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Establishment of Local Diagnostic Reference Level For Brain Ct Procedures

Medical Science

KEYWORDS :

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ABSTRACT

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. Study was performed to evaluate dose to critical organ for patient undergoing CT brain in modern medical center. A total of 244 patients (98 female and 146 males) were examined in this study. The data collected from 16 radiology department in Khartoum state. The patients were examined with the own department protocol using multislice CT (MSCT) dual slice, 16 and 64 CT slice from different manufacturers. The range of patient dose per CT procedure was 958.6 mGy.cm to 1686.91 mGy.cm. Diagnostic reference level (DRL) was proposed for brain CT procedures. Patient doses showed wide variation due to patient clinical indication, CT system modality and image acquisition parameters.

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. Therefore, the number of CT machines and hence the examinations has increased in last decade [1]. Although the patient's benefit from the accurate diagnosis is outweigh the radiation risk of radiation exposure, protection of patient from un productive radiation exposure is recommended [2]. Unproductive radiation exposure may be delivered when the image acquisition parameters are not properly attuned according to the patient size [3]. Therefore, application of the international Commission of radiological protection (ICRP) principles of radiation protection is essential to reduce unnecessary exposure. These principles stated that any medical imaging procedure that involves exposure to ionizing radiation must be justified on the basis of benefit to the patient. No practice involving exposure to ionizing radiation should occur unless it produces sufficient benefit to the exposed individual (4). Once the procedure is justified, the operator should use an optimum radiation exposure to fulfill the diagnostic task consistent with the required image quality. Since the patient has no dose limit, the ICRP [5] recommended the establishment of diagnostic reference level (DRL) in order to evaluate the practice. Establishment and application of DRL have previously demonstrated valuable tool for dose reduction in medical imaging procedure in order to reduce unnecessary radiation exposure since it first introduction in 1991 [6,7].In Sudan, which classified among countries with health care level III,[8] there are 46 CT machines with different modalities and manufacturers which ranged from single slice to 128 slices based on the survey conducted before starting this project which intended to propose national DRL in Sudan. At the core of optimization is the establishment of DRLs, first proposed by the ICRP in 1996 [5] and subsequently introduced into European legislation [6]. DRLs allow the identification of abnormally high dose levels by setting an upper threshold, which standard dose levels should not exceed when good practice is applied. Excessive doses in CT are not as readily identified through image quality affects, as in standard film-based radiography. Thus, an awareness of typical dose levels allows CT users to quickly identify and address any protocols which do not meet the ALARA (as low as reasonably achievable) principle, thus improving radiographic practice.

Previous studies showed that radiation doses during medical imaging procedures have dropped by a factor of two since 1980 due to improvements in radiological equipment and imaging protocol improvement. 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 study intended to evaluate patient doses during CT brain procedures in order to establish a local DRL in certain hospitals in Sudan.

Materials and Methods

The data used in this study were collected from 16 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 a quality control experts from Sudan Atomic Energy Commission (SAEC) and all the measure parameters were within acceptable range.

Patient Data

A total of 244 patients (98 female and 146 males) referred for brain CT Imaging procedure was investigated. Patient-related parameters (e.g., age, gender, diagnostic purpose of examination, body region, and use of contrast media) and patient dose were collected. In addition to that, Exposure-related parameters (gantry tilt, kilovoltage (kV), tube current (mA), exposure time, slice thickness, table increment, number of slices, and start and end positions of scans) on patient dose.

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 [9]. 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 based on each combination of typical scanning parameters obtained from the machine [9]. The required organ doses for this study were estimated using normalized CTDI values published by the ImPACT group [10]. For the sake of simplicity, the CTDI100, air will henceforth be abbreviated as CTDIair.

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 CTDIvol (mGy) were analysed to obtain the third quartile value as a reference value for DRL for each hospital and the overall average.

