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Original Article

The Patient Radiation Dose in Whole Abdomen and Thorax Computed Tomography at Songklanagarind Hospital

Anchali Krisanachinda, MD.[1], Suwimol Jittakul, MD.[2], Uppatham Polpichai, MD.[3], Amporn Funsian, MD.[4]

[1] Department of Radiology, Faculty of Medicine, Chulalongkorn University

[2] Department of Radiology, Tamod Hospital, Patthalung Province Public Health Office

[3] Department of Radiology, Sikarin Hatyai Hospital

[4] Department of Radiology, Faculty of Medicine, Prince of Songkla University

Abstract

The purpose of this study is to determine the patient radiation dose and the factors affecting in order to develop the potential methods for the radiation dose reduction. The basic population consists of 100 patients who underwent the chest and abdominal computed tomography examinations at Songklanagarind Hospital.

The result shows the average dose length product, DLP, calculated for chest and abdominal CT of 448.10 and 1,192.59 mGy.cm respectively. The average weighted CT Dose Index CTDIw were 8.4 mGy for chest and 11.2 mGy for abdomen. 47 patients or 94 percent for DLP chest CT were lower than the dose reference level of 650 mGy.cm. For abdominal CT, 44 patients or 88 percent of sample population received the radiation dose higher than the dose reference level of 800 mGy.cm. All CTDIw were below the dose reference level of 30 mGy for chest and 35 mGy for routine abdomen.

The major factors affecting the patient radiation dose are the scan techniques such as the tube voltage, tube current, the scan time, the slice thickness, the scan length and the number of the phases or scans. Adaptation of the scan techniques, the reconstruction algorithm and the adjustment of the slice thickness to the appropriate scan length enable the reduction of the patient dose. The result of this study will lead to the awareness of the radiologists and technologists for the proper use of CT especially whole abdomen in young adult and in pediatric studies.

Introduction

When Godfrey Hounsfield[1] developed the first clinical CT scanner in 1971, a new era of 3D visualization of the human body was initiated. During the 1970s the second, third and fourth generation scanners were developed, but by the end of the 1970s the basic principles of the CT scanner were well established, and the same principles are used in all scanners today. It was not until the late-1990s that rapid development started again. Largely this was the development of multi-row detector scanners and the culmination of efforts to increase the heat capacity or cooling of the x-ray tube. These faster scanning techniques enabled many more patients to be examined by the same number of staff. It also greatly increased the indications for the use of CT, partly because arterial and venous phases could be separated. As well as faster scan times and more clinical indications for the use of CT, the worldwide sale of CT scanners has more than doubled since 1998, and is predicted to continue at the same pace.

In recent years there has been increasing concern over the radiation dose to patients from CT studies.[2-4] The risk of cancer from all diagnostic x-ray procedures has recently been estimated to be between 0.5 and 3% of that for all cancers in developed countries. Although these risks seem relatively high, the current risks must be even higher, as most of the utilization data on diagnostic procedures in this published study was taken from the period 1991-96[6].

Since that time several generations of multi-row detector CT scanners have been introduced, resulting in increased patient throughput and increased indications for CT examinations. Recent papers have estimated that CT examinations now account for nearly 70% of the dose to patients in a tertiary care US hospital.[7] A recent radiation audit in a Canadian hospital provided essentially identical results, showing CT examinations delivering 60% of patient effective radiation dose.[8]

In diagnostic imaging the largest patient doses per examination come from CT and angiographic procedures. In angiography the therapeutic procedures generally give a higher dose to the patient than the diagnostic exams. In recent years, diagnostic angiography has largely been replaced by CT angiography in many radiology departments, possibly further increasing the overall dose to patients.

Materials

1. Computed Tomography System. Manufacturer Philips Medical System Model Tomoscan AV Serial number K 813952902. (Fig. 1)

2. Ionization chamber and Electrometer Manufacturer RADCAL Model 9095 (Fig. 2)

3. Body CT Phantom diameter 32 cm. with 100 mm. pencil ion chamber (Fig. 3)

4. Fifty patients for whole abdomen scan, fifty patients for whole chest scan.

Methods

1. Perform the quality control of the CT scanner

2. Determine the exposure dose using AAPM and IAEA protocols for

   2.1 CTDI in air

   2.2 CTDI in phantom

   2.3 The weighted CTDI, CTDIw

Before patient data collection, CTDI measurements were performed using a pencil-shaped ionization chamber with appropriate calibration

