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Patient doses from CT examinations in region of Prishtina, Kosovo

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ABSTRACT: The study was performed on the CT scanners installed in five medical centers, which provides 6, respectively 64 slices per gantry rotation.

The free-in-air CTDI was determined from measurements by exposing a CT pencil ionization chamber (PTW TM30009) without any build up materials around, which has been connected with electrometer, type PTW DIADOS E. The measurement of $CTDI_{100}$ was performed for three standard protocols (head, thorax and abdomen) using acrylic cylindrical phantoms with a diameter of 16 cm and 32 cm. These values were compared with the $CTDI_w$ displayed in the console to ensure that the radiation output from the machines were within international standards.
Based on results obtained on measurements of free-in-air CTDI, we conclude that all values are within the international standards.
A deviation value from measurements taken in this study for selected ThoraxHRSeq., respectively AbdomenSeq. scan CT techniques to mimic clinical conditions for an adult patient, results shows that in cases of machine A and E, percentage of deviation exceed norms by the international standards for AbdomenSeq. protocol, respectively for machine E for ThoraxHRSeq. protocol, too.

KEYWORDS: CT scanner, radiation dose, $CTDI_w$, $CTDI_{vol}$, dose length product, ionization chamber.

I. INTRODUCTION

For over one hundred years, the usage of ionizing radiation in medicine has grown spectacularly over the world, becoming an invaluable tool in diagnosis and treatment of diseases [1]. All medical imaging methods deposit some form of energy in the patient's body. Although the quantity of energy is relatively low, it is a factor that should be given attention when conducting diagnostic examinations. As the X-ray beam progresses through the body, it undergoes attenuation. The rate of attenuation (or penetration) is determined by the photon-energy spectrum (kV and filtration) and the type of tissue (fat, muscle, bone) through which the beam passes.
Computed tomography (CT) was introduced in the early 1970s and soon became a very important tool in medical diagnostic imaging. Technical developments have resulted in a number of distinct generations of scanners, including helical CT in the early 1990s and most recently Multiple Detector Computed Tomography (MDCT) scanners [2].
The use of computerized tomography (CT) is rapidly increasing in the last decades, and this method has become the major non-natural source of radiation exposure to the population. CT examinations delivers to the patients more radiation than all other imaging techniques, and contribute disproportionately to the collective dose of radiation. Compared with conventional X-ray imaging techniques, CT involves much larger radiation doses delivered to the patient. For example, the average effective dose of a CT scan of the abdomen or chest is more than 10 times or even 100 times larger than that of a conventional X-ray examination, respectively [3].
In medicine there are no legal dose limits for patients when exposing them to ionizing radiation. However, medical X-ray examinations must fulfill the two basic principles of radiation protection, i.e. justification (provide more good than harm to the patient) and optimization (following the ALARA principle 'As Low As Reasonably Achievable'), as first proposed by the International Commission on Radiological Protection (ICRP) in 1996 [4].
Evaluation of radiation dose in CT is performed by estimating the Computed Tomography Dose Index (CTDI), which represents the absorbed dose along the longitudinal axis (z-axis) of the CT scanner measured during a single rotation of the X-ray source (AAPM Report No.96, 2008) [5].

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II. MATERIALS AND METHODS

The study was performed on the CT scanners installed in five medical centers, which provides 6, respectively 64 slices per gantry rotation and consisted on measurements of CTDI free-in air and $CTDI_{100}$ to compare with the $CTDI_w$ displayed in the console.

a. CTDI Free-in-air measurements

The free-in-air CTDI was determined from measurements by exposing a CT pencil ionization chamber (PTW TM30009) without any build up materials around. The chamber (PTW TM30009) consisted of total 3.14 cc sensitive volume and a measuring length of 10 cm, which has been connected with electrometer, type PTW DIADOS E.

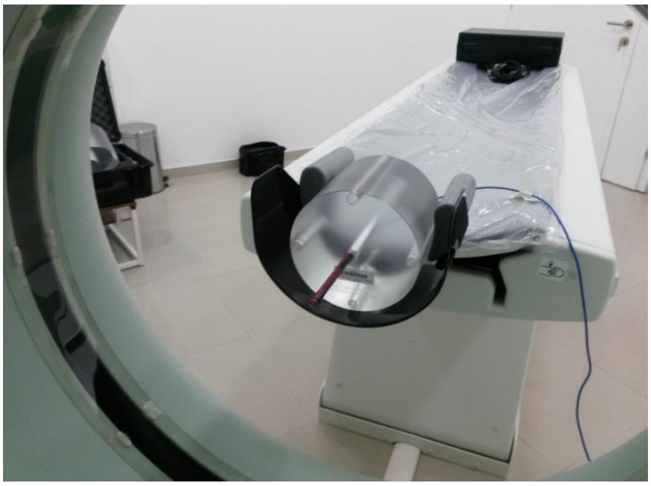

Fig. 1. Positioned CT pencil ionization chamber (PTW TM30009)

