Measurement of radiation dose in multi-slice computed tomography

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Article Info

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Abstract

The aim of this study was to measure the radiation doses for computed tomography (CT) examinations of the head, chest and abdomen in adult patients in Nepal in comparison to international standard. Dose length products (DLP) and effective doses for standard patient sizes were calculated from the reported volume CT dose index ($CTDI_{Vol}$). Details were obtained from approximately 90 CT examinations carried out in 128 slice CT scan. Effective dose was calculated for each examination using CT dose indices, exposure related parameters and CTDI-to-effective dose conversion factors. The CTDI and DLP were below the established international reference dose levels for head and chest while for the abdomen and pelvis, the CTDl and DLP were above the established international reference dose levels. The mean effective doses in this study for the head, chest, and abdomen were 1.7, 5.4 and 17.7 mGy respectively. In conclusion, for the routine head and chest protocol, CTDI, DLP and effective dose were found to be significantly lower compared to the recommendation of European Commission. However, abdomen CT scans showed higher dose values because of multiple phase scans and longer scan lengths.

Introduction

Computed tomography (CT) is an imaging modality that produces cross sectional images representing the X-ray attenuation properties of the anatomical structures.[1] European Union, in an ionizing radiation protection directive, has classified CT as a high dose diagnostic procedure and has pointed to the need to reduce the dose to the patient.[3]

Efforts towards dose reduction in CT have been recommended by the International Commission on Radiological Protection (ICRP). The ICRP, the International Atomic Energy Agency, and the European Commission have all recommended the setup and the implementation of CT dose guidance levels for the most common CT examinations to promote strategies for the optimization of radiation doses.[4] Computed Tomography Dose Index (CTDI) is the most widely used CT dose quantity, which integrates the long axis dose profile resulting from a single slice rotation of the X-ray tube. Another important dose quantity is the dose length product (DLP), which includes the patient, or the phantom volume irradiated during a complex examination.

The importance of radiation dose from X-ray CT has been underlined recently by the attention given in the scientific journals and literatures to issues of doses and the associated estimated risk. The dose levels contributed by CT exceeds those from conventional radiography and fluoroscopy and the usage of CT continues to expand, often by 10-15% per year.[5] Thus, CT will continue to contribute a substantial portion of the total collective dose delivered to the general public from medical examinations involving ionizing radiation. The rapid development of CT technology and the resultant explosion in new clinical applications, including cardiac CT, perfusion CT have created obligating need to teach, understand, and use CT dose information in more practical aspects.

The objective of this study was to measure CTDI and DLP during the most frequent CT examination. The mean values of computed tomography dose index weighted ($CTDI_w$), DLP and effective dose were calculated for each protocol and were compared with the recommendations of European Commission.

Materials and Methods

This retrospective study was carried out from July to September 2015. CT performance information and examination parameters (for head, chest, abdominal and pelvic protocols) from the Teaching Hospital were collected.

Details were obtained from 90 CT examinations carried out in 128 slices CT scan (Siemens, SOMATOM Definition AS). DLP and effective dose (ED) for standard patient sizes were calculated from the reported volume CT dose index $CTDI_{VOL}$. Effective dose was calculated for each examination using CT dose indices, exposure related parameters and CTDI-to-effective dose conversion factors. The findings were then categorized and analyzed using SPSS version 21 and Microsoft Excel 13. The examination of head, chest and abdomen were only included.

For each protocol, 30 cases were collected. The patients that were included in the survey were selected in order to correspond to the typical patient (weight 40-70 kg). Examination other than head, chest and abdomen were excluded. Patients with weight out of range were rejected. Patients with gross abnormalities were rejected.

Results

CT scans of head (n=30), chest (n=30) and abdomen (n=30) were done. The doses to the patient were expressed in terms of $CTDI_{vol}$, DLP and effective dose.

