

Establishment of Diagnostic Reference Levels for Computed Tomography Scanning in Hamadan

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ABSTRACT

Background: New advancements have increased the capabilities of computed tomography as a sectional medical imaging modality. An important note is assessing absorbed dose to patients and minimizing it when performing computed tomography examinations. One approach to control dose is to establish diagnostic reference levels.

Objective: This study aimed to investigate diagnostic reference levels of computed tomography in Hamadan.

Material and Methods: This work was conducted as an experimental study. Computed tomography dose index (CTDI) was measured using a Piranha quality control kit, head and body CTDI phantoms for brain, lung, abdomen-pelvic and coronary CT angiography examinations. Volume Computed Tomography Dose Index (CTDI_{vol}) was calculated from obtained data and 3rd quartile of that was determined as diagnostic reference levels.

Results: Diagnostic reference levels (DRLs) in terms of CTDI_{vol} for brain, lung, abdomen-pelvic and coronary CT angiography were 50/25, 6/73, 22/01 and 32/06 mGy respectively in Hamadan. Difference between displayed CTDI_{vol} and measured CTDI_{vol} is not significance for all examinations ($p > 0.05$).

Conclusion: DRLs depend on to many dose affecting parameters in CT. DRL for brain CT is greater than other scan regions. Application of DRLs which resulted from this study can help to optimize radiation dose to the patients while maintaining acceptable diagnostic images quality.

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Keywords

Tomography, X-Ray Computed; Diagnostic Reference Levels; Radiation Dosage; Phantoms, Imaging; Hamadan

Introduction

Computed tomography (CT) as a medical imaging modality has shown new capabilities in the diagnosis of different diseases [1, 2]. The emergence of advanced CT scanners with high temporal and spatial resolutions has resulted in new techniques such as CT angiography, CT perfusion and CT colonography [3-7]. Even recently, some researchers have reported that high resolution computed tomography of lung has a high sensitivity in the diagnosis of patient infected with COVID-19 [8, 9]. In spite of such as these improvements, unfortunately, dose

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delivered to patients and public has increased which in turn causes concerns about cancers induced by radiation. Studies about ionizing radiation effects have shown that multiple CT scans can increase the risk of leukemia and brain tumors in child and adolescences [10, 11]. Implementation of radiation protection and dose optimization strategies is very important when performing CT scan. Many factors such as operators and interpreter radiologists' knowledge and expertise, scanner type, filter, scan time, patient body thickness, exposure factors, including kVP and mAs as well as selected protocol affect dose delivered to patients in CT scan [12, 13]. Multiplicity of these factors and imaging goal achievement make it difficult to determine a specific level of dose for a CT experiment. Diagnostic reference levels (DRLs) have been suggested as a dose optimization solution by the International Commission on Radiological Protection (ICRP) [14]. Some countries proceeded to establish DRLs for CT scan examinations accordingly [15-18]. DRLs are usually defined as 3rd quartiles of dose quantities such as $CTDI_w$, $CTDI_{vol}$ or DLP for a normal patient in CT scan [19]. In modern scanners, these quantities are displayed on console before exposure to the patient and the operator can compare them with DRLs and correct the parameters if necessary [1, 2]. Several studies should be con-

ducted all around the country in order to meet the required data to establish national DRLs in CT scan. This study aims to establish local DRLs (LDRLs) in Hamadan.

Material and Methods

This work as an experimental study was approved by ethics committee of Hamadan University of medical sciences (Approval ID: IR.UMSHA.REC.1396.539). All active CT scan centres were included in Hamadan city at time of study. They all were multislice, including three 16 slices and one 128 slices, and had quality control labels approved by the Atomic Energy Organization of Iran (AEOI) on the gantry. Information regarding scanners such as models, number of slices, manufacturer and existence of CTDI indicator on console as well as protocols data consisting of scan mode, slice thickness, pitch factor, kVp, mAs and reconstruction kernel were collected. Four most common scans, i.e. brain, chest, abdomen -pelvic and coronary CT angiography were chosen for investigation. Computed tomography dose index (CTDI) was measured using the head and body phantoms with 16 and 32 cm diameter, respectively, in addition to 15 cm length in conjunction with Piranha quality control kit (RTI Electronic, Sweden). Setup for measurement of CTDI is shown in Figure 1.

