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Estimation of patient dose in computed tomography: an extension of IAEA Project in Brazil

Estimativa de doses em pacientes submetidos a exames de tomografia computadorizada: uma extensão do Projeto IAEA no Brasil

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Abstract

The aim of this paper was to estimate the patient's dose in routine procedures in Brazil and to identify the potential of optimization in adults and pediatric procedures. The sample included ten hospitals distributed in different states of the country. In each hospital, the routine protocols of head, chest, high resolution chest, abdomen, and pelvis were recorded. The values of C_w, C_{vol} and P_{kl} were estimated based on the ${}_nC_w$ values provided by IMPACT. For the same procedure, significant differences in patient's doses were verified between the hospitals and also in the same department. In some cases, the technical factors are so low that suggest a rigorous evaluation of the image quality. Problems were also observed regarding procedures records, and the information about the procedure is insufficient. This study indicated the necessity of an implementation of an action plan that includes training program to operate the scanner in an optimized mode, to carry out the dosimetry, and to evaluate the image quality. The large range of patient's doses indicated that there is an expressive potential of patient's dose reduction and optimization maintaining the diagnostic information.

Keywords: computed tomography, patient dose, optimization.

Resumo

O objetivo deste trabalho foi estimar a dose dos pacientes em procedimentos de rotina no Brasil e identificar o potencial de otimização em procedimentos adultos e pediátricos. A amostra incluía dez hospitais distribuídos em diferentes estados do país. Em cada hospital, os protocolos de rotina da cabeça, tórax, alta resolução do tórax, abdome e pélvis foram registrados. Os valores de C_w, C_{vol} e P_{kl} foram estimados com base nos valores de ${}_nC_w$, fornecidos pela IMPACT. Para o mesmo procedimento, diferenças significativas foram encontradas nas doses de acordo com os hospitais, também nos mesmos departamentos. Em alguns casos, os fatores técnicos são tão baixos que sugerem uma avaliação rigorosa da qualidade de imagem. Problemas também foram observados em relação aos registros dos procedimentos, já que a informação sobre eles é insuficiente. Este estudo indicou a necessidade de implementar um plano de ação que incluísse um programa de treinamento para operar o equipamento de forma otimizada, fazer a dosimetria e avaliar a qualidade da imagem. A grande variedade de doses indicou que existe um grande potencial de redução das doses e otimização, mantendo a informação do diagnóstico.

Palavras-chave: tomografia computadorizada, dose do paciente, otimização.

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Introduction

In Brazil, the number of computed tomography (CT) scanners increased exponentially in the last five years. Most of them are multi-slice CT scanners (MDCT), enabling new clinical application such as CT angiography and virtual endoscopy[1]. However, this new technology has been introduced before a preparation of the diagnostic radiology departments. There is a lack of health professionals trained in CT and in the instrumentation necessary to carry out the dosimetry and the image quality evaluation.

The advances in MDCT increased the resources to obtain an image of the patient with more diagnostic information. However, these scanners introduce new concepts to be understood and tradeoffs to be made. CT scanners have been recognized as a high radiation modality, when compared to other diagnostic X-ray techniques.

Even though the recognized benefits derived from CT procedures, the high frequency and the magnitude of the patient doses from these examinations have drawn the attention to potential risk from this practice. The amount of radiation dose received from a CT scan depends on many factors, including the design, maintenance and the operation mode. Especially the MDCT can potentially result in higher radiation risk to the patient due to the tendency to perform long scan lengths at high tube currents, fast acquisition times, and multi-phase contrast studies.

The protocols established by the manufacturer for the routine procedures should be evaluated to achieve lower patient dose and diagnostic quality image. It is also fundamental to adequate the protocol for the size and characteristics of the patients and the clinical indication[2]. While the determination of patient dose is a common practice in Europe, few surveys have been carried out in Brazil. This paper, with the support of the International Atomic Energy Agency (IAEA), is the first step to establish Brazilian reference levels for CT.

Materials and methods

Selection of the hospitals

Ten hospitals, public and private, distributed in four states, participated of the survey, they were: Rio de Janeiro, Minas Gerais, Paraná, and Pernambuco. The year of fabrication of the CT scanner varied between 2000 and 2008. The scanners were single and multi-sliced.

