

Achieving reduced radiation doses for CT examination of the brain using optimal exposure parameters

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Abstract

Objectives: Examinations performed using CT scanners impart high radiation dose to patients and use of this modality is on the increase in the present day scenario. This study was intended to evaluate and optimize radiation dose imparted to patients during CT examination of brain performed using spiral CT scanner.

Materials and Methods: One hundred and one patients who underwent CT examination of brain were included in the study. The effective dose to patients was calculated using volume computed tomography dose index (CTDIvol) and dose length product (DLP) values. Patients were categorized according to the type of examination involved. Patients who underwent a complete examination of brain (non-contrast as well as contrast) were categorized in Group A and patients who underwent either a non-contrast or contrast examination were categorized as Group B.

Results: The effective dose to patients ranged from 0.65 mSv to 0.93 mSv for Group A patients and 0.28 mSv to 0.53 mSv for Group B patients.

Conclusion: There was a reduction of doses imparted to patients undergoing CT examination of the brain using optimized exposure parameters without any loss of diagnostic information.

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Keywords: Effective dose, dose length product, CTDIvol computed tomography (CT)

Introduction

The role of computed tomography has been of tremendous value since its inception in diagnostic radiology. Though there are other imaging modalities such as MRI and ultrasonography which are also widely used in the present scenario, CT imaging still continues to be on the increase due to its varied advantages despite the large radiation dose imparted to patients. Because of its widespread use, CT contributes a large fraction of man-made radiation dose to the human population; radiation dose to patients from this modality should be optimized [1]. Spiral CT is a specialized imaging modality in which there is continuous rotation of x-ray tube coupled with linear translatory movement of the patient through the gantry aperture in order to achieve volumetric data acquisition (helical CT). Advent of x-ray tubes of enhanced heat capacity, development of slip rings, advances in detector technology, and improvements in computers have permitted rapid sub-second axial and helical CT scans [2].

Tremendous effort has been expended in reducing patient doses from other radiological procedures with considerable success, but much of the collective dose reduction achieved has been offset by a concurrent increase in the

collective dose from CT [3]. The CT dose index (CTDI) and dose length product (DLP) have been proposed as the appropriate dose quantities for the establishment of diagnostic reference levels for optimizing patient exposure [4]. Integral dose quantities such as DLP and effective dose are the descriptors of the total amount of radiation absorbed by taking into account the extent of the body region being irradiated. The DLP plays an important role as an indicator of radiation dose of the patient [5].

The number of CT examinations on brain was higher than examinations such as abdomen and chest performed using CT scanner in the institution where the study was conducted. Reduction of radiation doses is possible by implementing dose auditing strategies during CT examinations. The current study intends to evaluate radiation dose imparted to patients during CT examination of brain using reduced current and tube potentials without sacrificing image quality.

Materials & Methods

Computed tomography examinations of the brain were performed using a Siemens Somatom Emotion CT machine (Erlangen, Germany). This state of art, sub-

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second spiral scanner had a speed capability ranging from 0.8s to 1.5s per rotation and acquisition capability of 80s at uninterrupted spiral mode. The tube potentials ranged from 80 kV to 130 kV with minimum total filtration of 6.4 mm Al equivalence. The size of focal spot for small focus was 0.8 mm x 0.4 mm and for large focus it was 0.8 mm x 0.7 mm in dimensions as specified by the manufacturer. The tube potentials and the tube current used along with dose indices were displayed on the control console of the scanner. Various other parameters such as the total time duration of the scan, field of view and pitch selection were also displayed on the console. All images were reviewed by a team of expert radiologists.

During CT examination of the brain, sequential mode (no involvement of pitch factor) was selected and the number of slices acquired was at the discretion of personnel performing the examination. The scanner facilitated preprogrammed protocols designed for quick and easy workflow. These protocols involved a complete examination of the region of interest along with a topogram, spiral or sequential ranges and reconstruction modes. Personnel involved in operating the machine had the option to change the preprogrammed protocols if there was a need. The preprogrammed scan protocols used were based on recommended exposure factors specified by the manufacturers as a starting point for clinical work. During the current study, optimized exposure parameters set by personnel performing the examination were used. Selection of factors below the set optimized parameters resulted in mottled images. The study was divided into two categories depending upon the type of examination performed on patients

