

Estimation of effective dose from CT scanning using dose length product in a Nepalese hospital

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Abstract

Aim: The aim of this study was to estimate the effective doses from CT scans using Dose Length Product (DLP) in a Nepalese hospital.

Materials and methods: This prospective study was conducted in 150 patients above 18 years of age who were referred for CT scan of head, chest and abdomen. The CT scan was performed on a 128 slice multi detector scanner. All the subjects who met the inclusion criteria were included in the study. Following the non-contrast imaging phases of the head, chest and abdomen CTDIvol, DLP, kVp and pitch were recorded for each patient from the console display of the scanner. The effective dose was calculated for each examination using DLP which were graphically analyzed and correlated with the age of the patient.

Results: The study showed the mean CTDIvol for head, chest and abdomen to be 53.95 ± 4.83 mGy, 5.28 ± 1.17 mGy and 11.15 ± 2.71 mGy respectively along with mean DLP to be 923.52 ± 71.11 mGycm, 229.32 ± 48.70 mGycm and 517.02 ± 148.32 mGycm respectively. Using these values, the mean effective doses were calculated and found to be 1.93 ± 0.14 mSv, 3.20 ± 0.68 mSv and 7.75 ± 2.19 mSv respectively.

Conclusion: The calculated effective dose values were lower than in other studies for CT examinations of chest and abdomen while higher or similar for CT examination of head. The results of this survey could motivate other researchers to investigate the radiation doses in other hospitals and help establish national diagnostic reference levels.

Introduction

Today, more than 25 computed tomography (CT) scanners are installed in Nepal. The use of CT has been increasing day by day. More than 150 cases are being examined monthly in Tribhuvan University Teaching Hospital (TUTH) that shows more than 60000 cases a year just in one hospital. These figures indicate the urging importance of CT in the future. Radiation

dose in medical imaging is a topic of concern and CT is associated with relatively high radiation doses. Although there has been a number of cases being carried on, there has been no record of the radiation dose given to the patient at all which is an issue of concern. The International Commission of Radiological Protection (publication 60 and 73) [1,2] and the European directive 97/43/Euratom [3] suggested the concept of diagnostic reference level (DRL) as a tool for optimization, especially where the patient doses are unnecessarily high. The concept of DRL was first proposed by European Commission 1999 [4]. As a consequence, many countries established national DRLs to optimize radiation doses.

The purpose of investigating Dose Length Product (DLP) and effective dose in TUTH is to raise awareness about the effective dose to different organs and establish national DRLs and reference guidelines in Nepal. This study can also motivate other researchers to initiate the process of establishing national DRLs in their respective countries. Furthermore, this study aims to compare the effective doses in TUTH with effective doses from other countries. This helps in providing a background for optimization of the radiation doses and keep them within acceptable ranges.

The European Commission (EC) specifies the criteria for patient dose for CT examinations and gives examples of good imaging techniques. The radiation dose that the patient receives during a CT examination is determined by two aspects – the radiation output characteristics of the scanner and the protocols regarding how the scanner is used in performing the examination [6]. In the European Guidelines (EG) on quality criteria for CT [6] published by the EC, two dose descriptors, computed tomography dose index (CTDIvol) and dose-length product (DLP), were proposed as reference dose levels (RDLs) for optimizing patient exposure. DLPs are used in calculating effective doses directly related to the stochastic risk to the patient and may be used to set reference values for a given type of CT examination to help ensure that patient doses follow the as low as reasonably achievable principles [7]. Comparison of both CTDIvol and DLP values for a specific examination using different protocols or scanners will provide information on their relative performance and compliance with set guidelines.

Materials and methods

This retrospective study was performed in the TUTH Department of Radiology and Imaging. The study population included all the patients referred to the department for a CT scan of head, chest and abdomen within the 4 months study period (September 2018 to December 2018). Non-randomized purposive sampling technique was used for sampling of the population. A total of 150 patients above 18 years of age were included in the study. Among them, 75 (50%) patients were female and 75 (50%) were male. Patients with metal implants were excluded.

The study was approved by the Institutional Review Board (IRB) of Institute of Medicine and a written informed consent was obtained from each patient.

