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Original Article

Assessment of Patient Dose from CT Examinations in Khorasan, Iran

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Abstract

Introduction
Computed Tomography scans are a very important tool for diagnosis and assessment of response to treatment in the practice of medicine. Ionizing radiation in medical imaging is undoubtedly one of the most powerful diagnostic tools in medicine. Yet, as with all medical interventions, there are potential risks in addition to the clear potential benefits.
Materials and Methods
Two reference dose quantities have been defined in order to promote the use of good technique in CT. These are weighted CT dose index ($CTDI_w$) in (mGy) for a single slice in serial scanning or per rotation in helical scanning, and dose–length product (DLP) per complete examination (mGy.cm), All measurements were performed using a pencil shaped ionization chamber introduced into polymethyl methacrylate cylindrical brain and body phantoms. This survey was performed on 7 CT scanners in Khorasan Province-Iran.
Results
DLP for brain, chest, abdomen and pelvic examinations had a range of 255 - 1026, 76-1277, 48-737, 69-854 mGy.cm, respectively.
Conclusion
The results obtained in this study show that the DLP values obtained in this province are lower than European Commission reference dose levels (EC RDL), in other words performance of all the scanners were satisfactory.

Keywords: DLP, CT, Ionization Chamber

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1. Introduction

Computed Tomography (CT) was introduced in the early 1970s and quickly became a very important tool in medical diagnosis. Technological developments which have improved the speed and the quality of the resulting images have also encouraged the growth of CT worldwide. The expanding use of CT worldwide has resulted in this modality becoming the major source of the population in exposure to X-rays, contributing to 40% of the resulting collective dose in the UK in 1997 [1]. Data from 1991 to 1996 show that globally CT was responsible for 34% of the annual collective dose from medical exposures [1]. Following new biological information on harm due to, radiation and modified risk estimates, the basic recommendations of the International Commission on Radiological Protection (ICRP) were revised in Publication 60, [2,3] and new quantities and concepts were introduced. In optimization, there is the important new concept of constraint, with the main implication in diagnostic radiology being that of dose constraints for the patient. CT is a radiological imaging modality which is associated with relatively high levels of effective dose exposure of the patient in comparison to conventional radiological techniques [4].

The complex conditions of irradiations in CT, involving highly collimated X-ray beams and at the same time also beam-shaping filters necessitate the use of specially defined dose descriptors, such as a CT dose index (CTDI). This is defined as the integral dose along a line parallel to the axis of rotation (*z*) of the dose profile (*D*(*z*)) for a single slice, divided by the nominal slice thickness *T*:

$$CTDI= - \int \quad ( ) \quad (mGy) \qquad (1)$$

The European Commission (EC) has suggested the use of a normalized dose index, $_{n}CTDI_{w}$, expressed as absorbed dose to air, which takes account of non-uniformities of CTDI values measured at the centre or the periphery of these phantoms: [5]

$$_{n}CTDI_{w} = - (- CTDI_{100.c} + - CTDI_{100.p}) \quad (mGy_{air}\ (mAs)^{-1} \qquad (2)$$

Here *C* is the radiographic exposure (mAs) and $CTDI_{100,p}$ represents an average of measurements at four different locations around the periphery of the phantom. The weighted CT dose index, $CTDI_w$, which is the first of the two reference dose quantities proposed by the EC, for a single slice in serial scanning or per rotation in helical scanning is then simply calculated using the following equation:[5]

$$CTDI_w = {}_{n}CTDI_w \, . \, C \quad (mGy_{air}) \qquad (3)$$

The second reference quantity is the dose–length product (DLP), which includes the patient, or the phantom volume irradiated during a complete examination:

$$DLP=\sum \quad CTDI_w.T.N.C \quad (mGy_{air}.cm) \qquad (4)$$

Here *i* represent each serial scan sequence forming part of an examination, and *N* is the number of slices, each with a thickness of *T* (cm). In the case of helical (spiral) scanning:

$$DLP=\sum \quad CTDI_w.T.A.t \quad (mGy_{air}.cm) \qquad (5)$$

Here, for each of *i* helical sequences forming part of an examination, *T* is the nominal irradiated slice thickness (cm), *A* is the tube current (mA), and *t* is the total acquisition time (s) for the sequence [6].