For each possible value of tube voltage (80, 110, 130 kV or 80, 100, 120, 140 kV), three measurements were carried out to give an acceptable mean value. Then, we found the mean value using next equation:

$$\overline{CTDI}_{air\_M} = \frac{(CTDI_{100M})_1 + (CTDI_{100M})_2 + (CTDI_{100M})_3}{3}$$

The deviation values were calculated by the following formula:

$$\varepsilon = \frac{(\overline{CTDI}_{air\_M} - CTDI_{air\_sp.M})}{CTDI_{w,calculated}} \cdot 100$$

where: $\overline{CTDI}_{air\_M}$ - mean value of three measurements of free-in-air CTDI, and $CTDI_{air\_sp.M}$ - $CTDI_{air}$ specified by manufacturer.

b. $CTDI_{100}$ measurements

The measurement of CTD_{100} was always performed for a single rotation of the X-ray source in the axial scan mode, for three standard protocols: head, thorax and abdomen. The obtained values, were compared with the $CTDI_w$ (or $CTDI_{vol}$) displayed in the console to ensure that the radiation output from the machines were within international standards.

For the CTDI measurements, we have used acrylic cylindrical phantoms with a diameter of 16 cm and 32 cm, both with 14 cm height. Both phantoms have five holes to place an ionization chamber, one in the center and the others at 0°, 90°, 180° and 270° each with a distance of 1 cm away to the surface of the phantom in 4 quadrants. Dose measurements were accomplished in all five positions with a volume scan.

The phantom was positioned on the table top in the “bracket” which keeps the phantom in place, and exactly aligned the etched crosshairs on the phantom using the CT machine lasers.

The CT pencil ionization chamber (PTW TM30009) was then inserted into one of five holes of the head or body phantom. During measurements, the other holes were filled by acrylic dummy plugs when not used.

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a) b)

Fig. 2. Positioned phantom on the table top in the bracket (a) Siemens Somatom Emotion 6, and (b) Siemens Somatom Definition AS.

The doses in the center of the phantoms ($CTDI_{100,\,c}$) and in four peripheral points were measured. The peripheral value ($CTDI_{100,\,p}$) is calculated as the mean dose at four points orthogonal on the phantom. The dose measured with the CT-chamber was divided by 10 (N*T) to calculate the effective CTDI for 1 cm length.

$$CTDI_{100} = \frac{1}{N \cdot T} \int_{-50}^{+50} D(z)dz$$

Where: N – number of slices, T – nominal slice width.

The weighted $CTDI_w$, then was calculated from the central and peripheral dose measurements as follows [6]:

$$CTDI_w = \frac{1}{3} CTDI_{100,c} + \frac{2}{3} CTDI_{100,p}$$

The deviation values were calculated by the following formula:

$$\varepsilon = \frac{(CTDI_{w,calculated} - CTDI_{w,displayed})}{CTDI_{w,calculated}} \cdot 100$$

The other important parameter is dose length product (DLP), which represents the exposure for a complete scan. It is calculated from the following equation [7]:

$$DLP = \sum_i CTDI_w \cdot N \cdot T = CTDI_{vol} \cdot L$$

Where: N – number of slices, T – nominal slice thickness, L - is the scanning length (or length of the collimator).

III. Results and Discussion

The CT radiation doses were estimated following instructions from the AAPM Report 96 (AAPM, 2008).
All obtained results for measurements of free-in-air CTDI are within accepted level of percentage based on international standards (±20%).

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Results from measurements of the free-in-air CTDI, are presented in the Table #1.

Medical center (Machine)	Manufacturer/Model	Tube voltage [kV]	Slice thickness [mm]	$\overline{CTDI}_{air\_M}$ [mGy]	$\overline{CTDI}_{air\_sp.M}$ [mGy]	Deviation [ε ,%]
A	**SIEMENS SOMATOM EMOTION 6**	**80**	**10.0**	**22.66**	**23.1**	**-1.94**
		110	**10.0**	**49.18**	**51.5**	**-4.72**
		130	**10.0**	**71.20**	**73.4**	**-3.09**
B	**SIEMENS SOMATOM EMOTION 6**	**80**	**10.0**	**21.56**	**22.2**	**-2.97**
		110	**10.0**	**48.56**	**49.6**	**-2.14**
		130	**10.0**	**68.33**	**70.1**	**-2.59**
C	**SIEMENS SOMATOM DEFINITION AS**	**80**	**10.0**	**21.81**	**23.5**	**-7.75**
		100	**10.0**	**40.35**	**42.3**	**-4.83**
		120	**10.0**	**63.82**	**65.2**	**-2.16**
		140	**10.0**	**91.14**	**92.0**	**-0.94**
D	**SIEMENS SOMATOM SENSATION 64**	**80**	**10.0**	**17.56**	**18.9**	**-7.63**
		100	**10.0**	**33.59**	**34.2**	**-1.82**
		120	**10.0**	**54.38**	**54.8**	**-0.77**
		140	**10.0**	**81.73**	**81.5**	**0.28**
E	**SIEMENS SOMATOM SENSATION 64**	**80**	**10.0**	**18.12**	**19.1**	**-5.41**
		100	**10.0**	**33.27**	**34.4**	**-3.40**
		120	**10.0**	**53.98**	**54.7**	**-1.33**
		140	**10.0**	**80.63**	**81.6**	**-1.20**