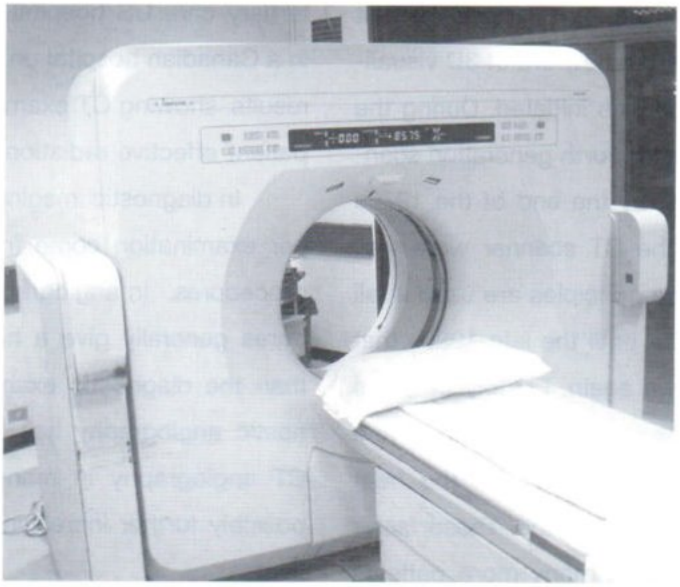

Fig.1 Computed Tomography System. Manufacturer Philips Medical System Model Tomoscan AV Serial number K 813952902.

Fig.2 Ionization chamber and Electrometer Manufacturer RADCAL Model 9095

Fig.3 Body CT Phantom diameter 32 cm with 100 mm pencil ion chamber set at the center of the gantry for CTDI measurements.

certificate. The measurements were done in air for simplification purposes, using the following technical parameters: 120 kVp, 5 mm, 100 mAs and 1 pitch. The CTDIair results were compared with the Impact Group results (http://www.impactscan.org/) which provides the CT dose information for every CT scanner type and practically every clinical protocol used in routine procedures.

2.4 Dose-Length Product (DLP)

DLP is a dose descriptor that characterizes the exposure of a complete examination and is estimated by the following formula:

$$DLP = CTDI_{wi}*T_i*N_i \quad [1]$$

where T_i is each different slice thickness used in the examination protocol, N_i is the number of T_i slices and CTDIwi is the value of CTDIw of each particular slice thickness T_i.

2.5 The Effective Dose (E) mSv

The effective dose is estimated by first estimating the energy imparted to the body region being scanned and then multiplying by the ratio factor for that particular region.

$$E = DLP.\, f_{mean}.\, k_{CT} \quad [2]$$

f_{mean} is the average conversion factor for the specified region

k_{CT} is the scanner factor

3. Patient data collection:

3.1. H.N.

3.2. Age, weight, height, gender

4. Patient dosimetric data collection.

4.1. Record the following parameters: kVp, mAs, slice thickness, the ratio of slice width and bed index, SW/BI, scan length, number of phases of study.

4.2. Determine the CTDIw, DLP for the chest and abdominal regions

4.3. Compare the result in 3.2 to the dose reference level, DRL

4.4. Calculate the patient effective dose

Results

1. The CTDI in air. The 100 mm ionization camber was placed in air at the central point of the gantry. The chamber was exposed 5 times and the average result was recorded in Table 1. The measured CTDI was compared to ImPACT data to obtain the percent error of the measurement. The result is accepted when within 10 percent of the ImPACT. (table 1)

2. The CTDI in phantom. The 100 mm chamber was inserted in the centre position of the body phantom and measure the dose as the result in table 2.

3. The CTDI at four peripheral positions of body phantom were measured as in table 3 and compared to the ImPACT scan value as in Table 4.

Table 1 The CTDI in air is compared to ImPACT value.

CTDI in air (mR)						Measured CTDI (mGy)	ImPACT CTDI (mGy)	Percent Error
1	2	3	4	5	Average			
2.14	2.19	2.18	2.13	2.18	2.16	18.92	19.3	9.8

4. The weighted CTDI determination:

CTDIw = 1/3 CTDI(center)+2/3CTDI (peripheral)
= 6.8 mGy

5. Patient dose determination. The weighted CTDI (mGy) and the DLP (mGy.cm) for 50 patients underwent CT of the chest and 50 CT of the whole abdomen were determined. The result on DLP is displayed as the average, range and compared to the dose reference level (DRL) as in the table 5. The weighted CTDI for chest and whole abdomen are shown in table 6 and compared to the DRL.

The dose length product for both studies exceeds the DRL of 3 from 50 chest and 44 from 50 whole abdomen as details in table 7.

The dose length product is increasing as the increasing number of slices as in table 8 and as the increasing number of phases as in table 9.

The scan technique in this study is as the followings, the range of mAs is 150-200, the slice thickness is 3-7 mm resulting in the DLP exceeds the DLR as in table 10.