Data collected

The participant hospitals voluntarily were in the survey. Data were collected with the technologist of the service according to a standard questionnaire prepared during the IAEA regional projects (RLA067 and 057). In the first part, the technologist provided to the physicist general information: state, manufacturer, model, age of the scanner and number of examinations per year for each procedure. In the second part, scan parameters related to standard protocols conducted on typical adult (average-size) and pediatric (<1 year, 7 years) were required. The selected procedures included: head, chest, high-resolution chest, abdomen and pelvis.

CT dose index

The diagnostic reference level (DRL) is a fundamental tool for the optimization process. The quantities used in the CT were: weighted CT kerma index (C_w), Kerma-volume product (C_{vol}) and kerma-length product (P_{kl}). Values of C_{vol} and P_{kl} were calculated for each procedure based on ${}_nC_w$ value from IMPACT[3] for the respective scanner model. When the tube current modulation was used, the doses were calculated using reported values of average mAs.

Results and Discussions

Data collected

For each hospital, the patient number varied significantly. Of the ten participant hospitals, only five forms were complete. These five hospitals correspond to two states only (Figure 1). The total number of patients per year in these five hospitals was 50.220. Hospitals C and B showed the highest and lowest patient number per year, respectively.

Distribution of the exams

Figure 2 shows the frequency of CT procedures performed annually in the different centres. CT of abdomen and pelvis are the most frequent procedures, which rep-

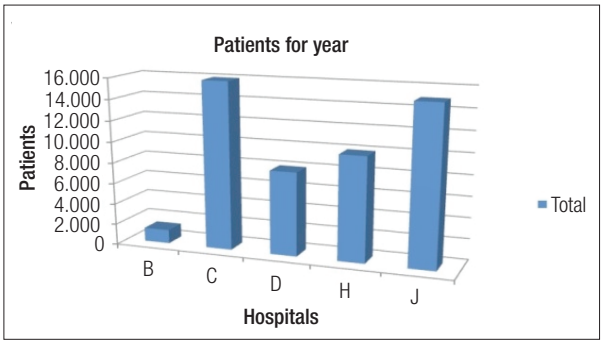

Figure 1. Number of patients per year in each hospital.

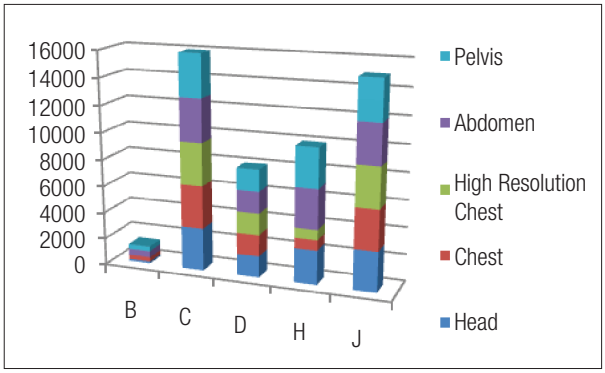

Figure 2. CT procedures distribution for each hospital per year.

resent aproximately 45% of the total number. Chest high resolution procedure is the least performed.

Technical factors

The routine protocols in most of the countries of Latin America and IRPA 2008 showed a very large range of technical factors for all procedures. The results obtained for adults are presented in Table 1.

The kVp values obtained in this study were similar to the ones in literature. However, the range of mAs was excessively large for all procedures, increasing consequently the C_w and P_{kl} values. This result indicated that some actions should be done in these hospitals, where the patient doses are unnecessary high.

The variation of C_{vol} values obtained for each procedure can be observed in Figure 3.

Comparing high resolution chest with other procedures, the technical factors used are much higher and in approximately 71% of the procedures the acquisition mode was axial. In Table 2 the doses values for children under one year are presented. Also, for this age, the variation of mAs is very expressive. For head, the range was from 80 to 200 mAs. The P_{kl} varied from 59 to 820 mGy.cm. Comparing the average values of P_{kl} for different procedures obtained in this study with the ones obtained in IRPA 2008, it is possible to observe that the P_{kl} values were: 16.5% above for head exams, 77.8% below for chest and 28.1% lower for abdomen.

The range of doses values for seven-year-old patients are presented in Table 3. Similar results obtained for under one year-old patients were observed including large ranges of mAs and P_{kl}. For head, the P_{kl} maximum was 2,146 mGy.cm.