The CT examination was conducted on a Siemens Somatom Definition AS+ 128 slice CT scanner (Siemens Medical Solutions, Forchheim, Germany). Following the non-contrast scanning phase of the head, chest and abdomen examinations, CTDI vol, DLP, kVp were recorded for each patient. The effective dose for each scan was calculated by multiplying the given DLP values with the k factor [21] which depends on the examined region and age of the patients.

KVp, quality reference mAs (from the protocol), rotation time and pitch are shown in table 1. For head examinations, a tube voltage of 120 kV was set in the scanner. The angular and z-axis dose modulation techniques were used in combination with a constant tube potential of 100 kV; the mAs values, automatically set by the scanner for chest and abdomen, were recorded. The mean effective tube current values were 334.79 mAs for head, 59.89 mAs for chest and 243.84 mAs for abdomen. For all scans, the gantry rotation time was 0.33 s. Helical CT scan was used in all patients with the pitch factor of 1.

Table 1. Scan parameters for CT examinations in TUTH

Anatomical region	Tube voltage (kV)	Effective tube current (mAs)	Rotation time (ms)	Pitch
Head	120	334.79±30.75	0.33	1
Chest	100	159.89±39.18	0.33	1
Abdomen	100	243.84±40.31	0.33	1

Statistical analysis was carried out with the help of SPSS version 23 and Microsoft Excel. Graphical representation of the results was performed, and correlation of the data was analyzed ($p < 0.05$ as threshold for statistical significance).

Results

The mean patient age was 46.946 (SD±18.392) years with maximum age being 89 years and minimum being 18 years. The maximum number of patients were in the age group of 54-62 years.

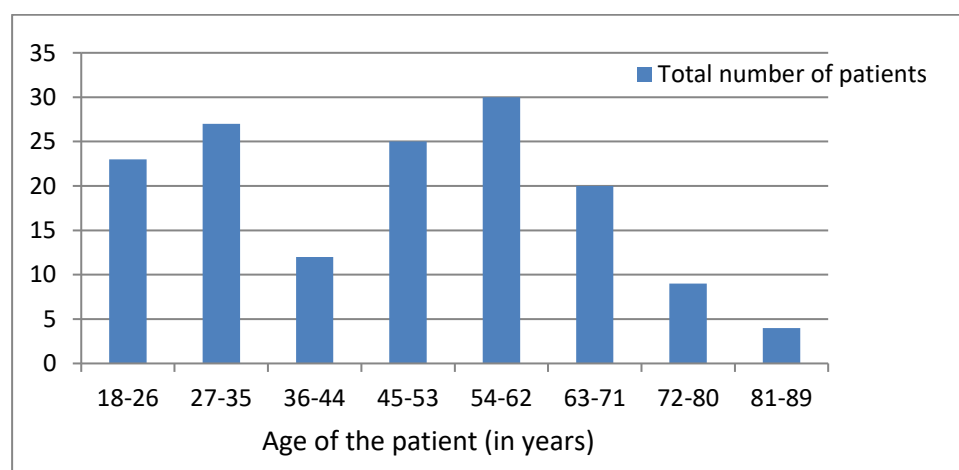


Figure 1. Age distribution of patients

The mean effective doses by age group are presented in figure 2 with highest mean dose observed for abdomen examinations in the age group 54-62 years and little variation in the effective dose from head examinations between groups.

There was no statistical difference between effective doses received by different patient age groups ($p < 0.05$).

