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Research Article

Survey of Patients Radiation Doses in Computed Tomography Chest Imaging: Proposal of Diagnostic Reference Level

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Abstract: Advances in CT system technology have improved the diagnosis of many clinical conditions and consequence new investigation methods emerged. However, CT procedures expose the patients to high an avoidable radiation doses which may increase the individuals lifetime radiation risk of developing cancer. This study was intended to evaluate patient doses during chest CT procedures in a certain radiological hospitals in order to establish a local diagnostic reference level (DRL). A total of 78 CT chest procedures were performed during one year. The range of patient dose per CT procedure was 126.0 mGy.cm to 1104.0 mGy.cm per chest procedure. The CTDIvol ranged between 3.0 mGy to 20 mGy per procedure. Patient dose variation attributed to CT modality and image acquisition protocol. Patients exposed to a higher radiation doses in 64 slices compared to other two modalities due to the use of sequential technique at the later one. Diagnostic reference level was proposed for chest CT procedures.
Keywords: Chest imaging, Radiation dose, Medical exposure, DRL, Computed tomography.

INTRODUCTION

Computed Tomography (CT) is a valuable medical imaging technique for the diagnosis of wide range of diseases. Due to development of powerful CT machines, new clinical applications are continue to emerge in medical fields. Radiogenic detriments of CT imaging procedures are increasing due to increase the frequency of medical use of CT machines worldwide. Nowadays, collective dose from CT dose can reach up 80% of the total collective dose [1]. The high radiation dose from CT procedures has increase the concern regarding the radiogenic risk connected CT imaging. Unlike conventional radiography, CT exposes patients to a higher radiation doses than do conventional diagnostic x-rays. For example, a chest CT scan (8 mSv) typically delivers more than 400 times the radiation dose of a routine chest X rays (0.02 mSv) [2]. The absorbed dose from a chest CT imaging procedure is corresponding to the amount of radiation exposure one experiences from natural sources in 2 years [3]. It had been estimated that CT radiation doses generate 0.7% of total expected cancer prevalence and 1% of total cancer death [4]. Furthermore, the study proposed that 6,800 prospect cancers may be attributable to chest CT scan examinations performed in 2007 alone and that 0.7% to 2% of all future cancers in the United States may be caused by radiation from CT scan [4, 5]. Although, the CT dose in chest imaging is high, tissue reactions are not expected because a specific threshold is required for it to occur (2 000 mGy) [6]. While in CT chest imaging, the skin dose to skin is ranged between 20 mGy- 40 mGy [7]. The international Commission on Radiological Protection (ICRP) recommended that diagnostic reference levels (DRLs) should be used by regional, national and local authorized bodies in order to reduce the patient doses from unnecessary exposure in order to ensure that patient doses are kept as low as reasonably achievable to ensure that any patient risks are minimized [6]. Patient dose reduction can be achieved by evaluation between the DRL value from the same imaging procedures for a appropriate standard group of patients or a standard phantom. A standard group of patients is typically defined within a certain range of demographic characteristics such as weight, height and body mass index (BMI). Many countries in Europe defined a DRL for most of radiological investigations [9-13]. As expected, the value of DRL is differing from country to another and for the same type of CT scan examination due to equipment, imaging protocol and patient pathology factors. To reduce the radiation doses to patients, and hence the tissue reaction effect (cancer and heritable effects), the operator must control the factors that affect the radiation doses. These factors include: tube voltage (kVp), tube current-time product (mAs) scan length, modulation of radiation beams, pitch and use of noise filtration parameters [14]. Therefore, implementation of local DRLs for particular CT procedure will assist in improving the practice. Few data are available regarding the current practice and dose level in different centers in Sudan. This objective of this study is to evaluate patient doses during CT chest procedures and to establish local DRLs.

