Survey of Radiation Exposure for adult and pediatric patients undergoing CT procedures in Latin America

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Abstract: Patient exposure from CT is among the highest in diagnostic radiology and contributes an increasingly greater proportion of the total collective dose from man-made sources of radiation. In addition, pediatric CT scans are often performed with the protocol used for a typical adult size. Recent dose surveys have indicated a large scope for dose reduction without compromising image quality required for the diagnosis. In Latin America the patient doses exposures from CT procedures are not estimated. The objective of this work was to evaluate the patient doses in routine procedures and analyze the adults and pediatrics protocols promoting a regional survey supported by the International Atomic Energy Agency. As many as 30 hospitals from eleven Latin American countries participated in the survey. Scanning parameters of routine procedures were collected using specific questionnaires distributed to all participating hospitals. The values of $C_{VOL}$ and $P_{KL}$ were estimated based on the $C_W$ established in the literature for each scanner. For the head scans $C_{VOL}$ values varied between 4 and 150 mGy and the $P_{KL}$ from 62 to 1780 mGy cm for adults, and $C_{VOL}$ from 7 to 90 mGy and $P_{KL}$ from 36 to 990 mGy cm for children. Values for abdomen scans $C_{VOL}$ from 1 to 43 mGy and $P_{KL}$ from 6 to 1560 mGy cm for children. Similar ranges were found for chest and pelvis scans. These results are compatibles with those from literature and indicate a large potential for optimization and dose reduction. However, some information about the technical factors, especially mAs, seems to be incoherent for the exam to obtain the image quality required. It indicates the inadequate training and insufficient knowledge of the scanner staff.

KEYWORDS: computed tomography, radiation protection, and doses patient.

1. Introduction

In Latin America, there was an exponential increased in the number of CT scanners installed in the last five years. Many installations have acquired multi-slice CT scanners (MDCT) creating the possibility of new clinical application such as CT angiography and virtual endoscopy [1]. However, this new technology has been introduced without much preparation in the diagnostic radiology departments. This lack of preparation indicates the necessity of specific training to the health professionals including the medical physicists and on the awareness of the new equipment necessary to carry on the dosimetry and the image quality evaluation.
The advances in CT scanners offer new diagnostics opportunities for improved patient imaging. However, these scanners bring with them new concepts to be understood and tradeoffs to be made. CT scanners have been recognized as a high radiation modality, when compared to others diagnostic X-ray techniques. As a result of the rapid development of these advanced technologies, its use has become more widespread and the patient dose should be a health concern.

Even thought the well known benefits derived from CT procedures the large number of CT scans performed each year and the magnitude of the radiation doses from these examinations has drawn the attention to potential risk from the practice. The amount of radiation dose received from a CT scan depends upon two main factors, the design of the scanner and the way it is used. Especially the MDCT can potentially result in higher radiation risk to the patient due to its increased capabilities such as long scan lengths at high tube currents with faster acquisition times and multi-phase contrast studies.

The selected scanning parameters, such as kV, mAs, table increment/pitch and scan length, will mainly affect the radiation dose to the patient. These parameters should be evaluated for dose reduction including those that can be modified based on patient size, study indication such as tube current, gantry rotation time, pitch, tube potential, scan covered, radiographic shields, automatic exposure control techniques, and noise reduction filters [2,3].

While the determination of patient dose is common practice in Europe, few surveys have been carried out in Latin America. Also, the results will help to Latin American Countries in the optimization of patient doses, by indicating the level, which should generally give acceptable image quality.

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2. Material and Methods

Selection of the Hospitals

Eleven countries participated in the survey: Argentina, Brazil, Chile, Costa Rica, Cuba, Dominican Republic, Ecuador, Nicaragua, Paraguay, Peru and Uruguay. The year of fabrication of the CT scanner varied between 1985 and 2006. The equipments were single-section or helical multi-detector rows sections.

Data Collected

The present survey is based on data collected from 30 hospitals from Latin America Countries. Each hospital voluntarily submitted a standard questionnaire. The questionnaire developed on the project was aimed to collect information on the practice in order to characterize the techniques and allows the calculation of relevant dose quantities. In this paper the dosimetric magnitudes presented were obtained from the data obtained from the questionnaire. The region through the continuation of project RLA/9/057 will in the future calculate the DRL based on the dosimetric measurements carried on in each center by trained experts.

There were two aspects to data collection, covered by separated sections in the questionnaire. First, general information such as: country, name of the institution, manufacture and model of the scanner, scanner fabrication year and person responsible for collecting the information was required. Second, information was asked in relation to the standard protocols for routine procedures conducted on typical adult (average-size) patients and pediatric (<1 year and 7 years old). The selected procedures include five examinations: head, chest, high-resolution chest, abdomen and pelvis. The number of examinations per year for each procedure was also required.

In each institution, a trained expert was responsible for applying the questionnaire to the technologist of the service, considering only the routine procedure, without one specific clinical indication. The
scan parameters required for each of the above procedures were: kV, mAs, scan mode (axial or helical), slice thickness, scan length, table increment or pitch and the number of slices per rotation.