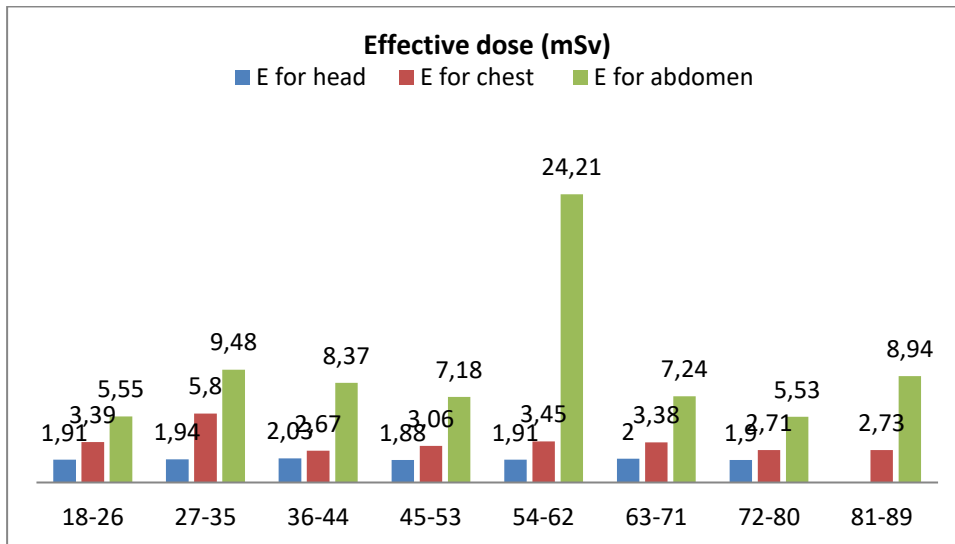


Figure 2. Mean effective dose from CT examinations in different age groups

There were no significant differences in the mean effective dose between male and female patients for both head, chest and abdomen CT-examinations (figure 3).

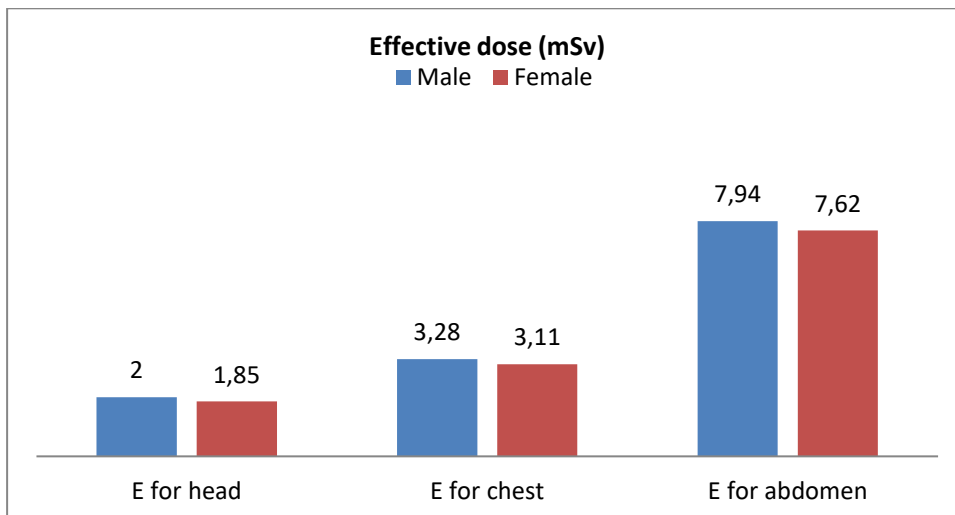


Figure 3. Mean effective dose for CT examinations by gender

The mean values for the three radiation dose indicators are presented in table 2.

Table 2. CTDIvol, DLP, Effective dose of head, chest and abdomen

Anatomical region	CTDIvol (mean and standard deviation)	DLP (mean and standard deviation)	Effective dose (mean and standard deviation)
Head	53.95±4.83	923.52±71.11	1.93±0.14
Chest	5.28±1.17	229.32±48.70	3.20±0.68
Abdomen	11.15±2.71	517.02±148.32	7.75±2.19

The CTDIvol observed in our study were compared with the values of different countries reported in DDM2 (Dose DataMed II) [22] and with EC reference dose level and it was found to be lower for our CT examinations (figure 4).

