Measurement of adult and pediatric Patient doses during head CT scan

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Abstract: The objectives of the study were to investigate doses from CT examinations of adult and paediatric patients in brain CT examination and compare the doses with international standards as provided in DRLs. A total of 59 patients (padiatric and adults) were examined at the Department of Radiology, Al -Ribat University Hospital-Khartoum. The mean age was 40.80 years for adults while the mean weight was 70.04 kg and the mean age for padiatric was 5.10 years while the mean weight was 20kg. DLP for adults were 1000.25 mGy.cm, 733.33 for padiatrics. The mean effective dose for adults patient was 0.48 mSv in rang (0.49-0.44) mSv, while for padiatric patients was 0.31mSv in rang between (0.49- 0.11) mSv. The DRL was 1120 mGy.cm, a value which is higher than the European Guidelines on Quality Criteria for Computed Tomography. The study has shown a great need for referring criteria, continuous training of staff in radiation dose optimization concepts. Further studies are required in order to establish a reference level in Sudan.
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1. Introduction

Computed tomography (CT) has rapidly evolved in terms of both technical performance and clinical use and become one of the most important of all X ray procedures worldwide. Spiral CT and in particular the latest generation of scanners with multi-slice capability in subsecond time frames have allowed improvements in speed of acquisition and image quality.

This has resulted in highly reliable information about every part of the body, without motion artifacts from peristalsis and breathing. Thus, completely new indications for CT are being reported, as well as completely new methods for performing and reading the studies.

Twenty years ago, a standard CT examination of the thorax took several minutes to conduct, while today similar information can be accumulated within a single breath hold period. This makes it more comfortable for patients and also easier for physicians to refer patients for examination, since the investigation is fast, well tolerated, accessible and, last but not least, regarded as highly reliable in its outcome (Edyean, 1998, and Itoh et al. 2000).

The individual risk from the radiation associated with a CT scan is quite small compared to the benefits that accurate diagnosis and treatment can provide. Still, unnecessary radiation exposure during medical procedures should be avoided.

Unnecessary radiation may be delivered when CT scanner parameters are not appropriately adjusted for patient size (Paterson etal 2001).

Personnel can tell if the patient was overexposed because the resulting film is overexposed, producing a dark image. However with CT, there is no obvious evidence that the patient was overexposed because the quality of the image may not be compromised.

Several recent articles (Kalender et al, 1999, Rehani and Berry., 2000, Rehani, 2000).

stress that it is important to use the lowest radiation dose necessary to provide an image from which an accurate diagnosis can be made, and that significant dose reductions can be achieved without compromising clinical efficacy.

The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR, 2000). has highlighted that worldwide there were about 93 million CT examinations performed annually at a rate of about 57 examinations per 1000 persons. UNSCEAR also estimated that CT constitutes about 5% of all x-ray examinations worldwide while accounting for about 34% of the resultant collective dose. In the countries that were identified as having the highest levels of healthcare, the corresponding figures were 6% and 41% respectively. Absorbed dose in tissues from CT are among the highest observed from diagnostic radiology (i.e. 10-100 mGy). These doses can often approach or exceed levels known to increase the probability of cancer.

Optimization means keeping the dose "As low as reasonably achievable, economic and social factors being taken into account". For diagnostic medical exposures this is interpreted as being a dose as low as possible, which is consistent with the required image gratuity and necessary for obtaining the desired diagnostic information .

The objectives of this study were to measure doses from CT examinations of adult and paediatric patients and to compare the doses with international standards as provided in DRLs.

2. Material and Methods

The data used in this study were collected from Department of Radiology, National Ribat University Hospital-Khartoum. Data of the technical parameters used in CT procedures was taken during May - June 2010. An informed consent was obtained from all patients prior to the procedure.

CT Machine

Multislice CT Scanner (MSCT) 16 slice (Siemens Sensation) a Sensation 16 scanner installed in the year 2004, (Siemens Medical Solutions, Forchheim, Germany). All quality control tests were performed to the machine prior to any data collection. Experts from Sudan Atomic Energy Commission (SAEC) carried out the tests. All the data were within acceptable range.

Patient Data

The dose assessment was performed for head CT examinations. The number of patients in the head CT was 59 patients referred to Al-Ribat University Hospital (RUH).

Patient Data

A total of 59 patients were referred to National Ribat University Hospital (NRUH) in the period of study for CT brain . Patient-related parameters (e.g., age,gender, diagnostic purpose).

