Patient doses from X-ray computed tomography examinations by a single-array detector unit: Axial versus spiral mode

S.M. Ghavami[1], A. Mesbahi[2,3*], I. Pesianian[1]

[1]Radiology Department, Paramedical School, Tabriz University of Medical Sciences, Tabriz, Iran
[2]Medical Physics Department, Medical School, Tabriz University of Medical Sciences, Tabriz, Iran
[3]Radiation Therapy Department, Imam Hospital, Tabriz, Iran

Background: X-ray computed tomography (CT) examinations deliver a significant amount of radiation doses to patients comparing to conventional radiography examinations. The objective of the current study was to analyze and investigate the average patient received dose from axial and spiral CT exams in a medical imaging center. **Material and Methods:** In this study, the patient imaging technique, weight and height were recorded. The patients' doses provided by CT unit in terms of $CTDI_w$ were also recorded. Then, other dosimetric quantities including dose-length product (DLP) and effective dose were calculated for each patient using the recorded data. The average values were obtained for all the studied dosimetric quantities. Also, their distribution in terms of examined regions and imaging mode; ie, axial and spiral CT were analyzed by SPSS software. **Results:** For all patients, the mean effective dose of 4.4 mGy with the standard deviation of 9.2 was found. The $CTDI_w$ for axial group was two times higher than spiral ones. Conversely, the effective dose of axial group was less than spiral group. Additionally, the effective doses of 2.3 and 5.2 mSv were found for axial and spiral, receptively. For both quantities of $CTDI_w$ and effective dose, the observed difference between axial and spiral modes were significant (P<0.001). **Conclusion:** Our results showed that although the patient doses in the current study was comparable with the reported values by similar studies in other countries, it was higher than the reported values of a similar study in Iran. Exposure technique's optimaization and further review in routine CT examinations were recommended. **Iran. J. Radiat. Res., 2012; 10(2): 89-94**

Keywords: *X-ray CT dose, patient effective dose, spiral CT, DLP, CTDIw.*

INTRODUCTION

Although X-ray computed tomography (CT) examinations contribute to 35-45% of total medical radiation dose to the patient population in USA and Europe, the recent studies on patients' received dose in X-ray CT examinations state that the number of CT exams are increasing with the advent of new technologies in this field [1, 2]. On the other hand, patient doses from CT exams, compared with other conventional radiological examinations, are small [3]. Also, there have been statistically significant epidemiological evidences of increase in cancer risk due to CT examinations [4, 5]. Thus, it can be readily understood that the relative contribution of CT exams to the dose per capita of the population received from medical diagnostic exposures is increasing. Therefore, it seems rational to pay special attention to control and optimize exposure techniques in CT in order to reduce patient dose without any change in the clinical efficacy. The first step to reduce patient dose is to estimate the mean doses of patients undergoing CT examinations in every imaging center. Based on the obtained dosimetric data, one can decide on the next steps for optimization and dose reduction. Many studies have been performed to provide an estimate for patient received dose from medical X-ray exams in different countries, and recommended reference dose levels [2, 6-15].

In the study of Bouzarjomehri *et al*. to estimate the patient dose from CT examinations in Yazd-Iran, it was found that their mean effective dose was lower than other

*Corresponding author:
Dr. Asghar Mesbahi,
Radiology department, Paramedical School, Tabriz University of Medical Sciences, Tabriz, Iran.
***Fax:** +98 411 3364660*
***E-mail:** amesbahi2010@gmail.com*

countries such as UK and New Zealand [7]. In another study by Ngaile *et al.* patient dose was calculated using CTDOSE software. Their results showed that the mean effective dose and its variation in Tanzania were comparable to six different counties in Europe [15]. Another point to consider is the new technologies, such as spiral (helical) techniques, which could affect the patient dose in CT exams. Spiral techniques reduce the scan time considerably and facilitate dynamic examinations. On the other hand, in spiral mode, the length of body exposed to radiation is increased in most cases [8].