**CT dose indices**

Guidelines to optimize the protection during CT procedure include diagnostic reference levels (DRL) or guidance levels [3]. The dose parameters suggested in the guidelines are the weighted CT kerma index ($C_W$) and the kerma-length product ($P_{KL}$).

Values of $C_{vol}$ and $P_{KL}$ were calculated for each axial or helical sequence on the basis of the representative $C_W$ coefficients published by IMPACT [4]. These relate to typical values of $C_W$ measured in the standard adult head or body CT dosimetry phantom for each particular scanner model. For scanners operated in auto dose reduction mode with automatic tube current modulation, doses were calculated using reported values of (average) tube current or mAs that included the effects of modulation [5]. However some centers didn’t have the information regarding a typical range for a standard adult patient.

Due to the discrepancies in the information received, on this paper the standard scan lengths for standard patients were assumed, in order to compare the $P_{KL}$ correctly. These lengths were derived based on typical distances between common anatomical landmarks for routine procedures [5].

3. **Results and Discussions**

**Scanner Sample**

The number of participating hospitals varied for each country as can be shown in **Figure 1**. Chile and Brazil were the countries with more participating centers, five and six hospitals respectively. In the survey, the scanners mode also varied, approximately 46% were single slices, 22% were Dual systems and 31% were multi-slices.

![Figure 1: Number of Hospital participating in each country](image)

3.2 **Distribution of the exams**

For the 30 participating hospitals, an average of 120,550 adults patients and 24,832 children undergo some CT procedure annually. In **Figure 2**, the patient frequency distribution undergoing CT procedures at each country is presented. Some countries did not have a register of the exact number of examinations carried on annually.
Figure 2: Frequency of Patients that undergo CT procedures annually in each center participating.

Figure 3 shows the frequency distribution of the different CT procedures carried out annually in all participating centers for children and adults. Head is the most frequent, in the case of children it corresponds to 60% of all procedures. Hi-resolution scans are not carried out on many hospitals, especially in those, with multi-slice systems. Also it is not common to conduct this procedure in children.

Figure 3: Distribution of the frequency for each routine procedure for the all sample

3.3 Technical factors

The analysis of the technical factors used by the participating hospitals revealed a very large variation of protocols (Table 1 and 2). This was not expected, considering that the information was for routine protocols for standard patients. Regarding the mAs value, the minimum was very low, indicating a possible misunderstanding by the technologists filling the questionnaire. The maximum values were higher than the reported by the other authors [1,3,5], but in this case the trend was verified to use high mAs in all procedures. Similar values were obtained for children indicating the use of adult protocols.
Table 1: Comparison of the Technical Factors for Adult Routine Procedures

<table>
<thead>
<tr>
<th>CT Exam</th>
<th>Used in this survey:</th>
<th>Literature [3]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Adult</td>
<td>Other countries</td>
</tr>
<tr>
<td></td>
<td>kVp</td>
<td>mAs</td>
</tr>
<tr>
<td>Head</td>
<td>90-140</td>
<td>20-600</td>
</tr>
<tr>
<td>Chest</td>
<td>90-130</td>
<td>40-440</td>
</tr>
<tr>
<td>Abdomen</td>
<td>90-140</td>
<td>40-457</td>
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Table 2: Comparison of the Technical Factors for the Pediatric Routine Procedures

<table>
<thead>
<tr>
<th>CT Exam</th>
<th>Children (1-7 years)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>kVp</td>
</tr>
<tr>
<td>Head</td>
<td>90-130</td>
</tr>
<tr>
<td>Chest</td>
<td>80-130</td>
</tr>
<tr>
<td>Abdomen</td>
<td>80-130</td>
</tr>
</tbody>
</table>

3.4 Comparison of C_w and P_KL mean values

The C_w and P_KL mean values were obtained for adults and children for each procedure and are shown in Figure 4.

Figure 4: Mean value of C_w and P_KL for routine procedures on adult and children patients.

For head, the C_w mean value for adults (40mGy) was approximately 25% higher than for children. However, in the other procedures the C_w for adults was 33% lower than for children. The adult mean values of C_w and P_KL for all procedures were lower than the DRL value recommended in the European guidelines [3]. The majority of the Centers performed the head examination using the axial mode. It can be observe that except for head procedure, the C_w obtained for children is higher than the adult values, indicating no specific pediatric protocols. Even considering the huge difference between the scan length for adult and children it was observed that in many cases the doses were very similar.

3.4.1 Head

Figure 5 presents the results for head procedures. The central points represent the mean values for each country and the extremes the minimum and maximum values obtained. It is important to observe that some countries participated with just one center or participated with specialized centers, (for example Costa Rica participated with one adult hospital and one children hospital). For comparison, the European DRL (C_w = 60mGy for adults) was indicated in the Figure as well the 3rd Quartile (56 mGy) obtained from all participating centers.
Considering all centers, for the same procedure and characteristics of the patient, the $C_w$ ranged from 25 mGy to 80mGy. Considering all countries, the values of $C_w$ vary up to 60 mGy. For adult patients, the $C_w$ mean value was lower than the DRL, except for Chile. The 75% percentile values for $C_w$ in the head were 56mGy for adults and 43mGy for children. Also, it is possible to observe the large ranges of doses for children in Figure 5 (b). In Uruguay, considering its three participating centers, the $C_w$ ranged from 27 to 80 mGy.