CT dose measurements

CT dose index (CTDI), 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.(1,1–5,41) 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 . The overall accuracy of ionization chamber measurements was estimated to be ±5%. Measurements of CTDI in air (CTDI100, air) were made as recommended by the EUR 16262EN basedon each combination of typical scanning parameters obtained from the machine EUR (1999).

The required organ doses for this study were estimated using normalized CTDI values published by the ImPACT group (27). For the sake of simplicity, the CTDI100, air will henceforth be abbreviated as CTDIair.

Organ dose determinations

The organ dose conversion factor f (organ, z) was obtained from the NRPB datasets (NRPB-SR250) based on the Monte Carlo simulations.(9) The CTDOSE software supplied by the ImPACT group Hart et al. (1994) was used. CTDIair normalized to 100 mAs (nCTDIair), CT scanner manufacturer, model, typical scanning parameters such as kV, mA, exposure time, pitch, slice thickness, gender, and start, and end positions of each scan were used as input data to the CTDOSE spreadsheet in organ dose estimations EUR (1999).

Estimation of absorbed organ doses and effective doses

ESD was used to estimate the organ equivalent dose (H) using software provided by the National Radiological Protection Board (NRPB-SR262) . It contains the results of Monte Carlo modelling conditions of exposure relevant to 68 common radiographic views on a mathematical phantom representing an adult patient of 70 Kg weight, 174 cm and BMI of 23.12 kg/m^2. For each view, normalized doses are presented for 26 organs or tissues.

The organ equivalent dose (mSv) is given by:

$$H_T = \sum_R w_R \cdot D_{T,R}$$

Where $D_{T,R}$ is the mean absorbed dose to tissue (T) from radiation (R) and w_R is the radiation-weighting factor from the recent ICRP recommendations .

Effective dose (E,mSv) is a quantity that has been introduced to give an indication of risk from partial or non-uniform exposure to risk from an equivalent body exposure.

E is given by the following equation .

$$E = \sum_T w_T \cdot H_T$$

Where HT is the equivalent dose to tissue T and wT is the weighting factor representing the relative radiation sensitivity of tissue T.

Patient and examination criteria

A proper measure of standard patient size is important, for comparison with other studies. This study was designed for adult and pediatric patients. CT operators recorded the actual scan parameters used for a number of individual standard patients during routine examinations.

3. Results

The result of the CT dose study with a summary of the data analysis for both adults and pediatrics. The average mean values of demographic data for all patients are displayed in Table (1). The average value is comparable to standard man. Table (2) presents the mean value and standard division of the demographic data for pediatric patients during CT procedures. Table 3 shows the mean values and standard division of the scan parameters for adult patients. Table 4. The mean values and standard divisions of the scan data for pediatric. Table 5 The mean values and standard deviation of the radiation dose data for adults. Table 6. The mean values and standard division of the scan data for pediatric

Table (1): The mean values and standard division of the demographic data for adults

	start position mm	end position	scan time	slice thickness	number of scan
average	286.1207	277.6915	1.479123	4.8	7.915254
Max	683.8	522.2	15.4	9	10
Min	-663.8	-521.2	0.75	4.5	5
Median	74.85	431	1	4.5	8
sdtv	286.5122	295.8322	2.703526	1.1	1.643043

Table (2): The mean values and standard division of the demographic data for pediatric

	Age	Height	Weight	BMI
Average	5.989	79.2	20	0.0025
Max	13	140	40	.004
Min	0.01	25	3	.001
Median	3.99	8.5	7	0.001
SDEV	41.8	6.06	8.5	.006

Table (3): The mean values and standard division of the scan data for adults

	Age	Height	Weight	BMI
Average	40.8	159.1	70.04	0.004
Max	81.0	190.0	170	.03
Min	17.0	75.0	30	.001
Median	44.0	170.0	70	0.003
Sd	17.33	8.9	9.9	0.006

Table (4): The mean values and standard division of the scan data for pediatric

	start position mm	end position	scan time	slice thickness	number of scan
average	234.95	214.34	0.88	5.25	8.17
Max	652.8	522.2	1	9	10
Min	-663.8	-521.2	.75	4.5	6
Median	352.7	316.8	0.88	4.5	8.5
SDEV	507.7	376.66	0.14	1.83	1.5

Table (5): The mean values and standard deviation of the radiation dose data for adults

	FOV	table feed per rotation	CTDI vol	DLP	Rotation time
Average	218.04	17.84	67.43	1000.25	2.4
Max	252	19.5	69.12	1419	2.5
Min	200	1	63	323	1
Median	220	18.5	67.25	995	2.5
SdEV	13.76	2.68	1.8	204.9	0.55

Table (6): The mean values and standard division of the scan data for pediatric

	FOV	table feed per rotation	CTDI vol	DLP	Rotation time
Average	173.5	18.25	43.67	733.33	2.28
Max	228	19	69.12	1244	2.5
Min	18	18	15.41	297	1.8
Median	199.5	18	44.05	695.5	2.5
SDEV	77.91213	0.49	26.01	432.9	0.34

4. Discussions

Radiation dose for Adults

A total of 59 patients were examined. Patient's demographic data, age, weight, are presented in Table 1. There were large variations in the radiation dose to the patients. In general, these variations of doses are due to differences in, tube voltages, number of scan, tube current and repeated scans.

