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Original Article

Radiation dose associated with common computed tomography examination

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ABSTRACT

Objective: To survey computed tomography (CT) radiation dose associated with non-contrast spiral Multislice CT examination in our institute.
Methods: Detailed parameters for 362 consecutive examinations, including the patient weight, height, volume CT dose index ($CTDI_{vol}$), scan length, and dose length product (DLP) were recorded from the dose report. Effective dose (E) was estimated for each patient. The differences between E doses were statistically analyzed using SSPS.
Results: Patients body mass index (BMI) was 13.4 to 51.42 (average BMI 29.5 kg/m). Patients dose data (1 scan phase for each patient) from dose information: the median value of DLP was 586.45 mGy cm (83.30–1179.70 mGy cm), median value of $CTDI_{vol}$ was 12.07 (2.20–23.9 mGy), median value of mAs used was 186.50 (34–334 mAs). Effective dose range was (1.1–16.5 mSv) according to international commission of radiological protection (ICRP) 103 and according to ICRP60 the range was (1.3–18.93 mSv). Median value of frequent CT examinations for the same patient was 2 (min 1 scan/year & max 11 scan/year). CT dose variation was highly significant (p value <0.01) depending on high variation on mAs with (r = 0.98). CT dose was moderate depending on BMI (r = 0.55).
Conclusion: There was statistically highly significant variation in effective radiation doses associated with non-contrast CT scan of abdomen and pelvis. The reason for this variation must be avoided.

1. Introduction

Computed tomography (CT) is a special X-ray imaging modality that plays an important role in medical diagnosis [1]. CT uses X-ray cross sectional [2,3] with different energies and intensity to create detailed pictures of two dimension, three dimensions and volumetric image of areas inside the body. CT uses the x ray attenuation properties of human body to detection abnormalities like cancer, trauma [4].

CT scanner was produced in 1972 by Godfrey Hounsfield in England [4,5]. Helical CT was introduced in 1990s [4], the dual-slice systems was produced in 1994 and multislice systems in 1998 [6].

Use of CT has increased substantially in recent years, with approximately 70 million CT examinations performed annually in the United States [5,7]. In the Netherlands in 2010, there were about 1.16 million CT studies, doubling the number compared to 2002 [1], CT examination accounts for only 5% of all X-ray examinations but it represents between 40% and 67% of the total medical dose received [8] and the use of CT continues to grow by 10–15% per year [9].

CT radiation dose depends on tube peak kilovoltage (KVP), tube current, and slice scan time. Tube current and slice scan time are taken together as milliamper per second (mAs). Increasing the mAs increases the dose proportionally [10].

Increasing KVP also increases radiation dose, because the beam carries more energy. However, KVP significantly lower mAs are needed to achieve similar image quality [10].

CT is associated with relatively high radiation doses, which led to increased risk of carcinogenesis [11].

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Surveys of CT doses have been done in many countries in recent few years. This was resulted in the establishment of national reference levels of CT doses. In our country the attention to CT dose is not good like others. The purpose of this study was to investigate effective radiation doses associated with common CT examinations in urology and a nephrology center.

2. Materials and methods

Study was approved by our institutional review board.

We used a CT scanner (Brilliance, Philips medical systems, Eindhoven city, Netherlands, with 64 slice rows.

2.1. Data

Data were collected from available Picture Archiving and Communications Systems (PACS) that let us select most common types of CT examinations on consecutive patients at the UNC and reporting systems that permitted us to query the clinical reasons studies were requested. Data collected for Non-contrasted spiral CT which was done in 362 consecutive patients seen in our Radiology department to evaluate acute flank pain and follow up after extracorporeal shock wave lithotripsy (ESWL). Study was done during 2014–2015.

Detailed parameters for non-contrast abdomen and pelvis spiral protocol, including the CT dose index volume ($CTDI_{vol}$), scan length, and dose length product (DLP) extracted from the scanner dose report. For all patients, participants were required to record information on: [1] patient parameters [sex, length, weight, body mass index (BMI)], [2] parameters of the scan technique tube current (mA), tube voltage (kVp), rotation time, and mean effective tube load (mAs).

2.2. Protocol

The local protocol was applied. In this local protocol, the kVp was fixed at 120 and tube current mAs were variable per patient examination (Table 1).