An evaluation of the ranges of $P_{KL}$ is observed in the Figure 6 for adults and children. For adults the 75% percentiles in the distribution of $P_{KL}$ in the head were approximately 133% higher than for children (1 year age). Also the 75% percentile was approximately 20% lower than the DRL $P_{KL}$ value for adult head. For adults, only the Dominican Republic and Chile presented a superior value than the DRL. For children, Paraguay and Uruguay presented a superior value of the 3º quartile. Also was found a wide range of doses for adults and for children.

3.4.2 Chest

Figure 7 shows important variation differences in the $C_w$ doses found, especially for children (b). The 75% percentile in the distribution of $C_w$ in the chest for adults were approximately 39% lower than for children with age lower than one year old. The 75% percentile for children was similar to the DRL for adults. Also, the results show a wide range of values in the pediatric procedures. In Ecuador, the $C_w$ ranged from 10 to 50 mGy. The same situation can be seemed in the other countries. This result indicates the urgent need to optimize pediatric protocols in the region.
Figure 7: Variation of $C_w$ values for head procedure in each country for adults (a) and children (b).

Figure 8 shows the 75% percentiles in the distribution of $P_{KL}$ for adult and children in chest examination. The values obtained were respectively 495 mGy.cm and 617 mGy.cm. The DRL for adult chest is approximately 24% lower than the European DRL and approximately 25% lower than the value obtained for pediatric chest procedure. For adults, the $P_{KL}$ mean values were lower than the European DRL, except for Ecuador.

3.4.3 Abdomen

Similar results as obtained for chest were found for abdomen (Figure 9). The 3º Quartile for adults is lower than for the European DRL and as well for children (1 year old). Considering the large difference between the scan lengths between these patients we identified serious problems in the choice of the exposure parameters and the unnecessary doses that the pediatric patient are receiving in the majority of the centers in Latin America. Ecuador showed the biggest difference range in $C_w$. 

Figure 8: Variation of $P_{KL}$ values for head procedure in each country for adults (a) and children (b).

Figure 9: Variation of $C_w$ values for abdomen procedure in each country for adults (a) and children (b).
In adult abdomen procedures (Figure 10 a), the values obtained for P_KL were much higher in the centers of Argentina Ecuador and Dominican Republic. Including these values, the 3º quartile was higher than the European DRL. Brazil showed a substantially wide range of doses in their centers for children (70 to 1.200 mGy.cm).

3.4.4 Hi-Resolution Chest and Pelvis

The range and the mean values of C_vol, P_KL and C_w for pelvis and Hi-res chest procedures are presented in Table 3. Comparing the mean values for the two procedures it is possible to conclude that CT radiation doses are lower than the recommended European Guidelines [2]. For pelvis the C_w value is 30mGy and P_KL is 650mGy.cm and for Hi-Res Chest the values are 35mGy and 600 mGy.cm respectively.

Table 3: Comparison of CT Doses for Pelvis and Hi-res chest Procedures for Adult and Children

<table>
<thead>
<tr>
<th>Procedures</th>
<th>Adult</th>
<th></th>
<th></th>
<th>Children</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C_vol</td>
<td>P_KL</td>
<td>C_w</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pelvis</td>
<td>1.29</td>
<td>32.3</td>
<td>1,080</td>
<td>3.2</td>
<td>43.2</td>
<td>23.6</td>
</tr>
<tr>
<td>Hi-Res-Chest</td>
<td>0.43</td>
<td>12.9</td>
<td>749.5</td>
<td>1.3</td>
<td>50</td>
<td>25.6</td>
</tr>
</tbody>
</table>

4. Conclusions

The 75 percentiles in the distribution of C_w and P_KL obtained in this survey was lower that the DRL European guidelines. However in all CT procedures, substantial differences were observed in patient radiation doses, for the same anatomic structure, in the different centers even in the same country. The large range of results reported reveals the differences in the techniques used at the centers of all participating countries.

In all procedures the pitch ranged from 0.7 to 2.0. For these routine examinations the European Guidelines [2] recommends a pitch equal a 1. The slice thickness in the majority of the procedures was lower than the recommendations [2]. Special attention should be paid in the centers that have the newer scanners (with improve technology) because they require special training to the clinical staff to obtain optimized procedures. In this survey, it was clear that the procedures are not optimized and
centers with multi-slice scanner showed more difficulties. It was observed that adult protocols are used for pediatric patients in Latin America centers. Special actions should be quickly implemented considering the higher sensitivity of children to the harmful effects of radiation.

**Acknowledgment**

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**REFERENCES**