In the current study the patient mean doses in terms of weighted computed tomography dose index CTDIw, Dose-length product (DLP), and effective dose (ED) in different CT exams were estimated. Furthermore, the effect of imaging technique axial and spiral on patient dose was investigated.

MATERIALS AND METHODS

A GE/Hi speed CT unit in a private imaging center (Tabriz, Iran) with single array detectors was used in the current study. A complete set of annual quality control procedures was performed for the unit. The study was begun after approval of the accuracy of kVp, mA and time and CTDIw of CT unit by Iranian atomic energy organization. The CTDIw provided by the CT scanner was also measured by a standard pen dosimeter (Unforce, Sweden) with the length of 10 cm inside head, and body phantoms with the diameters of 16 and 32 cm, respectively. The maximum difference between CT scanner reported CTDIw and the measured CTDIw was less than 10% in both head and body phantoms. Exposure technique for CTDIw measurement consisted of 120 kVp, 100 mA, 2 seconds, and 10 mm slice thickness. The mean CTDIw of five measuring points including one in the center and four at peripheral points were 13 and 5.5 mGy for head and body phantoms, respectively.

A total of 272 patients were entered the study, including 150 male and 122 female.

They were divided into two major groups of axial and spiral. Patient's information was recorded for each examination, including name, age, weight, height, region of study, mAs, kVp, slice thickness (mm), number of slices, and CTDIw (mGy). The mean values for the number of slices, slice thickness and body mass index (BMI) of the patients are shown in table 1. Other dosimetric quantities including nCTDIw, DLP and effective dose were calculated for each patient using the equations 1-3.

The nCTDIw, which is called normalized from of CTDIw, can be derived by the following formula:

$$nCTDIw = CTDIw/C \ (mGy/mAs) \qquad (1)$$

Where C is the amount of exposure or simply is the mAs used for an examination. The dose length product (DLP) in terms of mGy.cm describes the radiation exposure for a full scan for each patient and was calculated by equations 2 and 3 for axial and spiral CT respectively.

$$DLP = \sum i \ nCTDIw.T.N.C \qquad (2)$$

Where T, N and C denote the slice thickness (cm), number of slices and mAs respectively.

$$DLP = \sum i \ nCTDIw.T.A.t \qquad (3)$$

Where A and t are the tube current (mA) and total exposure time (s).

The final calculated quantity was effective dose (mSv) which was calculated by multiplying DLP by dose conversion factors for various body organs (formula 4) [16, 17]. Table 2 shows the list of dose conversion factors used in the current study.

$$Effective \ dose = DLP.EDLP \ (mSv) \qquad (4)$$

Where EDLP is the conversion factor in terms of $mSv.mGy^{-1}cm^{-1}$.

All examinations were performed with a large focus and 1.2 and 1.3 pitch values as a routine protocol for spiral techniques.

In the current study we used SPSS software (version.16) for the statistical analysis. The difference between the studied patient groups and quantities was statistically analyzed by *t-test*, one-way ANOVA and Post Hoc tests. P value <0.05 was considered as significant.

RESULTS AND DISCUSSION

For all patients in the study, the mean effective dose of 4.4 mGy with standard deviation of much more than mean 9.2 was found.

Figure 1 shows the distributions of CTDIw for axial and spiral CT scans. The results of statistical analysis of both groups showed that mean CTDIw for spiral scans was significantly lower (two times) than axial mode. It can be partly related to differences in the slice thickness of axial and spiral techniques. The mean slice thickness of 4.7 and 7.7 mm were obtained for axial and spiral modes, respectively. According to previous studies, for small slice thicknesses, usually less than 10 mm with thin collimation width, the relative contribution of X-rays in the penumbra of the dose profile increases and leads to higher CTDI [3, 9]. However, the magnitude of such an effect varies from one CT scanner to another and depends strongly on tube focus dimension, as well as collimation system [18].

