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Adjust of chest CT scan protocols using child phantoms

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1. Introduction

Computed Tomography (CT) images are very detailed and are used for medical diagnosis, being considered relevant in ionizing radiation applications. Due to the continuous increase in the demand for these tests, CT has become the diagnostic procedure that most contributes to the increase in the dose absorbed by the population [1-2]. The optimization of the image acquisition process aiming to reduce patient dose and maintain the diagnostic quality of the image has become an object of research in recent years, mainly in pediatric applications. Computed Tomography (CT) images are very detailed and are used for medical diagnosis, being considered relevant in ionizing radiation applications. Due to the continuous increase in the demand for these tests, CT has become the diagnostic procedure that most contributes to the increase in the dose absorbed by the population [3]. The optimization of the image acquisition process aiming to reduce patient dose and maintain the diagnostic quality of the image has become an object of research in recent years, mainly in pediatric applications[1]. For this work, three chest phantom that simulate different size of children were tested using different acquisition protocols, always starting from the routine chest protocol of the diagnostic service. The new protocols were implemented and used in patient scans and allowed the generation of images with very good diagnostic quality.

2. Methodology

Chest CT scans were performed on a GE CT scanner, Light Speed VCT model with 64 channels. The chest phantoms were developed by the research team of the Center for Research in Biomedical Engineering (CENEB), being representative of pediatric patient's chest. The chest phantoms have an oblong shape and they were made of polymethylmethacrylate (PMMA). Three oblong phantoms with different volumes were used, representing three typical child chest of 1-year (1Y), 6-month (6M) and newborn (NB). The 1Y, 6M and NB phantoms have cut areas of 9 x 17 cm^2, 8 x 16 cm^2 and 6.5 x 13 cm^2, respectivily. All the phantoms are 15 cm in length. They have openings that allow the measurement of absorbed dose values using a pencil-type ionization chamber. The Figure 1 shows drawings with the measurements of the oblong child phantoms.

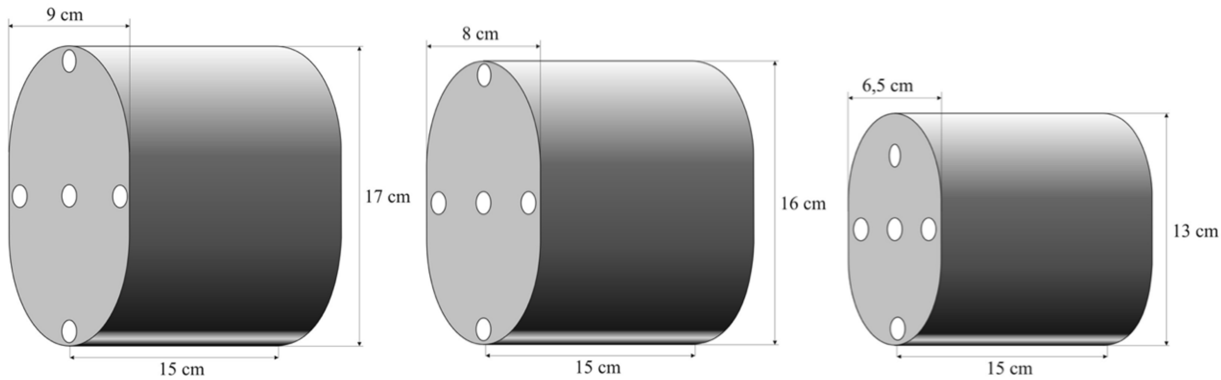

Figure 1: Sizes of pediatric chest phantoms: 1 year, 6 months and newborn

CT scans of the phantoms were performed using different acquisition protocols, always starting from the routine chest protocol for children of the diagnostic service. The tested protocols used different voltage values (80, 100 and 120 kV) and based on the test results, the best acquisition protocol for each phantom was defined. Dose measurements have been performed by positioning the chest phantom in the gantry isocenter and aligning the openings like as the positions 3, 6, 9 and 12 of an analog clock, through the help of the CT scanner lasers. The phantom openings are filled with PMMA rods which have been removed one by one to position the pencil ionization chamber, targeting the dose measurements in the five positions. The Figure 2 shows images of the central slices of the child chest phantoms.

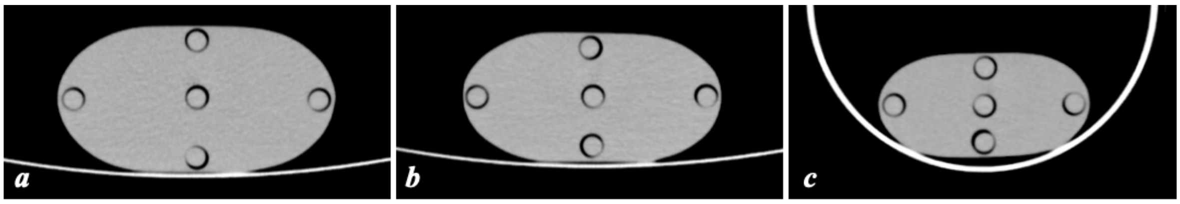

Figure 2: Central slice images of child phantoms. 1 year (a), 6 months (b) and newborn (c).