Table 1: CT systems

No	Hospital	Manufacture	Modality (number of slice/detectors
1	SHN	Philips	2
2	RIB	Siemens	16
3	KHB	Neosoft	16
4	ALB	G.E	16
5	YAS	Toshiba	16
6	ROY	Toshiba	64
7	ALA	Toshiba	64
8	DAR	Philips	64
9	DOC	Tosiba	64
10	GAR	Philips	128
11	FAS	Tosiba	16
12	KRS	Neosoft	16
13	ELG	Tosiba	16
14	ELZ	Toshiba	64
15	IBN	Tosiba	4
16	NSF	Tosiba	16

RESULTS

A total of 244 CT brain procedures were performed over one year in 16 different hospitals. Patient age per hospital were presented in Table 2. Radiation exposure parameters were presented in Table 3 and 4 for tube voltage (kVp) and tube current time product (mAs), respectively. Patient dose in terms of DLP (mGy.cm) and CTDIvol were presented in Tables 5 and 6 in that order. Table 7 presented the comparison between different measured parameters according to the gender. Although substantial variations were noticed in patient doses, no significant difference in patient populations in terms of age , tube voltage and tube current and gender.

Table 2: patient gae per hospital

Variables	Hospital	Mean	Std. Deviation	Maximum	Minimum
	SHN	46.12	19.075	82	18
	RIB	46.35	20.681	93	16
	KHB	42.80	12.173	60	23
	ALB	57.75	22.491	93	17
	YAS	38.85	15.192	70	20
	ROY	46.67	22.739	75	19
	ALA	45.36	17.477	75	25
	DAR	46.60	21.526	80	22
	DOC	46.20	19.927	80	25
	GAR	56.00	15.965	72	20
	FAS	50.50	14.570	70	25
	KRS	48.40	16.970	70	17
	ELG	32.50	12.039	62	21
	ELZ	42.18	24.879	90	20
	IBN	52.00	17.003	77	28
	NSF	46.44	19.635	77	22

Table3: Tube current per hospital

Variable	Hospital	Mean	Std. Deviation	Maximum	Minimum
mAs	SHN	232.80	106.165	360	120
	RIB	208.36	79.750	360	120
	KHB	468.30	.949	471	468
	ALB	160.83	49.075	280	140
	YAS	150.00	.000	150	150
	ROY	225.00	.000	225	225
	ALA	225.00	.000	225	225
	DAR	399.00	.000	399	399
	DOC	400.00	.000	400	400
	GAR	187.00	.000	187	187
	FAS	190.00	21.082	200	150
	KRS	326.67	29.921	360	300
	ELG	155.00	15.811	200	150
	ELZ	226.64	5.427	243	225
	IBN	200.00	.000	200	200
	NSF	446.44	73.667	471	250

Table 4. Patient Tube voltage (kVp) per hospital

	Hospital	Mean	Std. Deviation	Maximum	Minimum
kVp	SHN	132.00	10.000	140	120
	RIB	127.50	9.750	140	120
	KHB	120.00	.000	120	120
	ALB	140.00	.000	140	140
	YAS	120.00	.000	120	120
	ROY	120.00	.000	120	120
	ALA	120.00	.000	120	120
	DAR	120.00	.000	120	120
	DOC	120.00	.000	120	120
	GAR	120.00	.000	120	120
	FAS	120.00	.000	120	120
	KRS	120.00	.000	120	120
	ELG	120.00	.000	120	120
	ELZ	120.00	.000	120	120
	IBN	120.00	.000	120	120
	NSF	120.00	.000	120	120

Table 5: Brain dose and DRL per hospital

Variables	Hospital	Mean	Std. Deviation	Maximum	Minimum	3rd quartile
DLP (mGy.cm)	SHN	831.20	274.767	1358	414	950
	RIB	1355.16	631.652	3573	414	2085
	KHB	978.70	65.074	1073	938	1015
	ALB	1159.37	126.770	1436	1037	1250
	YAS	1021.08	120.529	1179	826	1012
	ROY	1371.50	165.471	1504	1056	1284
	ALA	1442.73	86.309	1624	1360	1420
	DAR	1140.50	119.483	1451	1003	1174
	DOC	1007.20	119.325	1208	887	1076
	GAR	1329.10	120.381	1520	1166	1400
	FAS	991.30	159.762	1258	752	912
	KRS	1208.67	236.586	1599	707	1240
	ELG	993.10	108.519	1205	888	1162
	ELZ	1686.91	143.548	2055	1544	1670
	IBN	958.60	59.003	1055	874	914
	NSF	1107.56	66.707	1220	1024	792