Among the exposure techniques, some of the affecting factors used for both axial and spiral scans are shown in table 1. It is evident that the number of slices and slice thickness used for axial scans are approximately 40-50% lower than those used for spiral scans. The body-mass index (BMI) of patients in both modes were not statistically

Table 1. The Mean values for number of slices, Slice thickness and BMI of patients. The values in the parenthesis show the standard deviation.

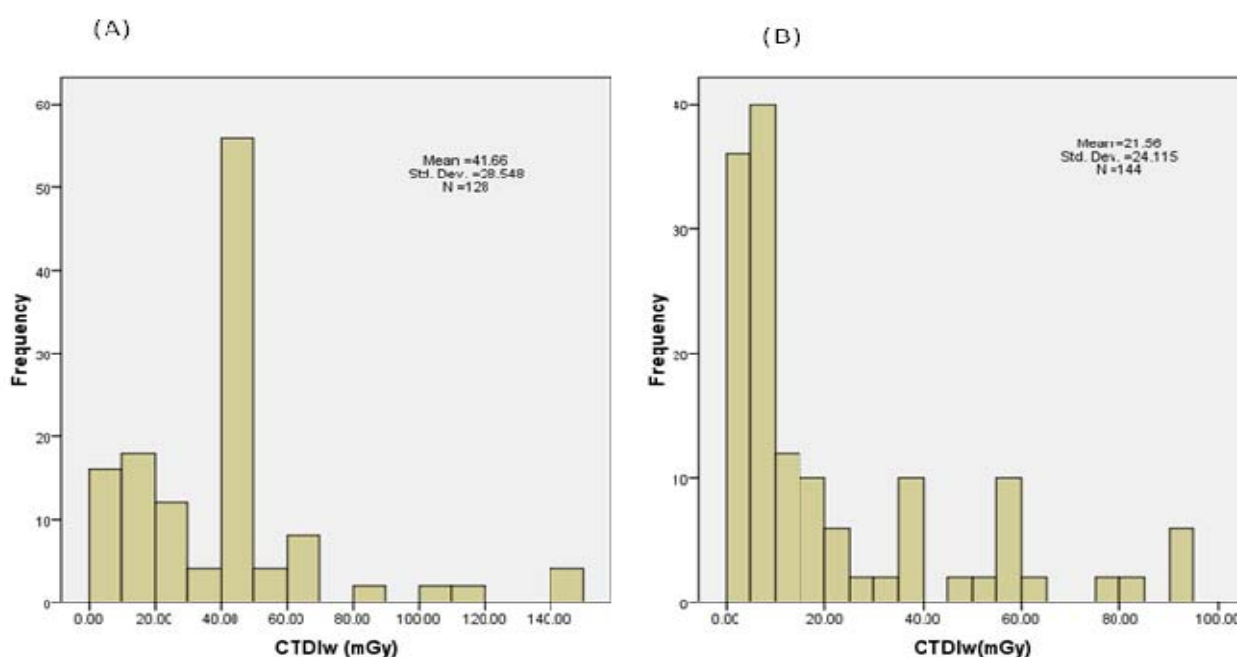| Technique	Number of slice	Slice thickness (mm)	BMI
Axial CT	24 (11)	4.7 (2.9)	26.4 (4.2)
Spiral CT	46 (20)	7.7 (2.8)	25.6 (4.9)

Figure 1. Patients CTDIw (mGy) from X-ray CT examinations in two modes (A) axial and (B) spiral .

different with P-value of 0.65. Also, the mean kVp and mAs were very close each other for both modes. For both groups the spearman, non-parametric correlation analysis was performed for BMI and effective dose in both groups, and no meaningful correlation was observed (P>2).

In figure 2, the effective dose of patients in conventional and spiral mode are shown. As it can be seen that the mean effective dose for spiral mode is considerably higher (> two times) than the conventional mode. This can be attributed to the higher DLP values for spiral technique where larger number of patient was examined. The average values of DLP for axial and spiral technique are shown in table 2. There are remarkable differences between DLP of axial and spiral modes for different body regions. The highest difference has been observed in head, neck and chest regions which was statistically significant (P <0.01).