There may be justifiable reasons for some variability in practice, of which the most important one is the difference in clinical indication. This difference is greater if operators and practitioners are insufficiently educated in newly emerging technology. Further, increasing demand in radiology may induce radiologists to use over-intense protocols for CT, for viability to supervise the examination directly while engaged in other work. It is perceived that this is more likely to occur with relatively inexperienced workers and it is also possible that some examinations are carried out more intensively than needed as a means of clinical risk limitations. These factors indicate strongly against measures to provide effective radiation protection. It is necessary to establish the minimum exposure threshold that will deliver adequate image quality in each application, preferably expressed in terms of clinical effectiveness.

Previous studies where systematic changes in scanning parameters were analyzed with respect to resulting image quality have reported dose reductions of up to 40% in CT scans of the head without loss of relevant information or diagnostic image quality.

Mulkens et al (2005). showed that systems based on both angular and z-axis modulation reduce the mean tube current by 20%–68% when applied to standard MDCT protocols at constant tube current. With such systems, these authors also showed a good correlation between the mean effective tube current and the patient's body mass index (BMI), with an adaptation in obese and overweight patients leading to the reference tube current level being exceeded. These devices have only a partial response to the issue of the radiation dose. Survey studies have shown that collective doses have increased as MDCT has replaced SDCT. However, the radiation dose has been dosemetry group over the last decade, mainly through AEC devices and reasonable use of tube current and tube voltage presets. This was achieved thanks to technological improvements and the willpower of several study groups to investigate the effect of dose reduction in terms of image quality and diagnostic performance. Nevertheless, as both the number of examinations and the number of clinical indications for CT increase, a major effort should be made in order to optimize the radiation dose. In addition, as survey studies have shown that great variations in doses among institutions remain, a supplementary effort should be made in order to recommend standardized acquisition protocols. One of the several problems limited the study: first one CT requested form, which was not included ideal clinical information and some time not justified.

Radiation dose for paediatric

This is important in children because the younger patient have greater the risk than adults due to higher sensitivity and long life expectation. In addition, organ radio sensitivity and the affective radiation dose from an individual CT examination are higher in children than in adults. This study intended to optimize the radiation dose for paediatric patients during CT examination. Therefore, an organized effort was established in order to fulfil this goal.

Regarding the patients demographic data, it is clearly the data showed that all patient within the normal level of BMI (18 - 24) kg/m2 .

Patient size or weight, particularly for children, is an efficient method for reducing radiation dose while maintaining diagnostic quality," he adds. Published literature also shows that mA and kVp are the most frequently adapted techniques for optimizing radiation dose to patient size. Due to large variations in pediatric weight, a very important technique are required for patient dose reduction based on patient's weight, clinical indication, and number of prior CT studies

The results of this survey have shown large variations in the frequencies of pediatric CT examinations. The variations can obviously reflect clinical requirements, but such large differences do show some trends worth looking at. In comparison with literature, an important study was covered 19 developing countries in Paediatric CT examination the variations in $CTDI_{vol}$ values received from the 19 countries. It oscillated between (4– 116.3) mGy, be side that there is wide range in DLP values from 76 – 326 mGy.cm, that by using international protocol. This study covered Sudan as developing country. It takes 17.1 mGy and 109mGy.cm for $CTDI_{vol}$ and DLP respectively. This agreed to my study in $CTDI_{vol}$ which give the value 16.7 mGy, but differ in DLP value, which gave 239 mGy.cm .

Conclusion

The aim of this research was to study the trend of CT dose from brain examinations in Khartoum State, and its relationship to patient weight. The result of the research could be used to establish a Diagnostic Reference Level (DRL) to assist in optimizing radiation dose for CT brain examination in Sudan.

Other researchers have also used the NRPB software of dose calculator used for this study. Therefore, the results from this study are comparable to related previous studies.

Finally, an evaluation in the relationship between image quality, exposure factor selection and dose is also useful for professional benchmarking in maintaining lower dose level. A separate protocol is recommended for paediatric and adults.

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