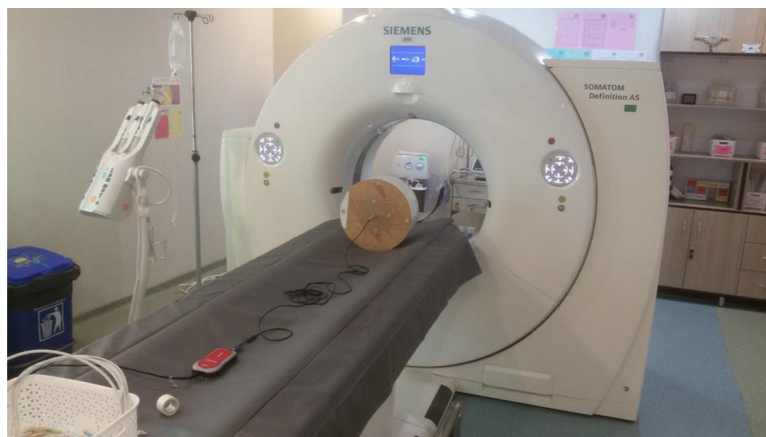


Figure 1: Setup for measurement of computed tomography dose index (CTDI)₁₀₀.

To establish DRL, we first measured $CTDI_{100}$. For brain, the head phantom was placed on the bed head support and CT dose profiler inserted once in the central hole and again in one of the peripheral holes. The body phantom was placed on the bed for other regions of interest. CT dose profiler connected to a laptop on which ocean software has already been installed. A scanogram was taken from the phantoms to determine the scan region. Then after using typical scan parameters for each region of the body, exposure was made simultaneously with the ocean software running. In order to estimate average dose across one slice, CTDI was converted to weighted CTDI ($CTDI_w$) by the following equation [20]:

$$CTDI_w = 1/3 CTDI_c + 2/3 CTDI_p \quad (1)$$

Pitch factor has an effect on $CTDI_w$. For a scan with the same parameters but different pitch factors, $CTDI_w$ is different. Volume CTDI ($CTDI_{vol}$) takes this effect into consideration as follows [20]:

$$CTDI_{vol} = CTDI_w / \text{pitch factor} \quad (2)$$

Effective dose is an important quantity by which we can estimate the risk of cancer and compare radiation dose between medical imaging modalities. In CT scan, it can be calculated from multiplying dose length product (DLP) by a constant (K). DLP is derived from the following equation [20]:

$$DLP = CTDI_{vol} \times L \quad (3)$$

L is the scan length for the region of interest. All scanners under study had the indicator of $CTDI_{vol}$ on their console which made it possible to compare that with calculated one. Third quartile of $CTDI_{vol}$ was considered as DRL.

Results

Scan parameters and displayed $CTDI_{vol}$

Scan parameters for the same examination were different to some extent between centers. They are shown in Table 1. Centers name are defined as A, B, C and D. Coronary CT angi-

ography is only performed in center D.

Measured CTDI

$CTDI_c$ and $CTDI_p$ were measured and results are separately shown for each region in Table 2. $CTDI_w$ has been calculated based on Equation 1.

$CTDI_{vol}$ and DLP

Table 3 shows the results for calculated $CTDI_{vol}$ and DLP for each center and region separately. Mann Whitney statistical test between measured and displayed CTDIs that the difference between these two quantities is not significance for all examinations ($p > 0.05$).