Comparison of P_{kl} and C_w values for each procedure according to the age group

The distribution of P_{kl} values for different adults CT procedures are presented in Figure 4.

Table 1. Comparison of technical factors for routine adult procedures.

CT exam	Present survey			
	kVp	mAs	Cw (mGy)	Pkl (mGy.cm)
Head	120-130	120-500	13.4-115	175-3744
Chest	120-130	70-285	7.7-16.3	94.1-684
Abdomen	120-130	80-350	6.2-20	162-767.3
CT exam	Literature adult			
	Other countries		European DRL	
	kVp	mAs	Cw (mGy)	Pkl (mGy.cm)
Head	120	250-270	60	1050
Chest	120-140	120-267	30	650
Abdomen	120	120-267	35	780
CT e xam	IRPA 2008 Adult			
	kVp	mAs	Cw (mGy)	Pkl (mGy.cm)
Head	90-140	20-600	4-77	62-1773
Chest	90-130	40-440	3-50	2.7-999
Abdomen	90-140	40-457	3-66	40-21.9

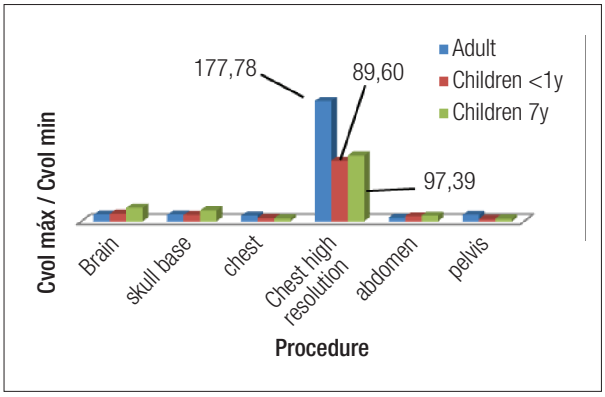

Figure 3. Rate of the maximum and minimum values of C_{vol} for each procedure and age group.

Table 2. Technical factors for the pediatric (<1 year-old) routine procedures used in this survey.

Exam	kVp	mAs
Head	80-130	80-200
Chest	120-130	41-80
Abdomen	120-130	41-150
Exam	IRPA 2008	
	C_w (mGy)	P_{kl} (mGy.cm)
Head	43	376
Chest	31	617
Abdomen	31	226

Table 3. Technical factors for the pediatric (seven years-old) routine procedures used in this survey.

CT exam	Present survey			
	kVp	mAs	C_w (mGy)	P_{kl} (mGy.cm)
Head	80-130	80-350	9-80,5	58,5-2146
Chest	120-130	70-100	9,0-23	120-337,3
Abdomen	120-130	41-150	9-27,6	113-441,6
CT exam	IRPA 2008			
	P_{kl} (mGy.cm)			
Head	546			
Chest	738			
Abdomen	498			

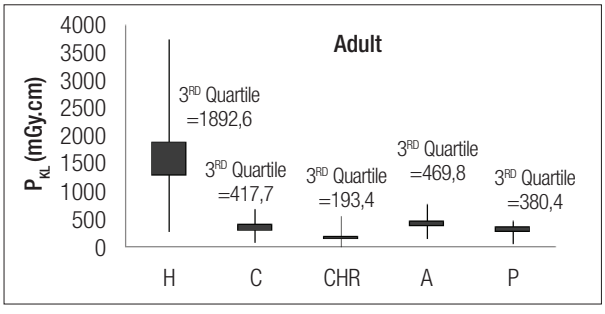

Figure 4. P_{kl} for adult patients. The procedures are represented as: head (H), chest (C), chest high resolution (CHR), abdomen (A) and pelvis (P).

Comparing the values of P_{kl} for various adult procedures, the largest range of P_{kl} values and the higher third quartile are observed. The third quartile of P_{kl} for head examinations was 80.3% higher compared to the European DRL and 106% higher than the IRPA 2008 value. For chest, the third quartile of P_{kl} was 35.7% and 16.5% lower than the European DRL and IRPA 2008 value. For abdomen, the P_{kl} was 39.8% and 47.5% lower than the DRL European and IRPA 2008.

The distribution of P_{kl} values for children under one year-old is presented in Figure 5. Also, for this age group, the range of P_{kl} values for the head CT was very large and the values higher than the ones obtained for the other procedures. For head and abdomen, the third quartiles were 10 and 30%, lower than the DRLs obtained in IRPA 2008. For chest, the P_{kl} value for pediatric patient was 374.6% lower than the IRPA 2008 value.