MATERIALS AND METHODS

The data used in this study were collected from six diagnostic radiology departments at Khartoum state during 12 month. Technical specifications of CT machines are presented in Table 1. Data of the technical parameters used in CT procedures was collected after informed consents were obtained from all patients prior to the procedure. Ethics and research committee was approved this study according to the Declaration of Helsinki on medical protocol. All CT machines are regularly inspected by quality control experts from Sudan Atomic Energy Commission (SAEC) and all the measure parameters were within acceptable range.

Patient Data

A total of 81 patients referred for chest CT imaging procedure were performed during 12 consecutive months. Patient demographic data (e.g., age, gender, diagnostic purpose of examination, body region, and use of contrast media) and patient dose were collected in terms of DLP (mGy.cm) and CTDIvol (mGy). All equipments were subjected to quality control test by experts from Sudan Atomic Energy Commission (SAEC). In addition to that, radiation dose -related factors (exposure factors (kilovoltage (kVp), tube current (mA), exposure time (s), slice thickness (mm), table increment (mm/s), number of slices, and start and end positions of scans) were registered for all patients using standard data collection sheet.

CT dose measurements

CT dose index (CTDI(mGy), which is a measure of the dose from single-slice irradiation, is defined as the integral along a line parallel to the axis of rotation (z) of the dose profile, D(z), divided by the nominal slice thickness, T as illustrated in the equation 1[15].

$$CTDI = \frac{1}{T}\int_{-\infty}^{+\infty} D(z)dz \qquad (1)$$

Due to reduction in radiation dose towards the center of the patients, deriving weighting factor is necessary to avoid under or overestimation the radiation dose. Therefore, the weighted CT air kerma index, CTDIW (mGy), used to combines values of CTDI measured at the centre (c) and periphery (p) of a standard CT dosimetry phantoms as illustrated in the equation 2 [15].

$$CTDIw = \frac{2}{3}CTDIp + \frac{1}{3}CTDIc \qquad (2)$$

CTDI (CTDIvol(mGy), which is defined as CTDIw divided by the helical pitch was To introduced for spiral CT system to take into account the effect of couch translation during irradiation and the associated helical pitch as iullustarted in equation 3[15].

$$CTDIvol = CTDIw \; x \; \frac{nT}{I} \qquad (3)$$

where n is the number of slices and T is the slice thickness and I is slice spacing.

To calculate the total dose per procedure, The dose length product (DLP (mGy.cm), which represents the integrated dose across the scan length, is used to calculate the dose per procedure as illustrated in equation 4 [15].

$$DLP = CTDIvol \; x \; L \qquad (4)$$

where L is the total scan length

CTDIVOL and DLP are displayed on CT scanners operator console and can be used to define the DRL, estimate effective dose using conversion factors.

In this study, CTDI was obtained from a measurement of dose, D(z), along the z-axis made in air using a special pencil-shaped ionization chamber (Diados, type M30009, PTW-Freiburg) connected to an electrometer (Diados, type 11003, PTW-Freiburg). The calibration of the ion chamber is traceable to the standards of the German National Laboratory and was calibrated according to the International Electrical Commission standards [16].

Statistical analysis

The data was analyzed using Statistical Package for the Social Sciences (SPSS) version. 16.0 Chicago, Illinois, USA, SPSS Inc.). Descriptive statistics, Bivariate statistics (t-test, ANOVA). DLP (mGy.cm) and $CTDI_{vol}$ (mGy) were analysed to obtain the third quartile value as a reference value for DRL for each hospital and the overall average.

RESULTS

A total of 78 chest CT imaging procedures (34 females and 44 males) were performed over one year in 6 different hospitals. Patient age per hospital was presented in Table 2. Radiation exposure parameters (tube voltage (kVp) and tube current time product (mAs)) were presented in the same Table. Patient dose in terms of DLP (mGy.cm) and CTDIvol were presented in Tables 2. Table 3, shows the results of the variables (Age, kVp, mAs, DLP, CTDI) according to CT system (mean , std. deviation, maximum, minimum, range). Table 4. shows the results of (One Way ANOVA),to determine the significance of the differences in the variablesc(Age,mAs,DLP,CTDI) according to CT modality(Daul slices, 16 slices and 64 Slices). There are statistically significant differences at the level of significance (0.05) or less in the variables (mAs, DLP, CTDI) attributable to Hospitals.There are not statistically significant differences at the level of significance (0.05) or less in the variable (Age) attributable to Hospitals.

