions of the newborn[3].

Moreover, these patients are overexposed to radiation in the repeated attempts to obtain radiographic images considered of good quality[3]. It is important to point out that radiation exposure during the first 10 years of life presents a risk attributed to the lifetime (for radiation-induced biological effects, deterministic and stochastic) 3 to 4 times higher when compared with exposures between the ages of 30 and 40 years and up to 7 times higher when compared with adults aged over 50 years.

Thus, it is extremely necessary the standardization of radiographic techniques to conduct pediatric tests in order to obtain good quality images with doses as low as reasonably achievable[4,5].

In this context, the objective of this study is the optimization of radiographic images inserted in pediatric patients aged between 0 and 1 year old by Optical Density Ratio (ODR), following the ALARA (As low as reasonable

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achievable), which prioritizes the acquisition of radiographic images considered of good quality with doses as low as reasonably achievable.

Methodology

The process of validation of radiographic techniques (combinations of kVp and mAs) seeks to find the combination to be optimum, which is able to generate radiographic images of good quality. This process was accomplished with the RAP (Realistic Analytical Phantom) aid, that is aimed at assessing the quality of radiographic images[6].

The RAP, as illustrated in Figure 1, is a phantom consisting of realistic and analytical structures, which follows the recommendations of ICRU (International Commissions on Radiation Units and Measurements) Reports 44 and 48[7,8]. The analytical structures found in RAP are test objects that allow the quantification of the image quality produced by different kVp and mAs combinations.

This phantom consists of a PMMA (polymethylmethacrylate) plate with dimensions of 30cmx30cmx5 cm, in which the test objects are inserted: (A) five acrylic steps plus air gaps, simulating cavities; (B) five acrylic steps plus PVC, simulating bone structures; (C) four nylon spherical segments simulating tumours; (D) three nylon cylinders simulating fat tissue; (E) six aluminium spheres to determine the degree of visualization of the bone tissue boundaries; (F) four groups of human organic micro-calcification, simulating cortical bone grain with different sizes; (G) one resolution grid (0.1 mm Pb Nr 1000943 LP/mm; Nuc. Assoc. Carle Plate, N.Y-07-538); (H) 1/2 human thoracic vertebra; (I) two steel spheres separated by 0.80 cm for magnification analysis; and (J) one tin wire to determine the coincidence of light and radiation fields[6].
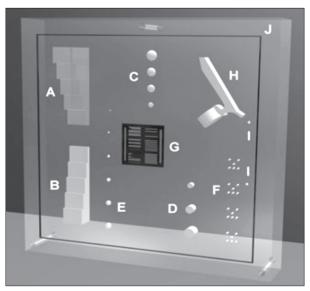
The process of optimizing radiographic techniques was carried out with the RAP-PEPP phantom, which is formed by coupling the RAP to the PEPP (homogeneous Phantom Equivalent to Pediatric Patient), as shown in Figure 2.

Figure 2 (A) illustrates the adaptation of the RAP to the PEPP. Table 1 shows the PEPP structure in the Anterior-Posterior (AP) projection. In this adaptation, the lower pair of PEPP was replaced by the RAP, which has the same equivalence in attenuation of the part that was replaced. The configuration of the posterior pair, referring to PEPP, was maintained original (thicknesses of PMMA and aluminum) for the simulation of the pediatric patient chest. Figure 2 (B) illustrates the RAP-PEPP coupled structure.

Quantitative analysis is performed using the parameter called Optical Density Ratio (ODR), which is calculated through the ratio between the optical densities of two distinct regions and interest in the images obtained with
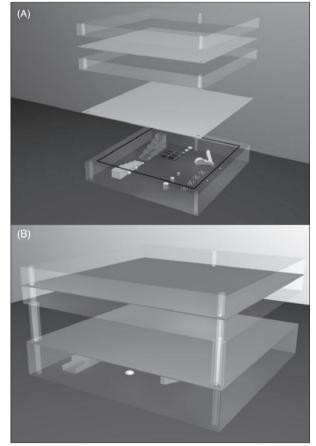

Figure 2. (A and B) Illustration of the RAP-PEPP structure used to obtain the radiographic techniques based on the quality of the acquired images.

Table 1. Thicknesses of PEPP material simulators, PMMA and aluminum (Al) in the Anterior-Posterior projection.

Top pair		Lower pair	
PMMA (mm)	Al (mm)	PMMA (mm)	Al (mm)
35.00	0.42	35.00	0.83

Figure 1. Schematic view of structures in the RAP.

the RAP-PEPP. For this study, we selected values of optical density (OD) for test objects designated by (A) and (B), represented schematically in Figure 1. The test object (A) represents the overlap of soft tissue and bone, which consists of steps with different amounts of PMMA and PVC. The test object (B) represents the overlap of soft tissue and air, simulating the interior of the chest, which consists of steps with different amounts of PMMA and air[9]. For this study, the steps with the greatest amount of PVC (test object A), air (test object B) and soft tissue (between test objects A and B) were chosen to simulate, respectively, the bone tissue, air inside the lungs and soft tissue that exist in the chest of a pediatric patient.

The ODRs were measured in two incubators, one manufactured by FANEM Vision and the other model manufactured by Isolette, and a cradle manufactured by FANEM (AQ 50 model), using a x-ray equipment manufactured by GE VMX Plus model, which has constant potential[10]. These devices belong to the Hospital das Clínicas da Faculdade de Medicina de Botucatu (UNESP-HCFMB).