According to the results in table 2, The $CTDI_w$ of neck was almost two times higher for spiral mode. Also, there was a great difference of 3 folds in $CTDI_w$ for abdomen between axial and spiral modes. The $CTDI_w$ values in other regions, were comparable. Additionally, DLP was higher in all regions for spiral mode in comparison with axial mode, and the effective dose for spiral mode was significantly higher than axial mode in all regions. In the study of Heggie, patient doses from X-ray CT exams were evaluated and some reference levels were proposed for different body regions. Our results in terms of DLP and effective dose were considerably (2-3 folds) higher than their results. This can be attributable to higher kVp and mA, as well as larger body length exposed in spiral CT exams in our studied center. According to their results patient dose optimization for CT exams should be performed for each institution for dose

Table 2. The mean values for $CTDI_w$, DLP, and effective dose for different body regions in axial and spiral scans.

| Region	DLP to ED conversion factor	Average CTDIw (mGy)	Axial Average DLP (mGy.cm)	Average Effective Dose (mSV)	Average CTDIw (mGy)	Spiral Average DLP (mGy.cm)	Average Effective Dose (mSV)
Head	0.0021	49.4 (23.4)	730 (781.7)	1.53 (1.64)	54 (21.5)	1345 (1621)	2.8 (3.4)
Neck	0.0048	7.1 (5.5)	85 (75)	0.4 (0.5)	18.3(13.4)	765 (830)	3.7 (4)
Chest	0.014	4.7 (5.2)	13.7 (16.2)	0.19 (0.22)	6.2 (3.5)	290 (315)	4 (4.4)
Abdomen	0.012	39.3 (34.4)	375.4 (739)	4.5 (8.9)	11.3(15.5)	569.7(578.7)	6.8 (6.9)
Pelvis	0.016	11.9 (3.6)	236 (175)	3.8 (2.8)	9 (3.6)	472.5 (305)	7.6 (4.8)
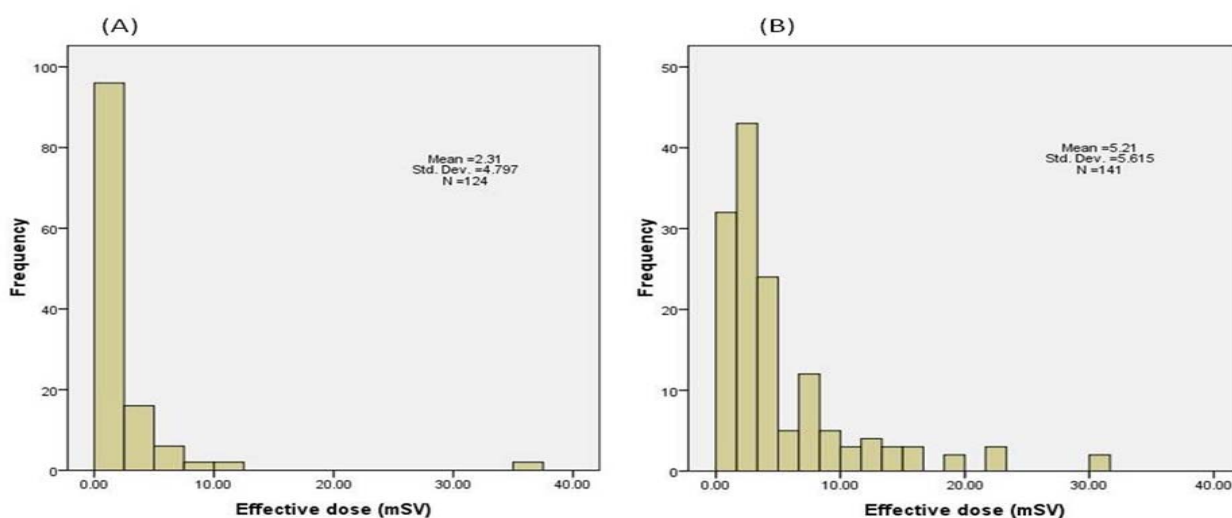
Figure 2. Patients' effective dose (mSv) from X-ray CT examinations in two modes (A) axial and (B) spiral.

reduction purposes [19]. However, comparing our results with the study of Brix *et al.* [8] showed that the patient dose from X-ray CT in our studied center was lower that their recommended reference values.