Reduction of the dose received by the patient by optimization of CT technical parameters and protocols is of principle concern in patient protection [7]. In this study radiation dose arising from four common CT examinations by conventional and spiral CT machines in Khorasan province was investigated.

2. Materials and Methods

This survey was performed on 7 CT scanners operating in Khorasan. Table 1 summarizes the scanners according to their manufacturers. All measurements were performed during 2009-2010 . Four typical CT examinations, namely routine brain, chest, abdomen, and pelvis, were selected for the study. For each examination, data concerning examination parameters, such as kVp, mAs, number of slices, slice thickness and couch increment were taken into consideration. Table 2 presents the different examination protocols used among the 7 CT scanners for the routine brain, chest, pelvis, and abdomen examinations. $CTDI_{100,air}$ measurements were made free-in-air using a 10 cm pencil shaped ionization chamber (model Radcal10X5-3CT; Radcal Corporation, Monrovia, CA) connected to a Radcal (model 9015; Radcal Corporation, Monrovia, CA) dosimeter.

Table 1. Distribution of CT units per manufacturer

Manufacturer	Scanner	Number of units
GE	GE 9800	1
Siemens	Siemens Balance	1
GE	GE Sytec	1
Shimadzu	ShimadzuSCT	1
Toshiba	Toshiba Asteion Multi4	1
Philips	Philips 310	1
Philips	Philips CX	1

Figure 1. Schematics of phantom and ionization chamber

Table 2. Protocol parameters used for the routine examinations (brain, chest, abdomen, and pelvis) in 7 CT scanners

Scanner	Exam	kVp	mAs	T(mm)	I(mm)	L(cm)
A	Brain	120	290	10	10	16.1
	Chest	120	140	10	10	27
	Abdomen	120	300	10	10	30
	pelvis	120	300	10	10	32
B	Brain	120	250	10	10	15.6
	chest	120	165	10	10	27
	Abdomen	120	340	10	10	30.5
	pelvis	120	340	10	10	32
C	Brain	120	180	10	10	16
	chest	120	144	10	10	25.7
	Abdomen	120	144	10	10	31
	pelvis	120	144	10	10	31.5
D	Brain	120	300	10	10	16.7
	chest	120	150	10	10	26
	Abdomen	120	200	10	10	31
	pelvis	120	200	10	10	32.5
E	Brain	120	330	10	10	16.5
	chest	120	330	10	10	26.3
	Abdomen	120	330	10	10	30.5
	pelvis	120	330	10	10	31.5
F	Brain	130	140	10	10	17
	chest	130	90	10	10	26.5
	Abdomen	130	110	10	10	30
	pelvis	130	110	10	10	32
G	Brain	120	224	10	10	16
	chest	120	280	10	10	26
	Abdomen	120	224	10	10	31.5
	pelvis	120	224	10	10	32

The chamber was aligned parallel to the scanner axis of rotation. Two polymethyl methacrylate (PMMA) cylindrical phantoms according to Food and Drug Administration (FDA) specifications [8, 9] were used for the measurements of ($CTDI_{100}$) in order to calculate ($_{n}CTDI_{w}$). The brain phantom was 14 cm long and 16 cm in diameter, with five holes drilled parallel to its long axis, one at the centre and four around the periphery, 90° apart and 1 cm from the edge. All holes could be filled with retractable PMMA inserts. The body phantom was 32 cm in diameter 14 cm in length, and was constructed similar to the brain phantom $CTDI_{100}$ measurements in this study were performed with the ionization chamber positioned at the four peripheral and central holes after removing the corresponding insert [5]. DLP was calculated by equation (5).

3. Results

The DLP values acquired for brain, chest, abdomen, and pelvis examinations were in the range of 255-1026, 76-1277, 48-737, and 69-854 mGy.cm, respectively. The average DLP obtained for the 7 studied machines for brain, chest, abdomen, and pelvis were 564, 444, 349 and 467 mGy.cm, respectively (Figure 2).
Minimum, maximum and 3rd quartile the of DLP distribution for brain, chest, abdomen, and pelvis are summarized in Table 3.
The values of $_{n}CTDI_{w}$ acquired for different machines were widly different, in some cases up to four folds, the range of figures obtained for brain, chest, abdomen, and pelvis were 5.7-26.2, 2.7-8.8, 2.1-9.9, and 2.1-9.9, mGy (mAs^{-1}), correspondingly.