For head examination

The mean age of the patients (male 15, female 15) was 27.9 ± 8.2 (SD) years. The average weight and height of the patients was 56.4 ± 6.7 kg and 1.6 m respectively. The mean body mass index (BMI) was 21.8 ± 2.0 kg/m^2.

The mean $CTDI_{VOL}$ before and after scan for routine head protocol was 45.9 ± 4.1 mGy and 45.5 ± 4.1 mGy respectively. The DLP before scan had a mean value of 756.7 ± 76.3 mGy-cm. The DLP after scan had an average value of 750.9 ± 77.3 mGy-cm. The mean effective dose was 1.7 ± 0.2 mSv.

For chest examination

The mean age of the patients (male 18, female 12) was 30.3 ± 13.7 years. The average weight of the patients was 56.4 ± 7.8 kg. The average height was 1.6 ± 0.1 m. The mean BMI was 21.6 ± 2.2.4 kg/m^2 .

The mean $CTDI_{VOL}$ before scan for non-contrast CT chest was 6.1 ± 1.9 mGy, and after scan was 5.6 ± 1.6 mGy (Table I). The mean $CTDI_{VOL}$ before scan for contrast enhanced were 6.0 ± 1.9 mGy and for after scan were 5.6 ± 1.8 mGy. The DLP before scan for non-contrast studies had a mean value of 215.0 ± 57.5 mGy-cm and for after scan were 189.6 ± 52.4 mGy-cm. The DLP before scan for contrast enhanced examinations had an average value of 219.6 ± 62.7 mGy-cm and for after scan, the mean value was 198.0 ± 60.2 mGy-cm. The average CTDI for both non-contrast and contrast enhanced studies was 11.2 ± 3.6. The mean DLP for both examinations was 390.5 ± 115.3. The mean effective dose was 5.4 ± 2.4 mSv.

Table I

Radiation dose parameters in CT chest and abdomen

Particulars	n	Before scan	After scan
Chest			
CTDI plain (mGy)	30	6.1 (1.9)	5.6 (1.6)
DLP plain (mGy-cm)	30	215 (57.5)	189.6 (52.4)
CTDI contrast	19	6.0 (1.9)	5.6 (1.8)
DLP contrast (mGy-cm)	19	219.6 (62.7)	198.0 (60.2)
CTDI sum after scan			11.2 (3.6)
DLP sum plain and contrast			390.5 (115.3)
Effective dose			5.4 (2.4
Abdomen			
CTDI plain	30	11.6 (3.5)	11.1 (3.5)
DLP plain (mGy-cm)	30	516.5 (155.2)	486.5 (156.7)
CTDI arterial	25	9.7 (4.1)	9.2 (4.0)
DLP arterial (mGy-cm)	25	336.4 (156.7)	288.9 (126.9)
CTDI portovenous	25	10.6 (3.6)	10.1 (3.5)
DLP portovenous (mGy-cm)		450.9 (159.3)	422.8 (157.6)
CTDI delayed		10.4 (4.0)	9.8 (4.0)
DLP delayed (mGy-cm)		418.1 (115.7)	391.3 (114.6)
DLP sum			1180.5 (507.8)
CTDI sum			30.8 (14.5)
Effective dose (mSv)			17.7 (7.6)

Data are mean; Data within the parenthesis are SD

For abdomen examination

The mean age of total 30 patients (21 male and 9 female) was 40.7 ± 15.8 years. The average weight of the patients was 57.9 ± 7.7 kg. The mean BMI was 21.8 ± 2.3 kg/m^2.