A pencil ionization chamber RADCAL ACCU-GOLD model 10X6-3CT was used to record the CT air kerma in PMMA ($C_{k,PMMA,100}$) in each opening of phantoms. First, a scout was made to check the correct alignment of the phantom as well as to demarcate the central slice position. Furthermore, the central slice of the phantoms was irradiated successively. For each ionization chamber positioning five measurements were performed, getting a minimum of 25 measurements for each protocol and for each phantom. In the central slice irradiations the remaining openings were filled using PMMA rods. From these results, the CT Dose Index values, weighted and volumetric ($CTDI_w$, $CTDI_{vol}$), were obtained for 10 cm scans of the central region of the phantoms in helical mode. The protocol parameters used for irradiation of the central slice in axial mode for all phantoms were done with a current of 100 mA, a charge of 100 mA.s, a tube time of 1 s and a thickness beam of 10 mm; using a voltage of 120 kV. Table I shows the protocols used in the services routines for all pediatric patients, regardless of size or age.

To manage the quality of the images noise values were calculated. In a ROI selected in the central area of the central slice image was abtained the average value in HU and the standard deviation. With these parameters the noise values were calculated. The maximum noise value accepted was limited to a maximum of 1%, considering the homogeneity of the PMMA phantom.

Table I: Routine protocol of pediatric chest CT scan.

Voltage (kV)	Current (mA)	Tube time (s)	Charge (mA.s)	Beam Thickness (mm)	Pitch	Reconstruction (mm)
120	280	0.5	140	5	1.375	2.5

3. Results and Discussion

Table II presents the weighted air kerma index in PMMA (C_w) calculated from the $C_{k,PMMA,100}$ measurements at the five positions of each phantom and adjusted by the charge value (mA.s), because the recorded data was obtained with 100 mA.s. It was calculated the standard deviation (SD) in each measurement.

Table II: Weighted Air Kerma (mGy)

Protocol	Phantom	Voltage (kV)	Charge (mA.s)	C_w (mGy)	SD
	1Y			29.94	0.03
Routine	6M	120	140	31.32	0.17
	NB			35.11	0.23
	1Y		36	7.70	0.08
Optimized	6M	120	28	6.26	0.03
	NB		24.8	6.22	0.04
	1Y		52	7.28	0.06
Optimized	6M	100	40	5.88	0.06
	NB		35.2	5.84	0.03
	1Y		100	7.74	0.07
Optimized	6M	80	72	5.86	0.03
	NB		56.8	5.33	0.03

It is possible to observe the variation of the C_w for all phantoms for all phantoms according to the protocol used. The NB receive the higher air kerma in PMMA value of 35.11 mGy with the routine pediatric protocol. The optimized protocols tested generated lower C_w values in all phantoms than the routine protocol. The lowest C_w value for the 1Y phantom 1Y was 7.28 mGy using the voltage of 100 kV. The lowest C_w value for the 6M and NB phantoms were 5.86 and 5.33 mGy using the voltage of 80kV. Comparing the C_w values of the routine protocol and the lowest C_w values obtained using optimized protocols the redution for the 1Y, 6M and NB phantoms was of 75,7% , 81,3% and 84,8%, respectivly. Also, the NB phantom presents the higher C_w value in the routine protocol of 35.11 mGy and the lowest value using the optimized protocol of 80 kV. In order to obtain the CT Dose Index (CTDI) values from the air kerma measurements were adjusted using a conversion factor (Fc) air/PMMA. The Fc used are 1.0418, 1.0324 and 1.0109 for the X-ray beam generated with 120, 100 and 80 kV, respectively.The Figure 3 shows a graphic with the $CTDI_vol$ values for the chest pediatric phantoms obtained according with the average current and pitch. Table III shows the $CTDI_{vol}$ values of the best protocol of each pediatric phantom.

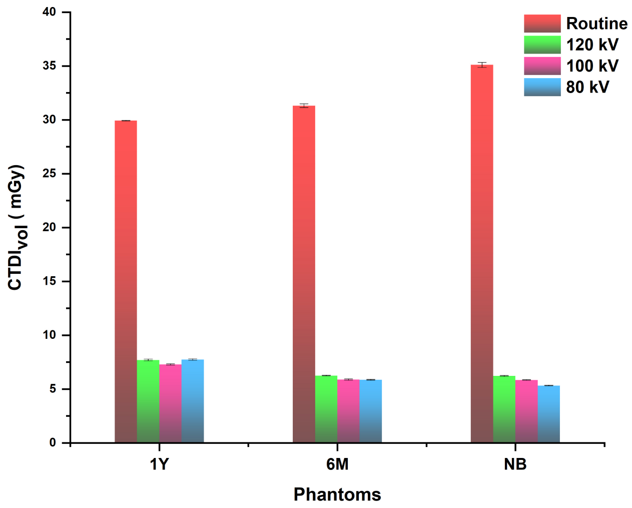

Figure 3: $CTDI_{vol}$ values for the chest pediatric phantoms of 1 year, 6 months and newborn.

Table III: $CTDI_{vol}$ in mGy to optimized protocols.

Phantom	Voltage (kV)	Charge (mA.s)	$CTDI_{vol}$ (mGy)	SD
1Y	100	52	5.46	0.05
6M	80	72	4.31	0.20
NB	80	56.8	3.92	0.20

4. Conclusions

The $CTDI_{vol}$ values were determined during chest CT scans of pediatric PMMA phantoms. Dose index values were significantly higher in the newborn phantom using the same routine pediatric protocol. The use of optimized protocols was better using smaller voltage values of 100 and 80 kV. So, this work demonstrated the necessity to use exclusive protocols for pediatric patients.

Acknowledgments

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References

[1] R. L. Dixon *et. al.*, "Comprehensive methodology for the evaluation of radiation dose in X-ray computed tomography", *AAPM*, (2010).

[2] J. M. Boone. "Comment on the 'Report of AAPM TG 204: Size-specific dose estimates (SSDE) in pediatric and adult body CT examinations", *AAPM*, vol. 39 (2012).

[3] Isaac Bankman, *Handbook of medical image processing and analysis*, Elsevier (2008).