Group A: Patients who underwent non-contrast as well as contrast CT of brain

Group B: Patients who underwent either non-contrast or contrast CT of brain

Dosimetry

The CTDIvol values were displayed on the control console of the CT scanner. These values were based on weighted CTDI (CTDIw) values obtained using Polymethyl methacrylate (PMMA) head and body phantoms. The CTDIvol is the parameter that best estimates the average dose at a point with the scan volume for a particular scan protocol since the CTDI, CTDIw are only indicators of the level of local dose in the irradiated slice. The CTDIvol was used in calculating the DLP which gave an indication of the energy imparted for a particular scan and is given as $DLP = CTDIvol (mGy) \times scan\ length (cm)$

The scan length depended upon the number of slices and slice thickness. The effective doses were estimated using DLP values and appropriate conversion factors. The formula for calculating the effective dose is given below;

$$E = DLP \times k$$

Where $k (mSv\ mGy^{-1}\ cm^{-1})$ is dependent upon the body region, its value for head according to the 'European guidelines on quality criteria of CT' is $0.0023\ mSv\ mGy^{-1}\ cm^{-1}$ [6].

Results

All examinations reported in this study were performed on adult patients. Of the hundred and one patients included in this study, twenty eight patients were in Group A and seventy three in Group B. For Group A patients, the tube potential of 110 kV was invariably selected during the entire examination (non-contrast as well as contrast studies) whereas the selection of slice thickness and mAs differed. In the initial non-contrast examination, 100 mAs with 10 mm slice thickness were selected and for the contrast examination, 80 mAs with slice thickness of 5 mm were selected. The total number of slices acquired ranged from 28 to 51 and results of these are shown in Table 1. The tube potential of 110 kV and mAs of 100 with slice thickness of 5mm were invariably selected for Group B patients.

Radiation dose imparted to patients during CT examination of brain are given in Table 2. The CTDIvol used in the study varied according to the exposure factors selected. For Group A patients, during the non-contrast examination, the CTDIvol was 15.3 mGy and during the contrast examination, it was 12.24 mGy. The resultant DLP was a contribution from both the non-contrast as well as contrast examinations and the average DLP was 356.09 mGy cm. For Group B patients, the CTDIvol value of 15.3 mGy was invariably selected since the exposure factors were same for all patients and the mean DLP value for CT of brain was 191.61 mGy cm. The effective dose for Group B patients ranged from 0.28 mSv to 0.53 mSv.

The mean DLP of 356.09 mGy cm reported in the current study from Group A category was lower than the European reference dose levels of 1050 mGy cm [6]. Table 3 shows the comparison of DLP and effective doses from Group A patients with previously reported studies in the literature. The mean effective dose reported in the current study was 0.82 mSv and this was lower than effective doses reported by majority of studies in the literature. The effective dose of 0.98 mSv estimated by using DLP reported by Hidajat et al., [7], was comparable to the maximum effective dose of 0.93 mSv reported in the current study.

Discussion

There is a risk of imparting high radiation doses to patients during examinations performed using CT with multiple exposures inherent in the examination. Modern CT scanners are versatile in their operation and with a wide range of facilities available on these scanners; there is an

Table 1. Exposure parameterus used during CT of brain examinations

Groups	No. of cases	kV	mAs	No. of slices Mean (Range)	Slice thick-ness (mm)
A	28	110	100, 80	37,57 (28 - 51)	10, 5
B	73	110	100	25.22 (16 - 30)	5

Table 2. CTDL vol, DLP and effective dose values during CT of brain examination

Groups	DLP mGy cm CTDL vol mGy	Effective dose mSv	
		Mean \pm S.E. Range	Mean \pm S.E Range
A	15.3, 12.24	356.09 \pm 5,63 (283.05 - 405.45)	0.82 \pm 0.01 (0.65 - 0.93)
B	15.3	191.61 \pm 2.07 (122.4 - 229.5)	0.44 \pm 0.005 (0.28 - 0.53)

Table 3. Comparison of DLP and effective doses during CT examination of the brain with previously reported studies