An effective dose had been defined for all patients, dose parameters such as, volume CT dose index ($CTDI_{vol}$), average effective mAs, and dose-length product (DLP) were recorded for every patient from the dose report.

Effective dose (E) was evaluated by multiplying the DLP by recently established ICRP-$_{103}$-based E/DLP coefficients for the relevant anatomical regions (K) for Multislice CT abdomen-pelvis is 0.0141 [12,14]. k value using ICRP-$_{60}$ for 120 kVp for abdomen-pelvis is 0.0161 [12,13].

$$\text{Effective dose (E)} = \text{DLP} \times \text{k} \quad \text{Eq. (4) [10]}$$

where the k coefficient is specific only to the anatomic region scanned.

Table 1
CT protocol.

Multi-slice CT, Philips, Brilliance 64	
Scanning parameters	Site protocol
kVp	120
Effective mAs	~
Pitch (mm)	1.172
Gantry rotation (s)	0.75
Collimation (mm)	64 × 0.625
Reconstruction thickness mm)	4 mm
Scan length (mm)	~
Matrix	512
Filter	Standard

2.3. Statistical analysis

The data were entered manually into SPSS program. SPSS program was used to analyzed data. Total number of CT studies, the mean range of DLP, $CTDI_{vol}$, and effective CT dose in millisieverts is calculated.

3. Results

Survey for common computed tomography examination showed that total number of CT examinations was 54,959 for two years (Table 2), non-contrast abdomen and pelvis was 81.5% of total examinations. Other examinations were 18.5%. Numbers of NCCT examinations have been annual increased (Fig. 1).

In 2014 the range of NCCT number was 1257 patient/month to 2301 patients/month with average 1700 patients/month and total number of 20,400 patients/year.

In 2015 the range of NCCT number was 1400 patient/month to 2247 patients/month with average 2037 patients/month and total number of 24,444 patients/year.

Whereas NCCT increase the other CT examination was decrease from 5045 patients/year in 2014 to 3146 patients/year.

Patients in this study were sorted to five groups according to BMI (table 3), total number of patient under study were 362. Patient's body mass index (BMI) range was 13.4–51.42 with an average of 29.5 kg/m. Patients dose data (1 scan phase for each patient): the median value of mAs used was 186.50 (34–334 mAs), median value of CTDI $_{vol}$ was 12.07 with range 2.20–23.9 mGy, and median value of DLP was 586.45 mGy cm with range 83.30–1179.70 mGy cm. Effective dose range was 1.1–16.5 mSv with average 8.22 mSv according to international commission of radiological protection 103 ($ICRP_{103}$) and according to $ICRP_{60}$ the range was 1.3–18.93 mSv with average 9.38 mSv (table 3).

A total of 225 patients had two or four unenhanced CT examinations for suspected renal colic, and 27 patients had five or more.

Median value of frequent CT examinations for a patient was 2 (min 1 scan/year & max 11 scan/year).

According to $ICRP_{103}$ the effective (6.38–9.3 mSv) doses were shared in all groups. Effective dose was 16.5 mSv in group four only for BMI 33.2 kg/m^2, whereas effective dose was 15.98 for BMI 41 kg/m^2 (table 3).

According to $ICRP_{60}$ the effective doses (7.29–10.7 mSv) were shared in all groups. Effective dose 18.93 mSv was in group four only for BMI 33.2 kg/m^2, whereas effective dose was 18.24 mSv for BMI 41 kg/m^2 (table 3).

The effective dose varied for the same BMI, on the other hand effective dose had moderate relation with BMI (Fig. 2).

The effective dose was increase with increased in DLP (Fig. 3).

The effective dose was increase with increased in mAs (Fig. 4).

The effective dose, effective mAs and BMI highly varied with statistically significant difference ($p < 0.01$). Effective dose showed high correlation ($r = 94$) with mAs and was moderately correlated ($r = 0.55$) with BMI.

The CTDI $_{vol}$ showed highly significant difference ($p < 0.01$). The CTDI $_{vol}$ was highly correlated ($r = 0.98$) with mAs.

DLP demonstrated highly significant difference ($P < 0.01$) and highly correlation ($r = 0.99$) with $CTDI_{vol}$.

Table 2
Number of CT examinations 2014 and 2015.

	2014	2015
Total CT examination No	25,445	29,514
Non contrast Abdomen pelvis examination	20,400	24,444
Other examination No	5045	3146