Original Article

A survey of computed tomography dose index and dose length product level in usual computed tomography protocol

ABSTRACT

Background: Nowadays, the use of computed tomography (CT) as a diagnostic tool has been considerably increased. Therefore, implementation of the program to conform the protection regulations on the CT scan is necessary to reduce the detrimental effects of radiation.

Objective: This study was performed to measure weighted CT dose index ($CTDI_w$) and dose length product (DLP) in routine CT protocols of the adult patients.

Methods: In this study, the patient dose was determined in routine CT protocols. The CT scanner used in this study was a single-slice Toshiba model. Scan parameters for each protocol were registered for 10 standard sized patients and then by applying it to the CT system, $CTDI_w$ and DLP mean values were calculated and finally the values of dose were compared with the reference dose limit.

Results: The mean values of $CTDI_w$ and DLP for head, para nasal sinuses, chest, abdomen, and pelvis protocols were 34.11, 19.67, 15.47, 13.95, 10.08 mGy and 362.67, 153.97, 307.33, 346.07, 189.37 mGy.cm, respectively. The mean values of $CTDI_w$ and DLP obtained in all of the protocols were less and even less than half in some of the protocols compared with the European guidelines and the UK reference values. However, mean values of CTDIw in the Chest and Abdomen protocols, were greater than IAEA reported values.

Conclusions: Using lower milli Amperes and higher kilo voltage peak as well as minimizing scan area and number of slices should be considered for more reduction in patients' dose.

KEY WORDS: Computed tomography, dose length product, reference dose level, weighted computed tomography dose index

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INTRODUCTION

Computed tomography (CT) scan has a wide range of usage as a tool for diagnosing.[1,2] Number of CT scan tests in the UK reached from 250,000 in 1980 to 5 million in 2013, which is a 20 times increase. During the same period in the USA, number of patients using the test reached from 2 million to 85 million (43 times increase).[3-5] CT scan tests in the UK and the USA constitute 11 and 17% of total X-ray based tests, respectively, and 67 and 49% of accumulated effective dose, respectively. It is notable that these figures in the world are 6 and 43%, respectively.[6-8] Absorbed dose to body tissue during CT scan test is one of the highest figures that patients received throughout diagnostic radiology processed (10–100 mGy). In general, these rates are above minimum dose level above which probability of cancer increases.[9] Surveys of CT scan tests carried out in the USA in 2007 showed that 29,000 new cases of cancer were caused by the tests.[10] This indicates the need to take into account advantages and disadvantages of CT dose length product test for the patient. On the other hand, a key principle to optimize utilization of CT scan tests is to limit patients' received dose based on as low as reasonably achievable. This entails knowledge of amount of patients' received dose.[9,11,12] To this end, weighted CT dose index ($CTDI_w$) and dose length product (DLP) are measured by CT scan facilities.[7,13-18] Taking into account the paucity of similar studies on standard CT protocols in Kashan, Iran, the above indices were measured in radiology

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ward of Kashan Shahid Beheshti Hospital and the results were compared with reference diagnostic level.

MATERIALS AND METHODS

The study was carried out in radiology ward using single-slice CT system (Toshiba) and based on standard protocols including head, para nasal sinuses (PNS), chest, abdomen, and pelvis. The parameters of each scan including distance from center, slice interval (I), slice thickness (T), milli Ampere (mA), kilo voltage peak (kV_p), number of slice (N), pitch factor (P), length of scan (L), and total acquisition time (t) were implemented on the system under clinical situation for 10 normal patients (height = 170 ± 10 cm; weight 70 ± 5). Afterward, by setting the system based on the parameters, the doses were measured and mean value of $CTDI_w$ and DLP was computed.

To measure the doses, pencil-form ionization chamber mode with active length of 10 cm and dosimeter UNIDOSE (PTW, Germany) and dose measurement standard phantom for head and body were used.

$CTDI_w$ and DLP were computed through the following methods.