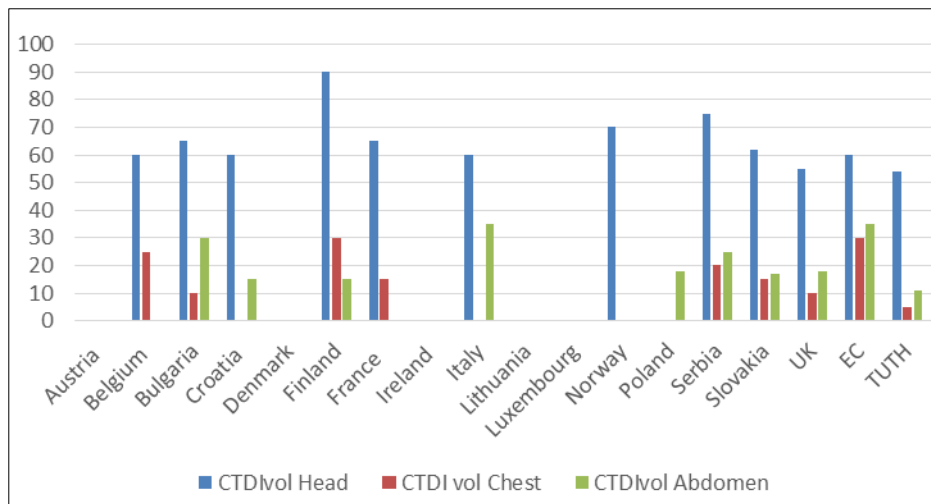


Figure 4. Comparison of CTDIvol for head, chest and abdomen CT examinations (mGy) in different countries

The observed DLP in the present study showed lower values for all examinations when compared to values of European countries reported in DDM2 and also as per EC reference dose level. However, the DLP values for head were slightly higher compared to that of Slovakia and for abdomen it was slightly higher than UK (figure 5).

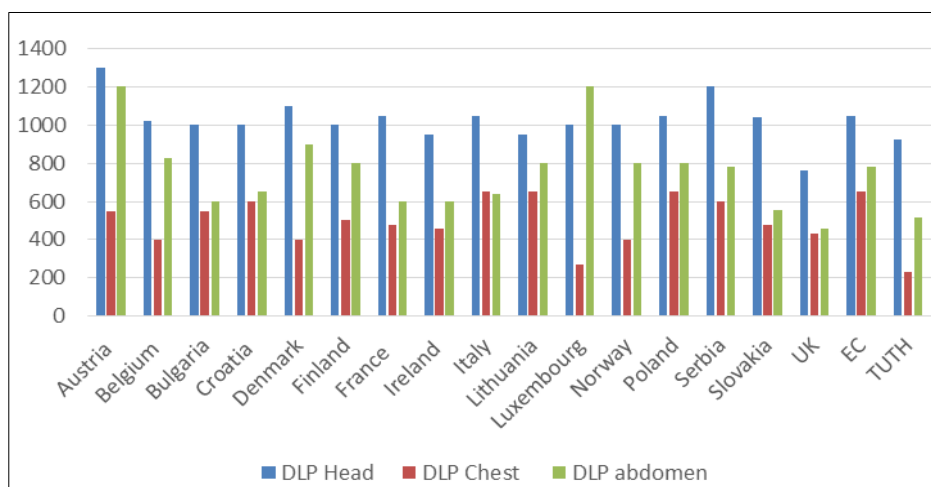


Figure 5. Comparison of DLP for head, chest and abdomen CT examinations (mGycm) in different countries

Discussion

The relatively high patient doses from CT were first highlighted to the radiology community by the publication in 1991 of systematic estimates of organ and effective doses for some common CT procedures on adults that arose from a national survey conducted in the UK [5]. Contemporary CT scanners facilitate the rapid imaging of large volumes of the patient in one rotation and are therefore promoting the development of new and complex diagnostic and interventional procedures, with clear potential for further increases in radiation doses to individuals and populations [14–16]. At the same time, increasing attention should also be paid to radiation protection optimization through improvements in CT technology and practice, with some possibilities for dose reduction [17–20].

In a similar study, Z Brady et al. [8] showed the effective dose for head to be 1.0-1.6 mSv and 1.8-13.0 mSv and 2.5-10.0 mSv chest and abdomen respectively. In our study, the calculated effective doses were 1.93 ± 0.14 mSv, 3.20 ± 0.68 mSv and 7.75 ± 2.19 mSv respectively. The calculated values were higher for head CT examinations whereas similar values were obtained for the chest and abdomen CT examinations. The higher tube voltage used in CT examination in our study might be the cause for the dose increase.