Table 2 The CTDI at the centre of the body phantom of 32 cm. diameter.

CTDIcerter (mR)						Measured CTDI (mGy)	ImPACT CTDI (mGy)	Percent Error
1	2	3	4	5	Average			
0.46	0.45	0.44	0.45	0.44	0.45	3.94	4.3	9.16

Table 3 The CTDI at 4 positions peripheral sites on the body phantom of 32 cm diameter.

	$CTDI_{PERIPHERAL}$ (mR)						Measured		ImPACT	
Position	1	2	3	4	5	Average (mR)	Average (mR)	mGy	mGy	Percent Error
Top	1.04	1.04	1.03	1.03	1.02	1.03				
Bottom	0.82	0.84	0.82	0.82	0.82	0.82	0.94	8.23	9.00	9.14
Right	1.00	0.98	0.98	0.99	1.00	0.99				
Left	0.93	0.94	0.93	0.93	0.94	0.93				

Table 4 ImPACT scan data for Philips Tomoscan Model AV LX SR 7000

kVp	Sub-group	Scanner	CTDI Head, mGy/100mAs			CTDI Body, mGy/100mAs			ImPACT Factor	
			Air	Centre	Perip	Air	Centre	Perip	Head	Body
120	PH.e.120	Philips AV, LX, SR7000	19.3	13.6	14.8	19.3	4.3	9.0	1.03	1.01

Table 5 The Dose Length Product, DLP (mGy.cm) for 50 chest and 50 whole abdomen scans.

Organ	Range (mGy.cm)	Average (mGy.cm)	DRL (mGy.cm)
Chest	288.29-709.63	448.10	650
Whole abdomen	613.54-1714.94	1192.59	800

Table 6 The weighted CTDI for this study

Organ	Average CTDIw (mGy)	DRL CTDIw (mGy)
Chest	10.5	30
Whole Abdomen	13.4	35

Table 7 Number of patients with DLP, mGy.cm exceeds the dose reference level

Organ	Number	Percent
Chest	3/50	6
Whole abdomen	44/50	88

Table 8 The dose length product for whole abdomen and chest CT scans in relative to the number of slices.

Number of Slices	Whole Abdomen DLP (mGy.cm)	Chest DLP (mGy.cm)
39-50	-	288.29-369.60
51-70	-	376.99-517.43
71-90	739.20 (75 slices)	524.74-591.36
91-120	896.60-1183.20	672.34-709.63 (96 slices max)
121-209	1192.58-1714.94	-

Table 9 The average number of phases and number of slices per phase

Organ	Average Number of Phases	Number of Slice per Phase
Chest	2.2 (1-3 phases)	28
Abdomen	2.7 (2-5 phases)	47

Table 10 The CT scan techniques resulted in the excess DLP in abdomen

mAs	Slice Thickness (mm)	Number of cases	Percent	Number of cases exceed DRL
150	7	2	4	1
175	7	11	22	9
200	7	32	64	31
150	3	1	2	1
175	5	1	2	1
200	5	3	6	2

Table 11 The Effective Dose (E, mSv) for Chest and Whole Abdomen

Study	E_{Av}, mSv	E_{min} mSv	E_{max}, mSv
Chest	2.44	1.57	3.86
Whole Abdomen	6.87	3.53	9.82

In order to compare CT procedures with other types of radiological examinations and to estimate the radiological risk, the effective dose, E (mSv) was calculateded according to Hidajat 1996,[11] as in the equation[2] and the results are shown in table 11.

Discussion

The EC[9] specify criteria for patient dose for CT examinations and give examples of good imaging technique. The dose that the patient receives in a CT examination is determined by two aspects of the particular scanner - the radiation output characteristics of the scanner and the clinical protocol of how the scanner is used in performing the examination. The first aspect can be determined using the $CTDI_w$ - a weighted measure of the amount of radiation the scanner "uses" per slice. This parameter in turn depends on the kVp, base filtration, shaping filters, slice width and the mAs per slice. The second aspect is essentially determined by the volume scanned. The combination of these two aspects determines the patient dose, which can be specified by effective dose or more simply by DLP.

The specification for CTDIw for the general chest CT is that it should be less than 30 mGy[9] which all CTDIw values in this study were 10.5. The protocol for chest is 120 kVp, 150 mAs and the slice thickness is 7.0 mm for all 50 cases. The average $CTDI_w$ for whole abdomen is 13.4, with minimum and maximum values of 10.5 and 14.0 mGy as in Figure 4. The abdomen protocol is 120 kVp, 150-200 mAs, and 3-7 mm slice thickness. These values are compared to the Dose Reference Level reported from the UK[10] of 35 mGy criteria for CTDIw.