Table 1: CT systems

No.	Hospital	No. of patients	Manufacture	Modality (number of slice/detectors
1	SHN	15	Philips	2
2	RIB	18	Siemens	16
3	ALB	8	G.E	16
4	YAS	9	Toshiba	16
5	ALA	8	Toshiba	64
6	NSF	20	Tosiba	16

Table 2: Patient mean and range of age and image acquisition parameters during chest CT procedures

Parameter/Hospital	SHN	RIB	ALB	YAS	ALA	NSF
Age (year)	44.9±15.6 (18-70)	58.6±16.2 (28-80)	49.6±16.3 (30-75)	62.6±23 (25-92)	54.8±15.2 (40-83)	49.93±19.4 (20-83)
Tube voltage (kVp)	120*	120*	120*	120*	120*	120*
Tube current-time product (mAs)	90.7±46 (44-180)	101.9±29 (34-125)	153.3±44 (66-187)	70.4±19 (43-115)	225.6±48 (200-299)	204.9±78.8 (44-249)
DLP (mGy.cm)	245.6±128 (126-546)	681.5±240 (202-1104)	487.6±182 (177-746)	226.3±100 (120-443)	632.4±171 (450-939)	615.9±83 (409-734)
CTDIvol (mGy)	7.23±4.23 (3.0-15.0)	12.7±7.0 (3.0-19.0)	15.6±5. 3 (5.0-19.0)	5.1±1.4 (3.0-8.0)	16.7±3.2 (13.0-20.0)	18.0±3.7 (7.0-20.0)
*Constant tube potential						

Table 3: Shows the results of the variables (Age, kVp, mAs, DLP, CTDI) according to CT system (mean, std. deviation, maximum, minimum, range)

Variables	CT modality	Mean	Std. Deviation	Maximum	Minimum	Range	N
Age	2S	44.93	15.572	70	18	52	15
Age	16S	54.44	18.962	92	20	72	55
Age	64S	54.75	15.239	83	40	43	8
kVp	2S	120.00	.000	120	120	0	15
kVp	16S	120.00	.000	120	120	0	55
kVp	64S	120.00	.000	120	120	0	8
mAs	2S	90.67	46.021	180	44	136	15
mAs	16S	141.69	75.181	249	34	215	55
mAs	64S	255.63	48.922	299	200	99	8
DLP	2S	245.60	128.265	546	126	420	15
DLP	16S	554.98	227.823	1104	120	984	55
DLP	64S	632.38	171.763	939	450	489	8
CTDI	2S	7.23	4.233	15	3	12	15
CTDI	16S	13.79	6.634	20	3	17	55
CTDI	64S	16.73	3.168	20	13	6	8

Table 4: Shows the results of (One Way ANOVA), to determine the significance of the differences in the variables (Age, mAs, DLP, CTDI) according to CT modality (Daul slices, 16 slices and 64 Slices)

Variables	Source of variation	Mean Square	F	Sig.
Age	Between Groups	470.420	1.488	.194
	Within Groups	316.125		
	Total			
mAs	Between Groups	49818.867	18.271**	.000
	Within Groups	2726.690		
	Total			
DLP	Between Groups	481856.612	10.251**	.000
	Within Groups	47004.266		
	Total			
CTDI	Between Groups	169551.220	4.944**	.000
	Within Groups	34291.398		
	Total			