The distribution of P_{kl} values and the respective third quartile values for pediatric patient (seven years-old) submitted to routine procedures are presented in Figure 6.

Comparing the third quartiles of P_{kl} obtained in this study with the P_{kl} presented in IRPA 2008, our results indicated that all values of this survey were lower than these references: 6.0% for head, 183.3% for chest and 31.4% for abdomen .

As can be observed in Table 4, the third quartiles of C_w obtained in this study were lower than the IRPA 2008 value and European DRL.

Comparing the third quartiles of C_w presented in Table 5 for children under one year-old, with the P_{kl} presented in IRPA 2008, it is possible to observe that all values of this survey were lower than these references: 13% for head, 63% for chest and 55% for abdomen.

Table 6 presents the C_w values for children of seven years-old in surveys of head, chest, and abdomen. For this age, the difference between the third quartile values of C_w obtained in this study and the IRPA values were much lower than the results obtained for adults and children under one year-old: 12.9% for head, 24.4 % for chest, and 26.1% for abdomen.

Conclusions

The C_w values both for adults and pediatric patients were lower than the European DRL and IRPA 2008. Due to the large differences in the scan length, pitch, table increment and mAs used in the protocols for patients with the same characteristics, the result of P_{kl} was not consistent. The most critical procedure was the high resolution chest.

The large range of technical factors is a concern and should be investigated. The difficulty to answer the form also indicates that the professionals do not have the training necessary to understand the scanner, which would be essential to the optimization program. In many procedures, the pediatric doses were higher than the adults' and much higher than the European DRL's. This suggests that a survey specific for children should be carried out in order to as soon as possible the hospitals implement optimization programs. It is also important to expand this survey in the other states of the country.

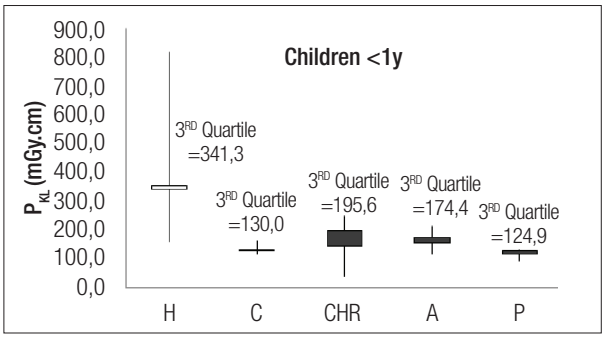

Figure 5. P_{kl} for pediatric patients (<1 year-old). The procedures are represented as: head (h), chest (c), chest high resolution (chr), abdomen (a) and pelvis (P).

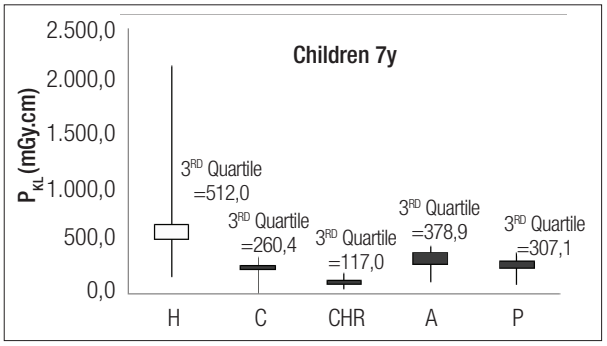

Figure 6. P_{kl} for pediatric patients (seven years-old). The procedures are represented as: head (h), chest (c), chest high resolution (chr), abdomen (a) and pelvis (P).

Table 4. Third quartile of C_w (mGy) for routine procedures: adults.

Study	Head	Chest	Abdomen
IRPA 2008	56	19	20
DRL European	60	30	35
Present survey	55	10	14.6

Table 5. Third quartile of C_w(mGy) for routine procedures: children under one year-old.

Study	Head	Chest	Abdomen
IRPA 2008	43,00	31.00	31.00
this survey	37,50	11.50	13.80

Table 6. C_w(mGy) values for the routine procedures: seven-year-old children.

Study	Head	Chest	Abdomen
IRPA 2008	44.00	25.00	26.00
Present survey	38.30	18.90	19.20

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