Dose length product is an overall measure of patient dose. The proposed diagnostic reference level for DLP is given as 650 mGy. cm for chest.[9] The average of the reported DLP values was 448.1, with minimum and maximum values of 288.3 and 709.6 mGy.cm as in figure 5. These values are very similar to those reported from the UK.[10]

For the whole abdomen, the average DLP was

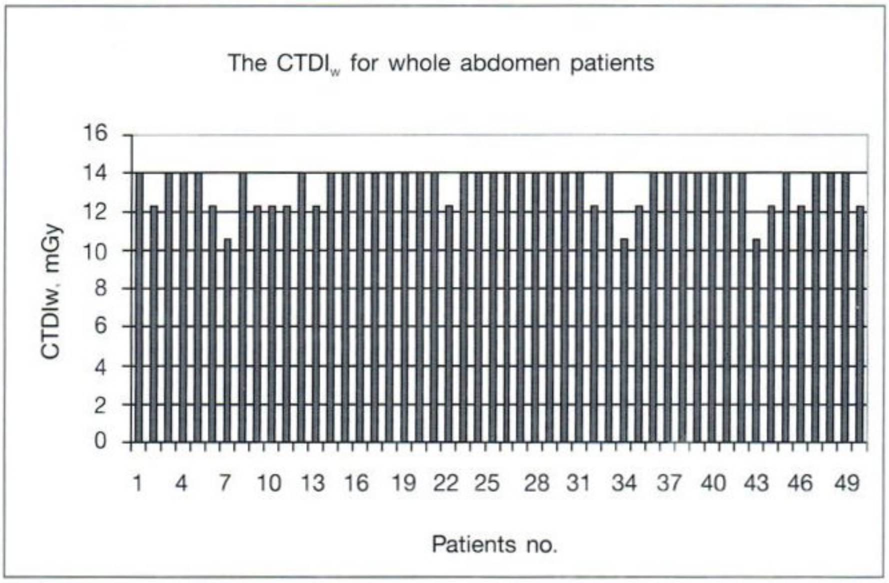

Fig. 4 The weighted CTDI for whole abdomen of 50 patients with DRL of 35 mGy

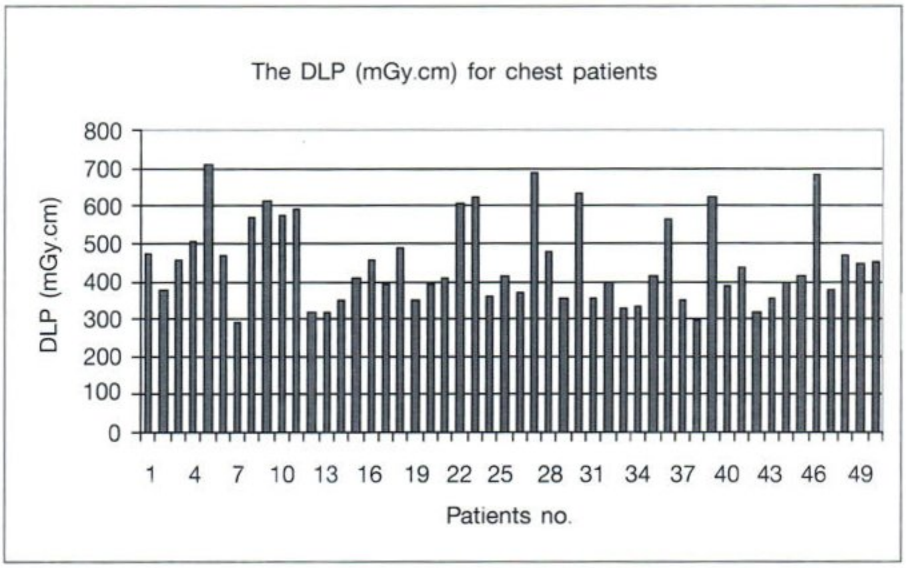

Fig. 5 DLP for chest patients with Dose Reference Level of 650 mGy.cm

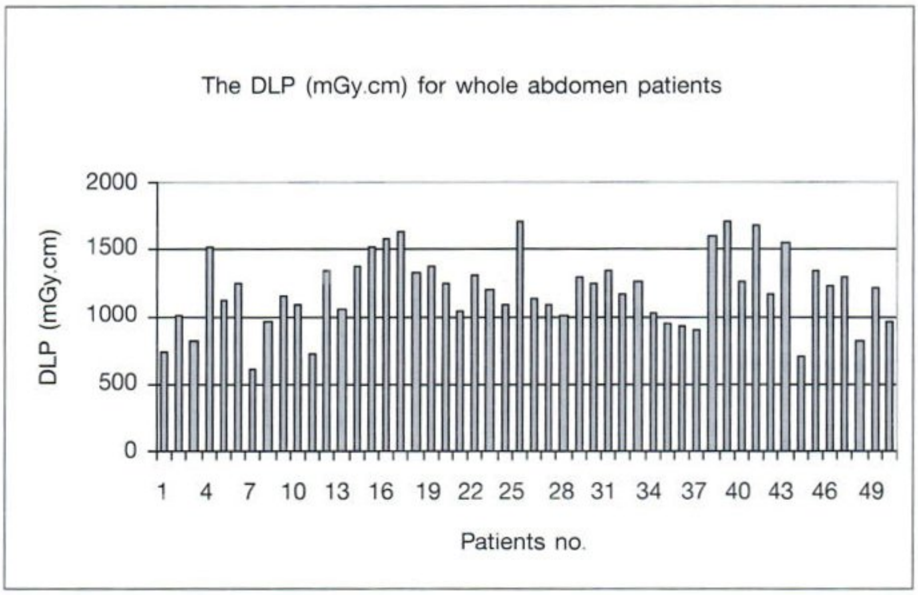

Fig. 6 The DLP for 50 whole abdomen patients which DRL is 800 mGy.cm

1,192.59 with the range of 613.54 - 1,714.94 mGy.cm as in figure 6. The DRL is 800 mGy.cm

The EC[9] in "examples of good imaging technique" states that the nominal slice width should be in the range 7 to 10 mm, with an inter-slice distance of zero (contiguous slices) or a pitch equal to 1 in the case of spiral scanners. Our technique used slice widths of 7.0 mm for chest CT and 3 to 7 mm for abdomen with one 3 mm, four 5 mm and forty-five 7 mm slice widths respectively.