The mean $CTDI_{VOL}$ before scan for non-contrast CT

Table II

Comparison of $CTDI_{VOL}$, DLP, ED of TUTH with European Commission (EC)

Examination		Mean (TUTH)	EC
Head	$CTDI_{vol}$ mGy	45.5	60
	DLP mGy cm	750.9	1050
	Eff. Dose mSv	1.7	2.4
Chest (Plain and contrast)	$CTDI_{vol}$ mGy	11.2	30
	DLP mGy cm	390.5	650
	Eff. Dose mSv	5.4	11.1
Abdomen (Plain and contrast)	$CTDI_{vol}$ mGy	30.8	35
	DLP mGy cm	1180.5	780
	Eff. Dose mSv	17.7	11.7

chest were 11.6 ± 3.5 mGy and after scan were 11.1 ± 3.5 mGy. The DLP before scan for non-contrast studies had a mean value of 516.5 ± 155.2 mGy-cm and for after scan were 486.5 ± 156.7 mGy-cm. The mean $CTDI_{VOL}$ before scan for contrast enhanced arterial phase were 9.7 ± 4.1 mGy and for after scan were 9.2 ± 4.0 mGy. The DLP before scan and after scan for contrast enhanced arterial phase had an average value of 336.4 ± 156.7 and 288.9 ± 126.9 mGy-cm respectively. The mean $CTDI_{VOL}$ before and after scan for portovenous phase were 10.6 ± 3.6 and 10.1 ± 3.5. The mean DLP before and after scan for portovenous phase were 450.9 ± 159.3 and 422.8 ± 157.6. The mean $CTDI_{VOL}$ before and after scan for delayed phase were 10.4 ± 4.0 and 9.8 ± 4.0. The mean DLP before and after scan for delayed phase were 418.1 ± 115.7 and 391.3 ± 114.6 respectively. The average CTDI and DLP after scan for all CT chest studies was 30.8 ± 14.5 mGy and 1180.5 ± 507.8 mGy-cm. The mean effective dose was 17.7 ± 7.6 mSv.

The range and mean values of volumetric computed tomography dose index ($CTDI_{vol}$), dose length product (DLP) and effective dose are given in Table II. The results are compared with European Commission guidelines (EC).

Discussion

The $CTDI_W$, DLP and effective dose were calculated in the patient who did not have any gross pathology. For head protocol, the mean $CTDI_{VOL}$ after scan, DLP after scan and effective dose were 45.5 ± 4.1 mGy and 750.9 ± 77.3 mGy-cm and 1.7 ± 0.2 mSv respectively. For chest examinations, the mean $CTDI_{VOL}$ for non-contrast studies after scan were 5.6 ± 1.6 mGy, for contrast enhanced were 5.6 ± 1.8 mGy, DLP for non-contrast studies after scan were 189.6 ± 52.4 mGy-cm, for contrast enhanced examinations after scan had a mean value was 198.0 ± 60.2 mGy-cm. The average CTDI for both non-contrast and contrast enhanced studies was 11.2 ± 3.6. The mean DLP for both examinations was 390.5 ± 115.3. The effective dose had a mean value 5.4 ± 2.4 mSv. For abdomen examinations, the mean $CTDI_{VOL}$ for non-contrast, arterial phase, portovenous phase and delayed phase after scan were 11.1 ± 3.5 mGy, 9.2 ± 4.1 mGy, 10.1 ± 3.5, 9.8 ± 4.0 respectively. The DLP after scan for non-contrast, arterial, portovenous and delayed phase were 486.5 ± 156.7 mGy-cm, 288.8 ± 126.9 mGy-cm, 422.8 ± 157.6, 391.3 ± 114.6 respectively. The average CTDI and DLP after scan for all CT chest studies was 30.8 ± 14.5 mGy and 1180.5 ± 507.8 mGy-cm. The mean effective dose was calculated as 17.7 ± 7.6 mSv.

Elameen et al. (2010) measured radiation doses in 160 CT examinations of the adults in three Sudanese hospitals.[6] The report of a CT survey indicated the mean DLP values for adult patients were ranged from 272-460 mGy-cm (head) 195-995 mGy-cm (chest), 270-459 mGy-cm (abdomen). Effective dose was calculated for each examination using CT dose indices, exposure related parameters and CTDI-to-effective dose conversion factors. CT air kerma index (CTDI) and dose length products (DLP) were below the established international reference dose levels. The mean effective doses for the head, chest, and abdomen were 0.82, 3.7 and 5.4 mSv respectively. Those values were observed that the effective dose per examination was lower in Sudan than in other countries. The difference was seen identified in CTDI, DLP and ED.