In table 3 our results of $CTDI_w$ for different body regions were compared with two other similar studies of Bouzarjomehri *et al.* and Hidajat *et al.* The mean $CTDI_w$ for head and abdomen in our study was higher than Bouzarjomehri *et al.* for both conventional and spiral modes. In other body regions, the mean $CTDI_w$ was very close and their differences were not statistically significant ($P > 0.3$).

The mean effective dose of patients of our study and other countries' are compared in table 4. As it is seen the results of present study are less than those reported by other countries, and in agreement with study of Bouzarjomehri *et al.* [6] additionally, they were significantly lower than values reported for Tanzania [15].

In the study of Imhof *et al.* it was recommended that radiologists should check each X-ray CT indication carefully and propose alternative imaging methods to avoid unnecessary exposures [18]. Also, CT examination should be limited to the required part of body. So patient dose can be reduced considerably in spiral mode, as it was done in our studied center. Moreover, X-ray CT exams with and without contrast medium injection should not be performed as a routine procedure. Our results showed that more than 40% of patients undertake spiral CT with and without contrast injection in the studied center. This may cause extra dose to patients in spiral technique and increase the risk of radiation induced harmful effects especially in young patients.

Finally, In spite of general belief among the medical imaging staff on the lower patient dose for spiral exams, the results of the current study revealed that the patients' mean effective dose is significantly higher for spiral mode. As a general role, higher pitch and lower mA and kVp are preferred for dose reduction in CT examinations. Additionally, application of shields for superficial sensitive organs such as eye-lens, thyroid, and testis are recommended.

Table 3. Comparison of $CTDI_w$ (mGy) of the current study with other studies.

Examination		Our study	Bouzarjomehri *et al.* [6]	Hidajat *et al.* [20]
Head	Axial	49.4	20.3	18.2-82.6
	Spiral	54	----	-------
Neck	Axial	7.1	23.3	15.8-61.6
	Spiral	18.3	26.8	15.7-52.5
Chest	Axial	4.7	8	18.8-40.3
	Spiral	6.2	7.8	7.41-39.5
Abdomen	Axial	39.3	8.3	18.8-47.5
	Spiral	11.3	8.9	11.9-26.4
Pelvis	Axial	11.9	8.3	23.7-47.5
	Spiral	9	8.9	12.6-25.3

Table 4. The comparison of reported mean effective dose (mSv) of patients from X-ray CT examinations from our study and some other countries.

Region of body	This study Iran-Tabriz	Iran-Yazd[7]	UK[21]	New Zealand [22]	Norway[17]	Tanzania[15]
Head	2.2	0.85	1.8	2.2	2	2.2
Chest	2.1	5.43	8.3	9.9	11.5	12.2
Abdomen	5.6	6.20	7.2	11.6	12.8	15.3
Pelvis	5.7	8.45	7.2	7.2	9.8	13.4

CONCLUSION

In the current study, the patient doses from X-ray CT examination was estimated for an imaging center in Tabriz-Iran. The results showed higher CTDI$_w$ for axial mode compared to spiral CT exams; however, the effective dose for sprial cases was higher than axial exams. In other words, spriral procedures caused higher radiation risk to patient in CT examination in the studied center. It can be concluded that in order to reduce the patient dose for sprial CT exams, shorter scan length, justification for spiral CT examination and limiting the number of cases for with and without contrast examinations are necessary.