DRLs

For each examination, 3rd quartile of $CTDI_{vol}$ and DLP were calculated and considered as diagnostic reference levels. The results are shown in Table 4.

Discussion

Results showed that for scan of different regions of the body, different parameters are used. Scan parameters are different for a specific body region in various centers. This is because CT operators usually select scan parameters based on their experience and knowledge to provide the best possible outcome for diagnosis purposes. In addition, thickness and density of various body regions are different. Incorrect or non-optimal scan parameters impose unnecessary dose to the patient which in turn can result in induced cancer risk. What matters is that CT operators must be well trained and kept as low as reasonably achievable (ALARA) principle in their mind.

Results for measurement of CTDI showed that $CTDI_c$ and $CTDI_p$ are different in head and body phantoms. $CTDI_p$ is slightly greater than $CTDI_c$. This can be explained by two reasons as follows: firstly, in the range of kilo voltage used in CT scan, depth dose falls rapidly with depth which in turn causes higher dose in the surface rather than the depth of the phan-

Table 1: Scan parameters which are often used in computed tomography (CT) centers.

Center	Scanner model	Scan mode	Scan region	kVp	mAs per rotation	Rotation time(s)	Slice thickness(mm)	Number of taken slices	Displayed CTDI _{vol} (mGy)	Displayed DLP(mGy.cm)
A	Siemens SOMATOM Emotion-16 slices	Axial	Brain	110	270	1.5	8	10	34.89	280.58
			Chest	130	100	1	1.2	31	3.03	93.97
			*Abdominal-pelvic	-	-	-	-	-	-	-
		Spiral	Brain	110	220	1	4	41	32.34	627.4
			Chest	110	70	1	5	31	4.8	88.53
			Abdominal-pelvic	110	120	0.6	5	32	8.16	152.32
B	Optima GE-16 slices	Axial	Brain	120	270	0.8	5	15	130	975
			Chest	120	195	0.8	2	28	39.21	219.5
			Abdominal-pelvic	120	210	0.8	5	35	11.77	205.9
		Spiral	Brain	120	256	0.8	2.5	32	41.32	713.72
			Chest	120	170	0.8	5	31	8.76	160.73
			Abdominal-pelvic	120	250	0.8	5	31	8.665	236.26
C	Siemens SOMATOM Emotion-16 slices	Axial	Brain	130	270	1.5	5	8	55.94	223.7
			Chest	130	100	1	1.2	34	3.5	14.28
			Abdominal-pelvic	130	100	0.6	10	40	10.78	431.2
		Spiral	Brain	110	100	1.5	6	31	16.63	309.3
			Chest	110	70	0.6	10	18	5.42	97.5
			Abdominal-pelvic	110	95	0.6	8	32	7.36	188.4
D	Siemens Definition AS-128 slices	Axial	Brain	120	390	1	5	27	61.53	849.1
			Chest	120	110	0.5	1	60	1.45	43.6
			Abdominal-pelvic	120	210	0.5	5	41	15.52	321.3
		Spiral	Brain	100	322	1	4	31	49.7	786.6
			Chest	120	110	0.5	5	29	7.42	148.9
			Abdominal-pelvic	120	210	0.5	5	30	13.97	224.9
			Coronary **CTA	120	180	0.3	3	42	39.12	620

*This protocol has not been defined for this center.

**Coronary CT angiography is only performed in this center.

Table 2: Measured computed tomography dose index (CTDI)_c and CTDI_p. CTDI_w has been calculated based on Equation 1.