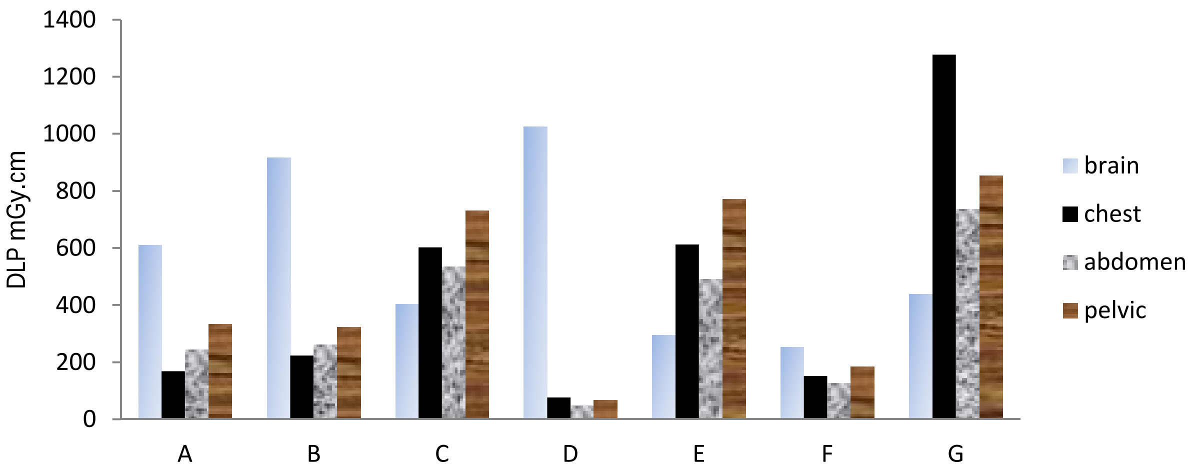

Figure 2. Measured DLP of the brain, chest, abdomen, and pelvis

Table3. DLP Values as obtained in this study (2010)

Examination	Dosimetry Quantity	Min	Max	3rd
Brain	DLP	255	1026	564
Chest	DLP	76	1277	444
Abdomen	DLP	48	737	349
pelvis	DLP	69	854	467

4. Discussion

The DLP value obtained for brain CT in this work (564 mGy.cm) is lower than the values reported by other researchers such as Torp et al. (740 mGy.cm) [10], Hidajat et al. (587 mGy.cm) [11], Shrimpton et al (787 mGy.cm) [12] and Hatziioannou et al. (677 mGy.cm) [5]. It should be noted, however, that all these reported values are much lower than the European DRL (1050 mGy.cm) [6]. The mean DLP (444 mGy.cm) acquired for chest CT in this study is lower than the IAEA-reported value (455 mGy.cm) [13,14], and the corresponding values reported by Papadimitriou et al (429 mGy.cm) for some centers in Greece and 483 mGy.cm for some centers in Italy [15]. The recommended DLP value in European guidelines for chest CT is 650 mGy.cm, which is higher than the corresponding value acquired in this study [6]. The wide range of results reported reveals the differences in the techniques used at different center. Since the DLP is the product of the $_{n}CTDI_{w}$ and the length of the patient's body it suggests that a particular examination is preformed differently in different centers, this is due to several reasons such as patient's problem, the operator's experience, and technical parameters applied and/or even the demographics for the given region (i.e., average height of the population).

DLP for abdominal CT (349 mGy.cm) is comparable to the values reported by Papadimitriou et al (493–551 mGy.cm) [15]. Hidajat et al [12] reported a lower DLP (247mGy.cm) when helical technique was used which is more than half of the corresponding value obtained in this study, showing once more the significance scan length.

DLP for abdominal and pelvic CT was 349 and 467mGy.cm respectively, which is lower than that reported by European guidelines (780 and 570mGy.cm) and Muhogora2009 [16]. These differences can be due to difference in exposure factors, scanner type, and technology.

5. Conclusion

Patient dose in general, $_{n}CTDI_{w}$ and DLP values in particular are greatly affected by technical parameters applied, technicians experience and CT machine type and technology. Patient's average height and weight are also relevant factors.

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