The scan length for each patient was variable and dependent on the number of phases. For chest,

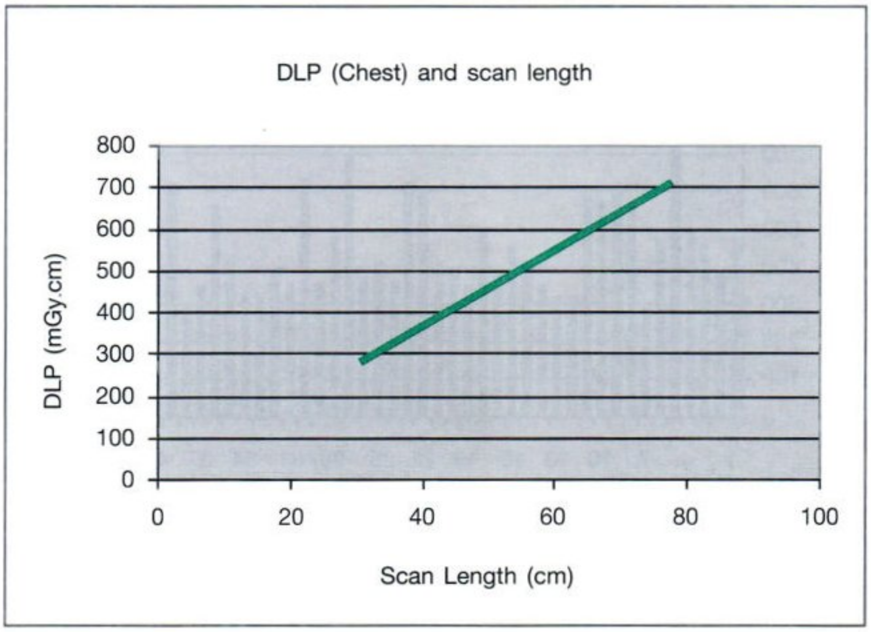

Fig.7 The linear relation of the scan length and DLP in chest CT patients.

the average number of phases was 2.2 and the range was 1-3. For abdomen the average was 2.7 and the range was 2-5 as in Table 11. The DLP was reflected by the scan length for chest. The maximum length of 74.4 cm, 2 phases resulted in DLP of 687.5 mGy.cm as in Figure 7.

Conclusion

As the number of CT examinations is increasing rapidly, patient dose reduction is a task that needs urgent attention. Appropriate use of reduced dose protocols for common clinical indications requires further investigation. Radiation dose reduction is a key in the pursuit of novel applications of multi-detector CT. Medical personnel involved in radiological imaging should be familiar with the variety of methods and techniques for radiation dose reduction to ensure that radiation exposure is kept as low as reasonably achievable.

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