Center	Scan region	CTDI _c	CTDI _p	CTDI _w
A	Brain	35.95	34.67	35.09
	Chest	3.417	5.848	5.03
	Abdomen-pelvic	5.936	10.06	8.68
B	Brain	47.17	8.531	21.41
	Chest	5.892	6.897	6.56
	Abdomen-pelvic	8.665	*	2.88
C	Brain	18.05	18.05	18.05
	Chest	3.724	7.138	5.99
	Abdomen-pelvic	5.407	*	1.8
D	Brain	50.58	49.38	49.78
	Chest	5.558	9.618	8.26
	Abdomen-pelvic	10.08	18.13	15.44
	Coronary CTA	15.43	21.14	19.23

*No data registered by QC kit used in this study.

tom. Secondly, rotational geometry of radiation around phantoms creates isodose points. This means in a specific depth from phantoms surface, the dose is the same, it, however, decreases with depth. More the diameter of the phantom, more the difference between CTDI_c and CTDI_p. Hence, the difference between them is slightly greater in body phantom [2].

In all centers, the brain CTDI_{vol} is higher than other body regions. This is associated with higher radiation intensity compared to other regions because of the high density bones in the skull. Brady et al., have addressed this subject in their study [21].

Comparison between measured and displayed CTDI_{vol} showed that the difference is not significance; hence CT operators can consider the latter to have a control on patient dose while looking at Table 4 established by this study.

Results obtained from studies conducted in other places revealed that DRLs are not the same for the similar body region. DRL is a quantity influenced by several parameters such as operators and interpreter radiologists' knowledge and expertise, scanner type, filter, scan time, patient body thickness, exposure factors, including kVP and mAs as well as selected protocol. Brady et al., reported the diagnostic reference levels for CT scan of brain, chest and abdomen-pelvic are 45, 23 and 15 mGy, respectively [21]. Afzalipour et al., conducted a study to establish CT DRLs for children head, sinus, chest and abdomen-pelvis in Tehran. For age group between 10-15 year old, DRLs were found to be 44.53, 31.33, 6.33, 7.65 mGy, respectively. The results were expressed in terms of CTDI_w [22]. In a study by Tavakoli et al., DRLs for CT scan of head, sinus, chest and abdomen-pelvis in terms of CTDI_w in Isfahan were established. They reported DRLs for the above regions as 28.76, 26.86, 12.9 and 12.85 mGy, respectively [19]. Results of these studies as well as other studies showed that DRLs is a local area dependent quantity which is influenced by parameters that we discussed about previously in this section.

Conclusion

Radiation dose optimization and minimization are very important in CT scan because of high cancer induction risk compared to radiography. Unfortunately, it is not possible to define a specific dose level for each CT examination due to many factors affecting dose. Instead, establishment of DRLs for dose optimization in CT scan is a simple and practical way by which operators can control patients' dose.

Table 3: Results of computed tomography dose index (CTDI)_{vol} and dose length product (DLP) for different regions and centers.

Center	Scan region	DLP(mGy.cm)	Measured CTDI _{vol} (mGy)	Displayed CTDI _{vol} (mGy)	p-value
A	Brain	575.58	35.09	32.34	0.317
	Chest	97.6	6.29	4.8	0.317
	Abdomen-pelvic	173.7	10.85	8.16	0.317
B	Brain	126.87	15.85	41.32	0.317
	Chest	73.97	4.77	8.76	0.317
	Abdomen-pelvic	32.55	2.10	8.665	0.317
C	Brain	72.2	18.05	16.63	0.317
	Chest	24.45	5.99	5.42	0.317
	Abdomen-pelvic	46.13	1.80	7.36	0.317
D	Brain	658.85	55.31	49.7	0.317
	Chest	99.86	6.88	7.42	0.317
	Abdomen-pelvic	386.16	25.74	13.97	0.317
	Coronary CTA	403.97	32.06	39.12	0.317

Table 4: Diagnostic reference levels for brain, chest, abdomen-pelvic and coronary computed tomography angiography (CTA) in Hamadan.

	Brain	Chest	Abdomen-pelvic	Coronary CTA
CTDI_{vol} based DRLS (mGy)	50.25	6.73	22.01	32.06
DLP based DRLS (mGy.cm)	658.22	99.29	333	403.97

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Conflict of Interest

None

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