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Dose Estimation in Abdominal CT scans From DICOM Header Data

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1. Introduction

The application of ionizing radiation in diagnostic medicine has dramatically increased worldwide in the last decades, increasing more than 100% in the average dose in the world population [1]. In this period, radiological examinations have become the primary source of exposure of anthropogenic nature. In many countries, the collective dose from medical procedures has already exceeded other artificial radiation sources. For example, in the United States, the effective dose per caput is 3 mSv for medical exposures. Besides, half of the effective doses (1.5 mSv) in the U.S. are originated from Computed Tomography (CT) examinations [2]. A similar situation has been occurring in other countries, indicating that CT is the main radiological procedure that contributes to the increasing of the collective dose in the population. Therefore, several studies have been initiated worldwide to estimate and monitor doses and evaluate means to optimize the doses from these examinations [3, 4].

Studies of dose estimation in CT procedures have obtained values through technical parameters such as Computed Tomography Dose Index (CTDI) and Dose Length Product (DLP). Both CTDI and DLP are necessary indicators for estimating the doses received by patients. In 2002, a normative was issued by the International Electrotechnical Commission (IEC) defining that these parameters should be informed by the CT scanners manufacturers [4]. Therefore, CTDI and DLP should be provided in the equipment console. Moreover, in 2007, these dose indices started to be informed in the Structured Radiation Dose Report (RDSR) issued by CT systems, facilitating its use to estimate the radiation dose received by patients [5].

However, not all CT scanners provide the RDSR; in these cases, tools such as the CT Expo software, a Monte-Carlo-based modeling, and computational phantoms have been used to estimate the effective doses, and the information needed for obtaining them is collected directly from the DICOM header. [6, 7].

Based on this information, the aim of this study was to estimate the doses received by patients undergoing CT scans in a public hospital in Santa Catarina - Brazil, employing data from the DICOM header and utilizing the Expo V-2.7 software.

2. Methodology

This work consisted of a cross-sectional, retrospective, descriptive study. Data were selected from 45 abdominal scans of adult patients performed in December 2020 in a GE Healthcare Revolution EVO 16-channel CT scanner from a public hospital located in Santa Catarina - Brazil.

The abdominal CT protocol applied to the scans used in this study consisted of 120 kVp, 400 mA reference, 0.40 mm total collimation, 1.35 pitch, time per rotation of 0.8 s. In addition to abdominal CT scans, some patients were undergone to thorax and pelvic CT scans. The parameters of the latter exams were also used to complement this study. Most of the exams performed consisted of two series: pre-contrast and one post-contrast intravenous, since the service did not have an injection pump.

The spreadsheets with the data extracted from the DICOM headers of each exam (e.g. age, kVp, mAs) were provided by the Santa Catarina Telemedicine System (STT), under the approval of the Research Ethics Committee (CAAE: 36650720.6.0000.5365).

The software is Monte-Carlo-based and uses mathematical phantoms. The male Phantom presented the features, 1.70 m tall, 70 kg, while the female phantom presented 1.60 m tall, 60 kg (Fig. 1). The effective dose was calculated by using the CTDIvol and DLP values, only for patients with abdominal and pelvic CT scans. The mean values and standard deviation for CTDIvol, DLP, and effective dose (E) were calculated and are presented graphically.

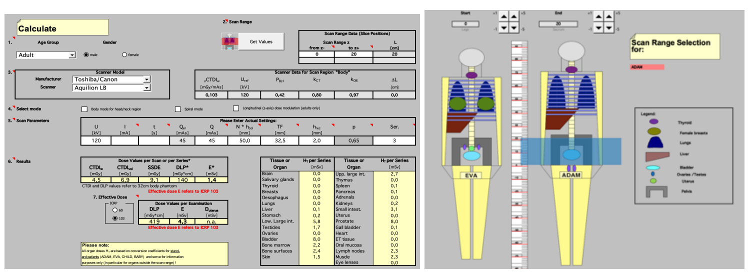

Figure 1: CT Expo Interface "Calculate" and “Scan ranger” [7].

3. Results and Discussion

The patient's sample had ages with a mean value of 52 (SD 18, Age_{max} 87, Age_{min} 22) years and the median was 44 years. Furthermore, 14 patients were female, and 31 were male. Other anthropometric characteristics of patients, such as weight, height, and Body Mass Index (BMI), could not be extracted from the DICOM header since they are not mandatory information for the exam, and are not usually entered by the professionals. Table 1 shows the technical parameters extracted from the DICOM header.

Table 1: Technical parameters used to calculate the dose from DICOM Header and CT Expo.