DISCUSSION

Establishment of DRL is a crucial part of the radiation dose reduction and optimization in medical imaging, without compromising the diagnostic findings. Patient dose measurement was performed in 6 CT machines were involved as illustrated in Table 1. Four CT machines (66%) were 16 slice CT machines, while the rest two were dual and 64 slice CT machines. Patient radiation dose during CT examinations is affected by two main sources, the CT modality and imaging protocol. The recent CT modalities can potentially result in higher radiation exposure and hence a higher radiogenic risk to the patient due to increased capabilities of X ray tube which enable long scan lengths at high tube currents. Therefore, significant variation of patient doses is expected. Patient mean ages were comparable, while the variation between minimum and maximum is great. Pediatrics and females have higher radiation sensitivity compared to adult male [7]. Image acquisition parameters are constant in CT imaging, there are a number of scan parameters and patient attributes that influence the dose and image quality in a CT exam. Some are user controlled (e.g. kV, mAs, pitch). Other factors are inherent to the scanner (e.g., detector efficiency, geometry). Still others are patient dependent (e.g., patient size, anatomy scanned). All these parameters are interrelated. A solid understanding of how each parameter relates to the others and affects both dose and image quality is essential to maintaining the dose as low as reasonably achievable (ALARA). Therefore, a careful evaluate the factors affecting patient dose is necessary.

Table 2 presents the tube current time current per hospital; it is well know that the radiation dose is proportional to patient doses (CTDIvol) during the radiological procedures. Table 3 illustrates that many hospitals, especially ALA and NSF hospital machines, used fixed tube current. The results of patient exposure parameters in this study showed large variations across the monitor radiological departments and even at the same hospital as illustrated in Table 2. All hospitals used a fixed tube voltage (120 kVp), in spite of the patient weight or BMI, suggesting that patients may exposed to unnecessary radiation dose. Patient doses in terms of DLP and CTDI showed wide differences across the hospitals. As previously mentioned this variation may be attributed to depending on CT scanner configuration and imaging protocols [19]. In this study, the patients doses (mGy.cm) during chest CT procedures lowest at CT machines with dual slices due to use of sequential techniques. Slight dose variation between 16 slices and 64 slices was noticed in this study. From Table 2, the variation between CT scanners of the same modality and the same manufacture, may be attributed to the imaging protocol, if all other factors were held constant. Therefore, optimization and setting DRL will reduce these discrepancies in patient doses.

Image acquisition factors affect patient doses include tube voltage, tube current, scan length and imaging technique (helical or sequential). However, the wide variation in patient doses can be minimized if proper exposure factors were selected, and patients will exposed to radiation to justifiable radiation doses consistent with the diagnostic purposes.

Fig. 1 showed that there is DRL decreased in European countries in recent years. This can be attributed to CT technology development and image acquisition protocols. In addition to that, the increase of the awareness regarding CT dose and related riks is a factor cannot be ignored. The DRL vales in Germany, Switzerland and Norawy [10-12] have an equal value (400 mGy.cm). The dose level in this study is comparable with the European data before 10 years ago, and dose values in Saudi Arabia [17]. This study illustrates that the develop in CT technology, awareness and image acquisition protocol will reduce the patient doses significantly

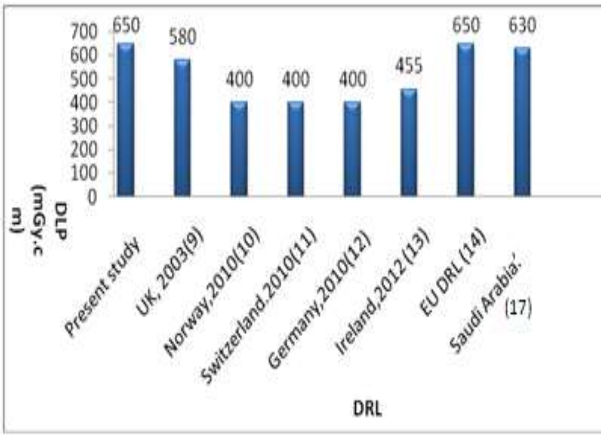

Fig. 1: Comparison between current study and DRL in other countries

CONCLUSION

Local DRLs for chest CT procedures was proposed. Proposed DRLs were up to 40% higher than the current values in certain European countries and were analogous to other international work. Patient doses showed a great discrepancy in CT doses among the departments and at the same department, suggesting that patients are exposed to unnecessary radiation exposure.

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