Abdullah (2009) measured Computed Tomography Dose Index in air CTDI (air) in Malaysian hospitals in 426 adult and 26 pediatric CT examinations.[7] Effective doses for examinations of routine head, routine chest and pelvis were within the same range with studies conducted for the European guidelines, the UK and Taiwan. For the routine abdomen examination, the effective dose were still within the range compared to the studies for European guidelines and Taiwan, but 55.1% higher than the value from the study conducted in the UK. It provided the third quartile values of effective doses for every CT examination collected so that they could be used as reference in establishing the dose reference level of CT examinations in Malaysia.[7] However, in this study, the CTDI and DLP were significantly higher than in UK for head, chest and abdomen scans.

Øberg (2011) measured the effective dose and its application to the medical field. Their objective was to calculate the effective dose (ED).[8] In this study, these data promises to provide the exposure doses

Table III

Comparison of CTDI, DLP, ED of CT head, chest and abdomen in different countries

	TUTH	Taiwan[13]	Italy[14]	Wales[15]	Poland[10]	Tanzania[16]	Ireland[17]	Berlin[18]	UK[10]
CTDI (mGy)									
Head	45.5	55	59.6	46	19	43	57.5	49.5	5
Chest	11.2	20	19.7	17	21.3	17	18.5	17.41	6.4
Abdomen	30.8	22	24.3	22	23.7	17	19.1	-	9.5
DLP (mGy-cm)									
Head	750.9	665	725	731	386	913	817	587	386
Chest	390.5	455	473	663	447	783	434	502	203
Abdomen	1180.5	453	517	745	550	982	433	-	446
Effective dose (mSv)									
Head	1.7	1.6	1.7	-	-	2.1	1.6	-	-
Chest	5.4	8.4	8.0	-	-	13	7.6	-	-
Abdomen	17.7	7.4	7.8	-	-	15	7.0	-	-

to routine CT examinations of head, chest and abdomen that may be further used for standard protocol.

Mastora (2009) calculated the $CTDI_{VOL}$, DLP and effective dose for different parts of the body (routine head, cervical spine, abdomen examination, and chest examination) and compared those obtained data with the EC.[9] The report of a CT survey indicated the mean DLP values for adult patients were ranged from (923.2-1394.6) mGy-cm (head) (923.2-1394.6) mGy-cm (chest), (854.7-1517.8) mGy-cm (cervical spine), (301.0-1029.1) mGy-cm (abdomen). The mean effective doses for the head, chest, cervical spine and abdomen were 2.47, 7.53/9.87, 6.20 and 9.49/15.22 mSv respectively.[9] The values were higher for head and chest examination while it was lower for abdomen examination than this study.

Several researches have been done on the doses delivered to patients undergone CT examinations. Some of them were made in Greece; Tsapaki et al[10] presented a study on the application of European Commission reference dose levels in Crete. Papadimitriou et al[11] presented a survey of 14 CT scanners in Greece and 32 scanners in Italy and Hatziioannou et al[12] as a contribution to the establishment of diagnostic reference levels in CT. Moreover, wide scale surveys were made in UK, Taiwan, Iran, Italy and Tanzania. The comparison of CTDI, DLP and effective dose measured with different countries are shown in Table III.