Table 6: CTDI vol and DRL per procedure

Variables	Hospital	Mean	Std. Deviation	Maximum	Minimum	3rd quartile
CTDIvol (mGy)	SHN	54.23	15.584	69	31	44
	RIB	77.36	31.873	225	31	81
	KHB	74.50	.000	75	75	75
	ALB	76.58	2.678	83	72	77
	YAS	52.90	.000	53	53	53
	ROY	79.80	1.581	81	77	79
	ALA	78.06	1.308	80	77	78
	DAR	70.70	.675	71	69	70
	DOC	57.66	2.789	61	56	59
	GAR	67.40	.000	67	67	67
	FAS	54.40	5.502	57	43	48
	KRS	61.87	11.262	76	37	52
	ELG	52.90	.000	53	53	53
	ELZ	78.36	1.567	80	77	79
	IBN	57.50	.000	58	58	58
	NSF	75.30	.000	75	75	75

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Table 7. shows the Results of independent samples T test,To know significance of the differences in the variables (age, kVp, mAs, DLP, CTDIvol) according to gender.

Variables	Gender	N	Mean	standard deviation	T-Test	Sig
Age	Female	98	49.35	19.502	1.922	.056
	Male	146	44.55			
kVp	Female	98	123.47	7.612	-1.475	.141
	Male	146	125.07			
mAs	Female	98	250.28	104.877	.561	.575
	Male	146	242.49			
DLP	Female	98	1195.68	378.646	.181	.857
	Male	146	1185.61			
CTDIvol	Female	98	69.68	17.338	.790	.430

Discussion

CT has been the highest growing medical imaging system since it emergence in 1971. CT enabled diagnosis of various diseases due short scanning time and volumetric acquisition. To increase the benefit of the imaging procedure, it is mandatory to evaluate the parameters that affect CT dose for the patient. In this study a total of 16 CT machines were involved as illustrated in Table 1. 50% of the equipment are 16 slice CT machines, 32% are 64 slice and dual slice, four slice and 128 slice are 6% each. Most of patients are mid aged patients, except ALB and YAS hospitals. It is important to note that there is singinficant number of young patients with age range from 20 to 25. Patients in these age groups are more sensitive than older ones, bue to long life expectancy. 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 3 presents the tube current time current per hospital; it is well know that the radiation dose is proportional to patient doses ($CTDI_{vol}$) during the radiological procedures. Table 3 illustrates that many hospitals, especially machines equipped with 64 CT machines and 4 slice machines, used fixed tube current. In spite of the fact that no significant difference of the most of people head, using fixed tube current is not is not justified due to the wide variation of patients age group. This fact proof that patients in these hospitals may be exposed the patients to avoidable radiation. The use of very high tube current time product is presents in two hospitals (NSF, KHB). Patients are exposed to a high dose up 450 mAs. When all factors held constant, the dose is proportional to tube current time product. Table 4 presents the tube voltage per hospital. 13 hospitals out of 16 used a constant tube potentioal of 120kVp. Three hospitals used a higher values up to 140 per CT brain. Tube potential determines penetration power of the X ray beam. Therefore, higher energy x-rays have a greater probability than lower energy x-ray of passing through the body and creating signal at the detector. With all else being equal, higher kV will increase signal to noise ratio (S/N). For the same scan parameters, changing the kV from 120 to135 increases the dose by about 33% [11,12]. The image noise is reduced since the dose is higher and more photons are reaching the detectors, but the tissue contrast is compromised as well [12]. In this study, there was large variation in the radiation dose to the patients as illustrated in Table 5. In general these variations of doses are due to differences in, tube voltages, number of scan, tube current and repeated scans. The mean dose in terms of DLP is ranged between 958.6 mGy.cm to 1442.0 mGy.cm for 4 slice and 64 slice respectively. Patient dose in Table 5 and 6 showed wide variation between different hospitals and even in the same hospital. There may be reasonable causes for this discrepancies in clinical environment, of which the most important reasons for these difference were due to clinical indication and CT scan modality and imaging protocol. This discrepancy is greater if the technologists are inadequately trained in CT imaging protocols and radiation dose reduction aspects. These factors indicate strongly against measures to provide effective radiation protection. Therefore, 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. Table 7 illustrate there is a significant variation of patients doses between the two genders. This can be attributed to the clinical indication for CT brain. Therefore, Careful analysis of patient doses might reveal the reason for this discrepancy.