Studies	Routine Head	
	DLP mGy cm	Effective dose mSv
Shrimpton et al (15)	-	1.78 (0.46 - 4.940)
Geleijns et al, (10)	-	1 - 2
Atherton and Huda (16)	-	9.1
Poletti (17)	-	1.8
Chamberlain et al., (18)	-	1 - 2
European Commission (RDL) (6)	1050	-
Goddard and Al-Farsi (13)	603 (413 - 702)	2.4 (0.3 - 8.2)
Hidajat et al., (7)	349	0.98
Clarke et al., (19)	-	1.6
Hiles et al., (12)	731 (306 - 1417)	-
Huda (20)	-	1
Current study	356.09 (283.05 - 405.45)	0.82 (0.65 - 0.93)
RDL - reference dose levels		

increasing need to assess the dose delivered during routine CT examinations [8]. The spiral CT scanners have the potential to offer adequate image quality with moderate radiation dose for the majority of clinical protocols [9]. For evaluating radiation dose to patients in the current study, it was necessary to categorize patients into groups according to the type of protocol involved. For Group A patients, a plain non-enhanced study was performed first followed by injection of contrast medium and an enhanced scan. These patients were mostly those who presented with seizures and headaches. The necessity of performing this examination was at the discretion of the clinician and the radiologist. Non-contrast CT examinations were performed for Group B patients who reported with trauma or stroke (where intracranial infarction and extracranial or intracranial haemorrhage were to be excluded). Contrast

enhanced CT scan was invariably performed on patients on whom presence of space occupying lesion or acute central nervous system (CNS) infection was suspected.

Table 1 shows the exposure parameters used during CT examination of the brain. For Group B patients, tube potential of 110 kV and 100 mAs was invariably selected by personnel performing the examination. It is noteworthy in this context that, use of 80 mAs for a contrast examination in Group A patients yielded necessary information as those obtained using 100 mAs performed on Group B patients. Exposure parameters of 120 kV and 363 mAs as reported by Geleijns et al., [10] was higher than the exposure factors used in the current study. Another study reported by McNitt-Gray [11] showed that the tube potential used for a typical head scan was 120

kV, the mAs was 300 and slice thickness selected was 5 mm. The tube potentials ranging from 120 kV to 142 kV and mAs ranging from 200 to 500 for CT of brain as reported by Scheck et al., [9] was also higher than the exposure parameters used in the current study.

Table 2 shows the radiation dose imparted to both group of patients who underwent CT examination of the brain. The CTDIvol for exposure factors of 110 kV and 100 mAs was 15.3 mGy and for 110 kV and 80 mAs, it was 12.24 mGy. For Group A patients the mean DLP (contribution of radiation dose from both non-contrast and contrast examination) was 356.09 mGy cm. Mean DLP of 191.61 mGy cm was reported for Group B patients. The DLP value reported by Hiles et al., [12], was 731 mGy cm and this was higher than those reported in the current study.

Table 3 shows DLP and effective doses for CT examination of the brain in comparison with other studies in literature. A survey of radiation doses from CT was reported by Goddard and Al-Farsi [13] which was done at six hospitals, the mean DLP reported in their study was 374 mGy cm (range: 296 mGy cm to 614 mGy cm). Results in the present study shows that the DLP values were well within those reported by Goddard and Al-Farsi [13]. The mean effective dose of 0.82 mSv for Group A patients was lower than effective dose ranging from 1 mSv to 2 mSv reported by Geleijns et al., [10]. The effective dose of 0.98 mSv estimated by using DLP reported by Hidajat et al. [7], was comparable to the maximum effective dose of 0.93 mSv reported in the current study. The mean value of effective doses reported by Tsapaki et al., [14], was 1.4 mSv. It is therefore noteworthy in this context that radiation dose during CT examination of the brain in the current study was lower than those reported by Shrimpton et al [15], Atherton and Huda [16], Poletti [17], Chamberlain et al [18], Clarke et al [19] and Huda [20].

Considering the various studies in literature and doses reported, it is important to keep doses as low as reasonably achievable. For Group A patients who required both non-contrast as well as contrast examinations, there is a possibility of radiation doses reaching beyond the dose reference levels set by regulatory bodies, if high exposure parameters are used. The CT collective effective dose can be reduced in several ways, an useful method being justification of each individual examination by a consultant radiologist, reduction of the scanned volume, optimum selection of technique factors such as kV, mA, rotation time, slice width and pitch (for helical scans) or couch increment (axial scans) [3]. Dose reduction is possible with the modern CT scanners if proper work practices are followed by personnel operating the machine. These scanners have the potential of imparting low dose to patients by adopting low dose CT protocols which can be programmed and used during CT examinations. Though there are preprogrammed exposure parameters

as specified by the manufactures for various anatomical regions, care should be taken by personnel in the selection of appropriate exposure parameters. It should also be noted that the images acquired using low dose protocols be reviewed by a team of expert radiologists and put into practice. Radiologists are responsible for medical radiation doses to their patients, and it is imperative that they understand the relationship between radiation dose and image quality [21].