Results from the $CTDI_{100}$ tests to compare with the $CTDI_w$ displayed in the console, are presented in the Table #2. Scan protocols for the head phantom study were set at HeadSeq. scan CT techniques to mimic clinical conditions for an adult patient. Results shows that a deviation value from measurements taken in this study for HeadSeq. (adult) protocol, are within accepted level of percentage based on international standards (±20%). But, in case of selected ThoraxHRSeq., respectively AbdomenSeq. scan CT techniques to mimic clinical conditions for an adult patient, results shows that in to cases of machine A and E, percentage of deviation exceed norms by the international standards for AbdomenSeq. Protocol, respectively for machine E for ThoraxHRSeq. protocol, too.

Medical center (Machine)	Manufacturer/Model	Selected protocol	Tube voltage [kV]	Tube current - time product [mAs]	Scan time [s]	Slice thickness [mm]	CTDIw. (calculated) [mGy]	CTDIvol. (displayed) [mGy]	Deviation [ε ,%]
A	**SIEMENS SOMATOM EMOTION 6**	**H**	**130**	**260**	**1.5**	**10.0**	**52.50**	**59.17**	**-12.71**
		Th	**130**	**100**	**1.0**	**1.0**	**15.15**	**14.10**	**6.93**
		A	**130**	**110**	**1.0**	**8.0**	**9.13**	**11.77**	**-28.99**
B	**SIEMENS SOMATOM EMOTION 6**	**H**	**130**	**250**	**1.5**	**10.0**	**60.36**	**58.76**	**2.66**
		Th	**130**	**128**	**1.0**	**1.0**	**11.62**	**13.31**	**-14.58**
		A	**130**	**104**	**0.8**	**10.0**	**9.10**	**10.22**	**-12.29**
C	**SIEMENS SOMATOM DEFINITION AS**	**H**	**120**	**380**	**2.0**	**10.0**	**42.58**	**48.11**	**-12.98**
		Th	**120**	**144**	**1.0**	**2.0**	**11.79**	**12.87**	**-9.14**
		A	**120**	**223**	**1.0**	**10.0**	**11.78**	**12.28**	**-4.29**
D	**SIEMENS SOMATOM SENSATION 64**	**H**	**120**	**380**	**1.0**	**10.0**	**40.89**	**46.47**	**-13.65**
		Th	**120**	**219**	**1.0**	**10.0**	**10.83**	**11.98**	**-10.65**
		A	**120**	**142**	**1.0**	**10.0**	**7.14**	**7.68**	**-7.51**
E	**SIEMENS SOMATOM SENSATION 64**	**H**	**120**	**430**	**1.0**	**10.0**	**46.1**	**52.59**	**-14.08**
		Th	**120**	**122**	**1.0**	**2.0**	**7.27**	**10.26**	**-41.19**
		A	**120**	**181**	**0.5**	**10.0**	**8.38**	**10.98**	**-31.00**

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IV. CONCLUSION

All obtained results for measurements of free-in-air CTDI are within accepted level of percentage based on international standards (±20%).

Scan protocols for the head phantom study were set at HeadSeq. scan CT techniques to mimic clinical conditions for an adult patient. a deviation value from measurements taken in this study, are within accepted level of percentage based on international standards (±20%).

The survey has revealed a significant variation of the recorded dose values. This discrepancy is explained by different technical scanning parameters. Protocol optimisation is required on some CT scanners.

Further efforts are required to reduce patient doses. These include: 1. periodical re-audits, 2. the establishment of DRL as tool for optimisation and 3. to introduce a clinical audits for identifying unjustified CT examinations and eliminate them.

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BIOGRAPHY

Sehad Kadiri was born in Prizren, Kosovo, in 1982. He received the diploma in Engineering physics and the M.Sc. from the University of Prishtina. Actually is PhD candidate in Polytechnic University of Tirana, Albania. His main areas of research include general radiation protection, dosimetry of ionizing radiation, metrology of ionizing radiation, shielding design, and radiation protection in medicine. He is currently working as dosimetrist at the Institute of Occupational Medicine/Radiation Protection Service in Obiliq, Kosovo.

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