Weighted computed tomography dose index

At first, head phantom to measure head dose and PNS and body phantom to measure chest, abdomen, and pelvis doses on CT bed surface were positioned at head rest and bed of CT. Then, ionization chamber was placed on central bore of the phantom and other bores were filled by acrylic bar and the dose values were measured through three scans and implementing clinical parameters on phantoms. Afterward, the same process was repeated for side bores of the phantom at 9, 6, 3, and 12 o'clock positions. The same steps were repeated for the 10 patients in each protocol.

Afterward, CTDI of each position was obtained as follows:

$$CTDI = \frac{1}{N.T}\int_{+50mm}^{-50mm} D(z)\,d(z) \quad (1)$$

Where, D (z) is radiation dose at Z direction, N is number of active detectors at each 360° rotation of X-ray bulb, and T is slice thickness.

Afterward, $CTDI_w$ was obtained:

$$CTDI_w = \frac{1}{3}CTDI_c + \frac{2}{3}CTDI_p\,(mGy) \quad (2)$$

Where, $CTDI_c$ is the obtained value of CTDI at central bore of head and body phantom and $CTDI_p$ is the average value of CTDI measured at 9, 6, 3, and 12 o'clock positions of head and body phantom.

Dose length product

DLP indicates patients' total dose received during a complete process of CT scan. To obtain DLP, we have:

$$\text{For axial scan: } DLP = \Sigma nCTDI.T.N.C\ (mGy, cm) \quad (3)$$

$$\text{For helical scan: } DLP = \Sigma nCTDI.T.A.t\ (mGy, cm) \quad (4)$$

Where, nCTDI is $CTDI_w$ divided by mAs, T is thickness of slice (cm), N is number of slices of each protocol, C is X-ray bulb current over radiation term (mAs), A is X-ray bulb current (mA), and T is total time of data collecting during a specific protocol(s).

RESULTS AND DISCUSSION

Maximum and minimum of scan parameters for different protocols in axial and helical modes are listed in Table 1.

As listed in the Table 1, PNS protocol has minimum mAs, slice thickness, and length of scan area; and chest protocol has maximum mAs and length of scan area.

Calculated DLP and $CTDI_w$ for different protocols in axial and helical modes are listed in Table 2.

Survey of the data listed in Tables 1 and 2 indicates that CTDIw of the protocols measured by head and PNS phantoms are more than those measured by body phantom. This is due to smaller diameter of head phantom, which results in distribution of radiation over smaller area. Value of $CTDI_w$ for head protocol is higher than PNS protocol given higher mAs of the former. Among chest, abdomen, and pelvis protocol, chest has highest $CTDI_w$ value given its higher mAs and Pelvis with lowest mAs has minimum $CTDI_w$. As to pelvis protocol, $CTDI_w$ of axial mode is less than that of helical mode, given lower value of mAs.

Axial mode of head, PNS, and pelvis show that DLP of head protocol is higher due to higher $CTDI_w$ (about four times) and

Table 1: Minimum and maximum parameters of different protocols in axial and helical modes

Protocol	Mode	kVp	mAs	P	T (mm)	I (mm)	L (cm)
Head	Axial	120	150-180	-	5-10	5-10	11
PNS	Axial		100	-	5	5	7.5-9
Pelvis	Axial		100-150	-	7-10	7-10	16.8-21
	Helical		120-150	1.2-1.5	7-10	7-10	20.9-30.6
Chest	Helical		200	1.5	10	10	26.5-33.1
Abdomen	Helical		180	1.2	7-10	7-10	24.6-33

kVp=Kilo voltage peak, mAs=Milli Ampere-seconds, P=Pitch factor, T=Slice thickness, L=Length of scan, I=Slice interval, PNS=Para nasal sinuses

Table 2: Mean value of dose length product and weighted computed tomography dose index for different protocols in axial and helical modes

Protocol	Mode	$CTDI_W$ (mGy)	DLP (mGy.cm)
Head	Axial	34.11	362.67
PNS	Axial	19.67	153.97
Pelvis	Axial	9.53	179.78
	Helical	10.64	198.96
Chest	Helical	15.47	307.33
Abdomen	Helical	13.95	346.07