DICOM TAG	DICOM Name	Name in CT Expo
[0018,1160]	Filter Type	Body Mode
[0018,0060]	kVp	kV
[0008,0070]	Manufacturer	Manufacturer
[0008,1090]	Manufacturer's Model Name	Scanner
[0010,1010]	Pacient’s age	Age Group
[0010,0040]	Patient’s sex	Gender
[0040,0254]	Performed Procedure Step	Scan ranger
[0018,9305]	Revolution Time	Aquisition Time

[0020,0011]	Series Number	Number of Scan Series
[0020,1041]	Slice Location	Scan Range
[0018,0050]	Slice Thickness	Reconstructed Slice Thickness
[0018,9311]	Spiral Pitch Factor	Pitch
[0018,9310]	Table Feed Per Rotation	Table Feed Per Rotation
[0018,9307]	Total Collimation Width	Total Collimation
[0018,1151]	X-Ray Tube Current	mA

Out of the 45 patients in the sample, 29 had CT exams without intravenous contrast, and 16 with intravenous contrast, all being total abdominal CT scans (upper abdomen and pelvis). The mean value of series performed for the contrast-enhanced exams was four, and two exams reached nine series, encompassing the pre- and contrast-enhanced phases and biopsy. A high number of series or exam phases is one of the main causes of high doses in CT patients.

In relation to the radiation dose received by patients during abdominal CT scans (with and without contrast) the mean values of $CTDI_{Vol}$, DLP and effective dose, with and without intravenous contrast, are shown in Table 2.

Table 2: Mean values of Effective Dose of abdominal CT scans.

Procedure (Phases)	**$CTDI_{Vol}$ (mGy)**	**DLP (mGy.cm)**	**Effective Dose (mSv)**
Abdomen with and without m contrast (n= 45)	11,83 ± 5	486,87± 217	8,02± 4
Abdomen without contrast (n=29)	12,18 ± 5	510,20 ± 226	8,41± 4
Abdomen com contrast (n=16)	11,19 ± 5	444,58 ± 200	7,31± 3

In the exams with contrast, the mean effective dose was lower than exams without contrast. That probably occurs since in the second examination, and there is naturally an optimization of the scanned area as also reported in other studies [8].

The mean organ doses (equivalent doses) from abdominal CT scans were calculated using the CT Expo software which uses computational phantoms and Monte Carlo modeling. The obtained values are presented in Figure 2. Overall, the organs that showed the higher equivalent doses were kidneys (19.5 mSv), spleen (18.5 mSv), stomach (18.9 mSv), and liver (18.1 mSv).

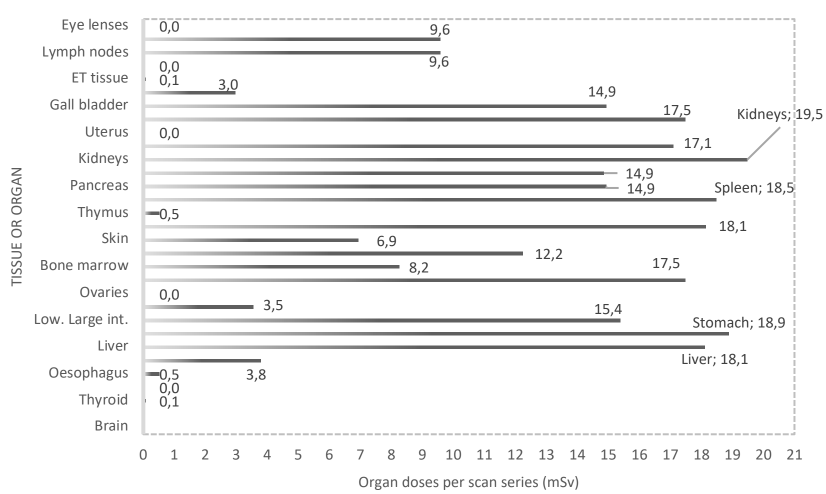

Figure 2: Average equivalent organ dose for abdominal CT scans calculated with CT Expo V 2.7 software.

The number of CT scans is growing worldwide, as are the doses from these procedures, despite advances in CT technology. These examinations can involve relatively high doses to patients, approaching or exceeding the currently proposed DRLs, and that could be related to an increased risk of developing cancer arising from medical exposures. Based on this, patient dose estimation studies are essential.

The DRLs established in international guidelines are routinely established based on the 75th percentile [9]. This study exclusively presented the mean values for effective doses and organ doses per scan series, with respective standard deviation and median, due to the limited number of samples. However, this study is part of a larger ongoing project which aims to investigate the doses (absorbed and effective) for CT procedures in different services in Santa Catarina, Brazil.

Several authors have used DICOM header data extraction combined with computational tools for dose estimation in radiological examinations [8, 9]. Therefore, we suggest the application of our method or a similar one to Services where CT scanners do not yet provide RDSR.

Furthermore, the adequate justification of the exams, the use of appropriate technical parameters, constant training of the team, adequate quality control, and the application of DRLs are actions that can contribute to the optimization of the doses [9].

4. Conclusions

The CT equipment with RDSR shows dose and dose index values at the end of each exam, allowing a faster and more practical evaluation of the patient doses, besides being an excellent dosage optimization tool. However, not all CT scanners contain the RDSR settings, and the use of software such as CT Expo can support the estimation of effective doses received by patients through the information extracted from the DICOM header. In the Brazilian reality, the presented methodology can be a useful tool to retrospectively estimate the doses in CT services in Brazil.

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