Conclusion

For the routine head and chest protocol, CTDI, DLP and ED were found to be significantly lower compared with the recommendation of European Commission (EC). Even though the CTDI, DLP and effective dose of the head and chest examination has been lower than the EC, these values did not affect the diagnostic image quality. For the abdomen and pelvis protocol the CTDI comparing with the EC was also lower. But, the DLP and effective dose for this examination is extremely high because of the very large scan length and multiple phase scans. For the abdomen examination, where the CTDI were found to be lower but the DLP and effective dose was higher, a revision of the scanning parameters using lesser scan length and less number of phase scanning is required whenever possible in order to reduce the value of effective dose. These data may be used as Dose Reference Level (DRL) values in Nepal.

Conflict of Interest

The authors declare that they have no competing interests.

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References

1. Suetens P. Fundamental of medical imaging. 2nd ed. Cambridge University Press, 2002.

2. Jessen KA, Shrimpton PC, Geleijns J, Panzer W, Tosi G. Dosimetry for optimization of patient protection in computed tomography. Appl Radiat Is. 1999; 50: 165-72.

3. Council Directive 96/29 EURATOM. Laying down basic safety standards for the protection of the health of workers and general public against the dangers arising from ionizing radiation. European Commission, Radiation protection division. 1996; 159: 29-36.

4. European Communities. European guidelines on quality criteria for computed tomography. Luxembourg, 1999.

5. Linton OW, Mettler FA Jr. National conference on dose reduction in CT, with an emphasis on pediatric patients. Am J Roentgenol. 2003; 181: 321-29.

6. Elameen S. Technique and radiation dose in CT examination of adult patients. Master Thesis. Sudan Academy of Sciences (SAS) Atomic Energy Council, 2010, pp 3-23.

7. Abdullah A. Establishing dose reference level for computed tomography (CT) examinations in Malasiya. Master Thesis. Universiti Sains Malaysia, 2009, pp 3-16.

8. Oberg M. Patients doses for CT examinations in Denmark. Master Thesis. Technical University of Denmark, 2011, pp 3-25.

9. Mastora S. Patient dose in common CT. Master Thesis, University of Patras, 2009, pp 5-55.

10. Tsapaki V, Kottou S, Papadimitriou D. Application of European Commission reference dose levels in CT examination in Crete, Greece. Br J Radiol. 2001; 74.

11. Papadimitriou D, Perris A, Manetou A, Molfetas M, Panagiotakis N, Lyra Georgosopoulou M, et al. A survey of 14 computed tomography scanner in Greece and 32 Scanner in Italy: Examination frequencies, dose reference values, effective doses to organ. Radiat Prot Dosimetry. 2003; 104: 47-53.

12. Hatziioannou K, Papanastassiou E, Delichas M, Bousbouras P. A contribution to the establishment of diagnostic reference levels in CT. Br J Radiol. 2003; 76: 541-45.

13. Tsai H, Tung C, Yu C, Tyan Y. Survey of computed tomography scanners in Taiwan: Dose descriptors, dose guidance levels and effective doses. Med Physics. 2007; 34: 1234-43.

14. Origgi D, Vigorito S, Villa G, Bellomi M, Tosi G. Survey of computed tomography techniques and absorbed dose in Italian hospitals: A comparison between two methods to estimate the dose-length product and the effective dose and to verify fulfillment of the diagnostic reference levels. Eur Radiol. 2006; 16: 227-37.

15. Hiles P, Brennen S, Scott S, Davies J. A survey of patient dose and image quality for computed tomography scanners in Wales. J Radiol Prot. 2001; 21: 345-54.

16. Ngaile J, Msaki P, Kazema R. Towards establishment of the national reference dose levels for computed tomography examinations in Tanzania. J Radiol Prot. 2006: 26: 213-25.

17. Clarke J, Cranley K, Robinson J, Smith P, Workman A. Application of draft European Commission reference levels to a regional CT dose survey. Br J Radiol. 2000; 73: 43-50.

18. Hidajat N, Maurer J, Schroder R, Nunnemenn A, Wolf M, Pauli K, et al. Relationships between physical dose quantities and patient dose in CT. Br J Radiol. 1999; 72: 556-61.