$CTDI_W$=Weighted computed tomography dose index, DLP=Dose length product, PNS=Para nasal sinuses

Table 3: Comparing the scan parameters of this study and other studies

Protocol	Scan parameters	Current study	Kenya[14]	Iraq[17]	IAEA[20]	Taiwan[19]
Head	kVp	120	130	140	120	121
	mAs	165	249	256.5	260	343
	L	11	31.4	12	16.91	12.2
Pelvis	kVp	120	125	*	*	121
	mAs	125	225	*	*	295
	L	21.68	50	*	*	18.7
Chest	kVp	120	125	120	123	122
	mAs	200	181	180	157.6	268
	L	29.8	49.1	32	31.2	22.1
Abdomen	kVp	120	130	140	120	121
	mAs	180	209	360	147.6	292
	L	29.4	57	30	41.1	20.4

*Data were not available. kVp=Kilo voltage peak, mAs=Milli Ampere-seconds, L=Length of scan, IAEA=International Atomic Energy Agency

Table 4: Comparing weighted computed tomography dose index and dose length product values of this study and other studies

	Abdomen		Chest		Pelvis		Head	
	DLP	$CTDI_w$	DLP	$CTDI_w$	DLP	$CTDI_w$	DLP	$CTDI_w$
Current study	346.07	13.95	307.33	15.47	179.78	9.53	362.67	34.11
IAEA[20]	696	10.9	447	9.5	*	*	527	47
UK[21]	472	20	488	17	*	*	787	66
EC[22]	780	35	650	30	570	35	1050	60
Taiwan[19]	453	22	455	20	410	22	665	55
Kenya[14]	1143	21	745	21	943	24	1364	51
Iraq[17]	707	22.1	447	12	*	*	1094	45.6

*Data was not available. $CTDI_w$=Weighted computed tomography dose index, DLP=Dose length product, IAEA=International Atomic Energy Agency

despite smaller scan area (about half of pelvis protocol), DLP of PNS protocol is lowest given length of scan area and lower $CTDI_w$.

Abdomen DLPs level in helical mode was higher than that of chest and pelvic protocols, which is due to lower pitch factor and DLP of pelvis protocol was minimum due to smaller scan area.

Table 3 compares scan parameters including kVp, mAs, L, with the recommended values of IAEA and studies conducted in Taiwan, Kenya, and Iraq.

As listed in Table 4, value of $CTDI_w$ and DLP are lower than recommended values by European Committee and UK-2003 guidelines; even half of the recommended values in some cases are listed. This is probably due to difference in scan parameters under study. Value of $CTDI_w$ and DLP in head protocol was less than reported values from Taiwan, Iraq, and Kenya and also IAEA recommendation, which is probably due to lower mAs and length of scan area. $CTDI_w$ of chest protocol is higher than values reported from Iraq and IAEA recommendations; however, due to shorter length of scan area, value of DLP was less than those reported by other studies. It is notable that value of DLP and $CTDI_w$ due to less radiation power in the study was less than reported values from Taiwan. Regarding pelvis and abdomen protocols, value of $CTDI_w$ and DLP was less than reports from Taiwan, Kenya, and Iraq, which is due to lower scan parameters setting in this study. Regarding abdomen protocol, the obtained $CTDI_w$ was higher than IAEA recommendation, which is due to higher mAs; additionally, DLP was less than IAEA recommendation, which is due to shorter scan area.

CONCLUSION

Using of the lower mAs and higher kVp as much as quality of image and noise level allow are recommended for more reduction in patients' dose. In addition, minimizing scan area and number of slices as far as coverage of the whole anatomic area permits is recommended. Helical mode must be used instead of axial mode as far as increase of X-ray bulb temperature allows. Furthermore, to reduce patients' received dose, it is better to shorten total scan time by adopting higher pitch in helical mode.

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Conflicts of interest

There are no conflicts of interest.

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