It was further quantified the dose absorbed in the entrance surface. This was estimated from of the amount of exposure measured in air, on the phantom (RAP-PEPP) in the center of the useful beam of X-rays, using an electrometer (model 9015) and an ionization chamber (model 10X5-6), both manufactured by Radical Corporation. Measurements were made taking into account the backscattered radiation.

The association of the radiographic image with better quality and the absorbed dose in the entrance surface was considered as a figure of merit (FOM).

Results

Figures 3 and 4 present the results of quantification of the radiographic images quality by optical density ratio measurements in radiographic images with the RAP-PEPP phantom. The ODRs were evaluated between soft tissues and bone, and between soft tissue and air, for the incubators FANEM Vision and Isolette, and to the Cradle FANEM AQ 50, presented, respectively, in black, dark gray and light gray.
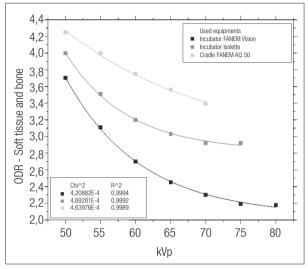

Figure 3. Optical Density Ratio measurements between soft tissue and bone as a function of the voltage applied to X-ray tube (kVp) were evaluated, respectively, for the incubators FANEM Vision (black), Isolette (dark gray) and Cradle FANEM AQ 50 (light gray).
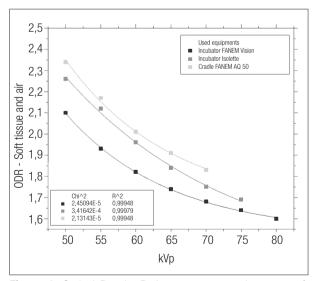

Figure 4. Optical Density Ratio measurements between soft tissue and air as a function of the voltage applied to X-ray tube (kVp) were evaluated, respectively, for the incubators FANEM Vision (black), Isolette (dark gray) and Cradle FANEM AQ 50 (light gray).

Table 2. Combinations between the voltage (kVp) and load (mAs) applied to X-ray tube, absorbed entrance surface doses of the RAP-PEPP (ESD) given in μGy, and the optical density ratio (ODR) obtained between bone and soft tissue (Bone-soft), and between the soft tissue and air (Air-soft), evaluated for optimized radiographic techniques in this study (Ot.) and techniques commonly used in the HCFMB-UNESP clinical routine (Rot.).

| | | kVp | mAs | ESD(μGy) | ODR | |
					Bone-soft	Air-soft
Incubator FANEM-Vision	Ot.	55	2.50	52.71	3.05	1.95
		60	1.25	82.57	2.70	1.84
	Rot.	66	2.50	131.6	2.41	1.73
		71	1.00	66.83	2.19	1.69
Incubator Isolette	Ot.	50	3.20	74.01	4.00	2.30
		60	1.00	42.17	3.20	2.05
	Rot.	57	3.20	112.2	3.22	1.93
		65	2.00	84.32	3.05	1.84
Cradle FANEM-AQ 50	Ot.	50	2.00	65.25	4.28	2.34
	Rot.	55	2.50	81.56	3.95	2.17
		60	2.00	84.35	3.78	2.02

The recommended optimal radiographic techniques were then compared with those normally applied in clinical routine of HCFMB-UNESP. These techniques were applied in the RAP-PEPP in order to quantify the image quality parameter using ODR. Table 2 presents the radiographic techniques obtained in this study and the techniques normally applied in clinical practice, which are obtained empirically and may vary by a factor of 10 between different diagnostic services specialist in pediatric patients[11].

Discussion and conclusions

The data presented in Table 2 show that radiographic techniques (combinations of kVp and mAs) used in HCFMB-UNESP routine clinical generate radiographic images with quality reduced by up to 18.8% and 13.7% when evaluated by the ODRs, respectively, between the soft tissues and bone, and between soft tissue and air. These reductions are due to higher effective energy of x-ray beam used, compared to the energies used in radiographic techniques optimized. It is worth emphasizing that the voltages applied to the optimized radiographic techniques have values below those recommended by the Commission of European Communities (between 60 and 65 kV)[12].

The doses used in clinical routine show also increased by 60% when compared to the doses applied by the optimized techniques. These last are still, mostly, below 80μGy, a value recommended by the Commission of European Communities on the exams for children[12].

The radiographic optimum techniques obtained using the RAP-PEPP has provided the acquisition of the figures of merit. The results of the image quality quantification showed that the figures of merit do not have the highest ODRs, but are obtained with voltages applied to the X-ray tube between 50 and 60 kVp and load in a range between 1-3 mAs.

Absorbed entrance surface doses show linear behavior with the load applied to the X-ray tube and quadratic with the voltage applied to the tube[10,13]. Thus, the radiographic techniques used in routine provide this increase in absorbed dose due to the higher values of voltage and load applied to the tube.

The optimizing of the chest radiographic images quality performed for pediatric patients in this study is a contribution to better quality images when compared with those obtained by clinical routine and have lower radiation doses, thus following the 3D principle (diagnostic, dose and dollar), which prioritizes the acquisition of quality images, providing a safe medical diagnosis, with radiation doses as low as reasonable achievable, consequently encouraging the lowest cost to the institution for the execution of radiographic examinations[2].

Acknowledgment

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