The results from this study showed that dose reduction was achieved in CT examination of brain with the use of reduced tube current and tube potentials without sacrificing diagnostic value. On account of the continuous increase in the number of CT scanners and their use in most of the hospitals currently, it is recommended that the DLP and CTDIvol values be monitored during CT examinations in order to obtain radiation doses as low as reasonable practicable without sacrificing image quality. Therefore, standard protocols with optimized exposure parameters should be designed and adhered to in order that radiation doses may be reduced in the future [13].

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References

1. Rehani M M and Berry M. Radiation doses in computed tomography: the increasing doses of radiation need to be controlled. *BMJ*. 2000; 320:593-594.
2. Edward L. Nickoloff and Philip O. Alderson. Radiation Exposures to Patients from CT. *AJR*. 2001; 177:285-287.
3. Crawley MT, Booth A and Wainwright A. A practical approach to the first iteration in the optimization of radiation dose and image quality in CT: estimates of the collective dose savings achieved. *BJR*. 2001; 74:607-614.
4. Hatziiannou K, Papanastassiou E, Delichas M, Bousbouras P. A contribution to the establishment of diagnostic reference levels in CT. *BJR*. 2003; 76:541-545.
5. Nagel Hans D. Radiation exposure in computed tomography. Fundamentals influencing parameters, dose assessment, optimization, scanner data, terminology. Fourth edition CJB publications; 2002.
6. European Commission. European Guidelines on quality criteria for computed tomography. Report EUR 16262 EN. Luxembourg: Office for official publications of the European Commission, 1999;66-78.
7. Hidajat N, Maurer J, Schroder RJ et al. Relationship between physical dose quantities and patient dose in CT. *BJR*. 1999; 72:556-561.
8. Wade JP, Weyman JC and Goldstone KE. CT standard protocols are of limited value in assessing actual patient dose. *BJR*. 1997; 70:1146-1151.
9. Scheck RJ, Copenrath EM, Kellner MW et al. Radiation dose ad image quality in spiral computed tomography: multicentre evaluation at six institutions. *BJR*. 1998; 71:734-744.

10. Geleijns J, Van Unnik JG, Zoetelief J, Zweers D and Broerse JJ. Comparison of two methods for assessing patient dose from computed tomography BJR. 1994; 67:360-365.
11. McNitt-Gray MF. AAPM/RSNA Physics tutorial for residents: Topics in CT. Radiation dose in CT. Radiographics 2002; 22:1541-1553.
12. Hiles PA, Brennen SE, Scott SA and Davies JH. A survey of patient dose and image quality for computed tomography scanners in Wales. J. Radiol. Prot 2001; 21: 345-354.
13. Goddard CC and Al-Farsi A. Radiation doses from CT in the sultanate of Oman. BJR 1999; 72:1073-1077.
14. Tsapaki V, Kottou S and Papadimitriou D. Application of European Commission reference dose levels in CT examinations in Crete, Greece. BJR. 2001; 74: 836-840.
15. Shrimpton PC, Jones DG, Hiller MC et al. Survey of CT practice in the UK. Part 2: Dosimetric aspects. NRPB-249. London: HMSO, 1991.
16. Atherton JV and Huda W. Energy imparted and effective doses in computed tomography. Med Phys 1996; 5:735-741.
17. Poletti JL. Patient doses from CT in New Zealand and a simple method for estimating effective dose. BJR. 1996; 69:432-436.
18. Chamberlain C, Huda W, Rosenbaum A, Garrisi W. Adult and pediatric radiation doses in head CT examinations. (abstr) Med Phys 1998; 25:A216.
19. Clarke J, Cranley K, Robinson J, Smith S, Workman A. Application of draft European Commission reference levels to a regional CT dose survey. BJR. 2000; 73:43-50.
20. Huda W. Effective doses to adult and pediatric patients. Pediatr. Radiol 2002; 32:272-279.
21. Huda W, Ravenel JG, Scalzetti EM. How do radiographic techniques affect image quality and patient doses in CT? Semin Ultrasound CT MR. 2002; 23(5):411-22.

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