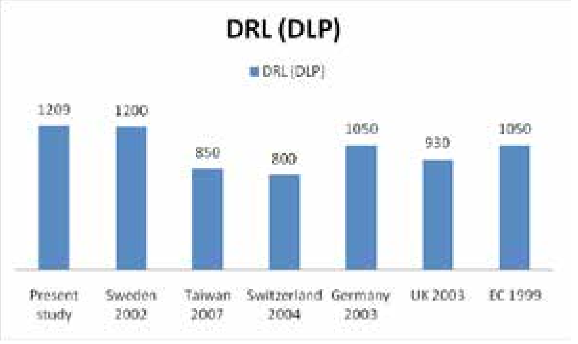

Figure 1. Comparison between current study and DRL in other countries

Figure 1 present a comparison of patient DRL for CT brain procedures. The value of DRL is comparable with Sweden DRL while is higher by 30% compared to recent studies. This value is preliminary results, initiated to increase the attention about the avoidable or unnecessary radiation dose for patients in CT imaging. Figure 1 showed that there is a substantial variations in DRL in various countries, and even at the same country from time to time due to advancement in imaging technique. This study must be expanded to include all other investigations. The available data can be used to establish DRL, but this could be a baseline for further studies concerning dose optimization. To the best of our knowledge, no values have been proposed to date for DLP during CT abdomen procedure. Therefore, a third quartile value of 1209 mGy.cm can be used as DRL in a local basis for CT brain procedure for adults.

The use of DRL has been shown to decrease radiation dose to the patients. A reduction of radiation doses up to 30% was reported for certain imaging procedures from 1984 to 1995 and an average drop of about 50% between 1985 and 2000 in UK due to advancement in imaging technology and staff awareness. [13,14]

Conclusions

Patient doses during CT procedures are vary among different department and even at the same department. Wide variation of technical setting, suggest that there is a great need for staff training. Patient doses are higher compared to other studies worldwide. Diagnostic reference level was proposed for brain CT procedures. Patient doses showed wide variation due to patient clinical indication, CT system modality and image acquisition parameters.

REFERENCE

1. Pearce MS, Salotti JA, Little MP, McHugh K, Lee C, Kim KP, Howe NL, Ronckers CM, Rajaraman P, Sir Craft AW, Parker L, Berrington de Gonzàlez A, et al. Radiation exposure from CT scans in childhood and subsequent risk of leukaemia and brain tumours: a retrospective cohort study. Lancet. 2012;380:499–505. | 2. Gregory KJ1, Bibbo G, Pattison JE. Uncertainties in effective dose estimates of adult CT head scans: the effect of head size. Med Phys. 2009 Sep;36(9):4121-5. | 3. International Commission on Radiological Protection 1990 Recommendations of the International Commission on Radiological Protection. ICRP Publication 60. Annals. of the ICRP. 21 (1-3) : Pergamon Press, Oxford. (1991). | 4. European Commission (EC). Radiation protection 109. Guidance on diagnostic reference levels (DRLs) for medical exposures. Directorate-General, Environment, Nuclear Safety and Civil Protection, 1999 | 5. ICRP, Diagnostic reference levels in medical imaging: review and additional advice. Ann ICRP 2001, 31 (4), 33 | 6. Hart D, Wall B.F., "U.K. Population Dose From Medical X-ray Examinations," European Journal of Radiology, June 2004. | 7. Shrimpton P.C., Wall B.F., Hart D., "Diagnostic Medical Exposures in the U.K.," Applied Radiation and Isotopes, January 1999. | 8. United Nations Scientific Committee on the Effects of Atomic Radiation (2000). 2000 Report to the General Assembly, Annex D Medical Radiation Exposures. United Nations, New York | 9. International Electrotechnical Commission (IEC). Medical electrical equipment. Part 2-44: Particular requirements for the safety of X-ray equipment or computed tomography. IEC 60601-2-44. Geneva, Switzerland; 1999. | 10. Imaging Performance Assessments of CT (ImPACT). CT patient dosimetry spreadsheet (v0.99u, 10/12/2007). Retrieved April 2008 from www.impactscan.org/ctdosimetry.htm. | 11. Downes P, Jarvis R, Radu E, Kawrakow I, Spezi E. Monte Carlo simulation and patient dosimetry for a kilovoltage cone-beam CT unit. Med Phys. 2009;36(9):4156–4167. | 12. 108. Horiguchi J, Fujioka C, Kiguchi M, Yamamoto H, Kitagawa T, Kohno S, Ito K. Prospective ECG-triggered axial CT at 140-kV tube voltage improves coronary in-stent restenosis visibility at a lower radiation dose compared with conventional retrospective ECG-gated helical CT. Eur Radiol. 2009;19(10):2363–2372.