ACKNOWLEDGMENTS

REFERENCES

1. Rothenberg LN (2001) CT dosimetry and radiation safety. *RSNA,829: 79.*
2. Kaul A, Bauer J, Bernhardt Nosske D, Veit RV (1997) Effective doses to the members of the public from diagnostic application of the ionizing radiation in Germany . *Eur Radiol, 7: 1127-1132.*
3. Furlow B (2010) Radiation dose in computed tomography. *Radiol Technol, 81: 437-450.*
4. Faletra FF, D'Angeli I, Klersy C, Averaimo M, Klimusina J, Pasotti E, Pedrazzini GB, Curti M, Carraro C, Diliberto R, Moccetti T, Auricchio A (2010) Estimates of lifetime attributable risk of cancer after a single radiation exposure from 64-slice computed tomographic coronary angiography. *Heart, 96: 927-932.*
5. Robbins E and Meyers PA (2010) Ionizing radiation: an element of danger in every procedure. *Pediatr Blood Cancer, 55: 397-398.*
6. Bouzarjomehri F, Zare MH, Shahbazi D (2006) Conventional and spiral CT dose indices in Yazd general hospitals, Iran. *Iran J Radiat Res, 3:183-189.*
7. Bouzarjomehri F, Zare MH, Shahbazi-Gahrouei D (2011) Patient dose resulting from CT examinations in Yazd,Iran. *Iran J Radiat Res, 4:121-127.*
8. Brix G, Nagel HD, Stamm G, Veit R, Lechel U, Griebel J, Galanski M (2003) Radiation exposure in multi-slice versus single-slice spiral CT: results of a nationwide survey. *Eur Radiol, 13:1979-1991.*
9. Cho P, Seo B, Choi T, Kim J, Kim Y, Choi J, Oh Y, Kim K, Kim S (2008) The development of a diagnostic reference level on patient dose for CT examination in Korea. *Radiat Prot Dosimetry,129:463-468.*
10. Choi J, Cha S, Lee K, Shin D, Kang J, Kim Y, Kim K, Cho P (2010) The development of a guidance level for patient dose for CT examinations in Korea. *Radiat Prot Dosimetry, 138:137-143*
11. kamman RL, Geleijns j, Berting R, van der Brink HA (2000) An approach for radpid establishment of patient effective dose during radiology and results for two large university hopitals. *Radiat Prot Dosimetry, 90:145-147.*
12. Kim JE and Newman B. (2010) Evaluation of a radiation dose reduction strategy for pediatric chest CT. *Am J Roentgenol, 194:1188-1193.*
13. LaBounty TM, Leipsic J, Mancini GB, Heilbron B, Patel S, Kazerooni EA, Sundaram B, Lin FY, Dunning A, Saltzman AJ, Weisz G, Weinsaft JW, Choi JH, Koduru S, Min JK. (2010) Effect of a standardized radiation dose reduction protocol on diagnostic accuracy of coronary computed tomographic angiography. *Am J Cardiol 106:287-292.*
14. Leng S, Yu L, McCollough CH (2010) Radiation dose reduction at CT enterography: How low can we go while preserving diagnostic accuracy? *Am J Roentgenol, 195: 76-77.*
15. Ngaile JE, Msaki P, Kazema R (2006) Current status of patient radiation doses from computed tomography examinations in Tanzania. *Radiat Prot Dosimetry, 121: 128-135.*
16. Mahesh M (2010) Medical radiation exposure with focus on CT. *Rev Environ Health, 25: 69-74.*
17. Olerud HM (1997) Analysis of factors influencing patient dose from CT in Norway. *Radiat Prot Dosimetry, 71:123-133.*
18. Imhof H, Schibany N, Ba-Ssalamah A, Hojreh A, Kainberger F, krestan C, Kudler H, Nobauer I, Oh YR (2003) Spiral CT and radiation dose. *European Journal of Radiology, 47: 29-37.*