Kharuzhyk et al. [10] calculated the effective doses to be 1.4 ± 0.4 mSv for head, 6.9 ± 2.2 mSv for chest and 7.0 ± 2.3 mSv for abdomen. The study was done without any dose modulation techniques. The calculated values in our study showed similar effective doses for abdomen. The calculated effective dose for head CT examination was higher in our study while lower for the chest CT examinations. Automatic tube current modulation (ATCM) and automatic tube voltage selection (ATVS) techniques were switched on for the chest and abdomen CT examinations that modulated the technical parameters thus decreasing the effective doses. In CT scan of head, no such modulation techniques were used in our study.

Along with the different studies, the study done by A. J Van der Molen et al. [11] showed the effective dose to be similar to that of our study. However, the study showed significant difference in the effective dose for head, chest and abdomen to be 2.8 mSv, 11.8 mSv and 22.5 mSv respectively. These values were higher than the calculated values in our study.

Compared with the doses calculated by Etard et al., [9] that the effective dose for abdomen CT examinations was found to be similar with the dose we have calculated in our study.

The highest CTDI_{vol} values obtained in our study were found in head examinations, which suggested that the protocol parameters such as kVp and mAs were essentially higher than the ones used in Slovakia. The use of a tube voltage of 140 kVp for lumbar spine studies has shown an increase in radiation dose up to 25% [12].

The mean CTDI_{vol} and DLP of our study compared to the data published from other studies including the data from European Commission [13] showed relatively lower values, for all of the CT examinations.

The smaller irradiation volume or length of scan area may be an important contributory factor to the lower dose values recorded, as few of the CTDI_{vol} values which are used to determine the DLP and ultimately patient dose appear to be within range of EC's DRLs

recommendations. Moreover, the body habitus of Nepalese people is also smaller than that of the people in the European countries. Reducing the scan length as much as possible, without missing any vital anatomical regions essential for diagnosis, could be a first step for lowering DLP and subsequently the effective doses. Reducing mAs used for the examination protocol is important for decreasing the radiation dose to the patient during the CT examinations, especially for patients who are smaller than the standard sized patient. In our study, the mAs were modulated on the basis of the patient habitus thus avoiding the unnecessary higher patient radiation dose.

The most commonly cited effective doses for CT are from surveys in the UK adopted by the European Union and by the American College of Radiology CT accreditation program [13,14,15]. The radiation doses calculated in our study were compared with those published in UK surveys (2003) and it was observed that our values were consistently lower in all examinations except abdomen. The relatively low values in our institutions may be the result from use of ATVM and ATCM. Observations in DDM2 (20011) suggest that the DRLs in many countries should be revised; they might be based on published values or old data, which do not properly represent current national practices.

In addition, the effective dose obtained for an adult patient could be used to estimate the population exposure dose in clinical practice and in referral guidelines to help physicians to understand the variations during different examination techniques. Effective doses is used as a guide in the prospective dose assessment for planning and optimization in radiological protection, and demonstration of compliance with dose limits for regulatory purposes. The effective dose is thus a central dose quantity for regulatory purposes. Along with the effective dose, the evaluation of CTDIvol and DLP also showed significant difference compared to the studies mentioned above.

The study will help in establishing national DRLs in the future and motivate international researchers to focus on the need of implementing DRLs in their countries. DRLs are an essential tool in optimization of CT scanning protocols with focus on radiation dose reduction.

Conclusion

The study showed a lower dose level in CT examinations of chest and abdomen in comparison with other studies but higher or similar dose for CT examination of head. The lower dose for CT examinations of chest and abdomen was due to the use of ATCM and ATVS. The body habitus of Nepalese people might also be the reason for the decrease in the radiation dose. In the CT examination of head, however, the ATCM and ATVS were not used. The variation in CT effective dose indicate that there is still room for optimization whereby the details of our data may allow for more practical feedback than possible before.

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