East African Scholars Journal of Medical Sciences
Abbreviated Key Title: East African Scholars J Med Sci
ISSN 2617-4421 (Print) | ISSN 2617-7188 (Online) |
Published By East African Scholars Publisher, Kenya

OPEN ACCESS

DOI: 10.36349/easms.2019.v02i02.002
Volume-2 | Issue-2 | February-2019 |

Original Research Article

Establishment of Computed Tomography National Diagnostic Reference Level (DRL) for Abdomen procedures in Paediatrics CT scan

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Abstract: Computed Tomography (CT) is increasingly used in abdominal imaging with a subsequent increase in the collective radiation dose. This is of particular concern, especially in young patients and in those with chronic diseases who undergo repeated CT studies including treatable cancers. The objective of this study was to establish the Computed Tomography National Diagnostic Reference Level (NDRL) In Paediatrics Radiography. 96 patient of CT abdomen and pelvis, 23% (22) of them were routine, 8% (8) tri-phase Abdomen, and 69% (66) CTKUB. The DRLS in 75% value was 637, 1095 and 514 mGy.cm Sequentially, Most of the patients were sent for the urinary tract problems especially renal stones, to check routinely without contrast agent, so DRLs (75%) for the abdomen in this study was proposed (575 mGy / cm). The data collected from 8 radiology departments .The patients were examined with the own department protocol using multi-slice CT (MSCT) dual slice ,8, 16 ,64 and 128 CT slice from different manufacturers. The range of patient dose per CT procedure was between 160 mGy.cm to 916 mGy.cm. Diagnostic reference level (DRL) was proposed for abdomen CT procedures. It is necessary to take a lot of precautions to reduce the radiation dose of children, especially direct exposure to the genital areas, by means of appropriate radiation protection, and the appropriate examination after consultation between the technician and the doctor and radiologist, and the existence of a reasonable interval between the examination and return.

Keywords: Dose reference levels, Computed Tomography, Paediatrics, Abdomen.

INTRODUCTION:

Computed Tomography (CT) is increasingly used in abdominal imaging with a subsequent increase in the collective radiation dose. This is of particular concern, especially in young patients and in those with chronic diseases who undergo repeated CT studies including treatable cancers (Keyzer, C., & Tack, D. 2011). Children are special cases, since they have a two to four times higher risk of late manifestations of the detrimental effects of radiation Caroline supposed that the presets, Z-axis coverage, and repeated exposure before and after intravenous administration of (UNSCEAR Report 2000). iodinated contrast material should always be adapted to the suspected diagnosis. Repeated acquisitions should not be performed in circumstances where they do not specifically yield additional information. The standard presets recommended by the constructors with regard for the guidelines from the Commission of the EU and the NRPB should be only used in patients with suspected neoplasia and/or metastasis, old patients, or severe trauma. Automatic modulation of the tube current as a function of the patient's absorption is now available on all modern MDCT scanners. Differences still exist between manufacturers regarding the methods used for this modulation and the dose reductions subsequently obtained. The most important feature of these devices is that the radiation dose is adapted to the patient's weight and absorption. Consequently, the role of the CT user is not to adapt the tube current to the patient's weight but more to select appropriate tube potential and image quality to fit with the clinical indication of the CT examination. If the CT equipment includes AEC device, it should be always switched on for abdominal MDCT scans. It is preferable to use smooth reconstruction algorithms if possible. If the reconstructed images appear too noisy, MPR with increased slice-thickness can be used .All available keys of the CT equipment allowing dose reduction (i.e. autokV, ASIR, IRIS, AEC,…) should be used appropriately and ‘‘mixed’’ to

Quick Response Code

Journal homepage:
http://www.easpublisher.com/easjms/

Article History
Received: 05.02.2019
Accepted: 14.02.2019
Published: 25.02.2019

obtain a diagnostic image at the lowest possible dose (Keyzer, C., & Tack, D. 2011).“Diagnostic reference levels” means dose levels in medical radio- diagnostic practices or, in the case of radio-pharmaceuticals, levels of activity, for typical examinations for groups of standard-sized patients or standard phantoms for broadly defined types of equipment. These levels are expected not to be exceeded for standard procedures when good and normal practice regarding diagnostic and technical performance is applied. (Diagnostic Reference.2004 3September)

We present a wide variety of experimental data indicating that linear no threshold theory (LNT) greatly exaggerates the cancer risk from low level radiation. LNT is based on cancer initiating hits on DNA molecules, but many other factors affect the progression from DNA damage to a fatal tumor, such as availability of DNA repair enzymes, immune response, and cell suicide. Data are presented to show that these are generally stimulated by low level radiation (LLR) and suppressed by high doses that serve as calibrations for LNT. Since the great majority of cancers are caused by natural chemical processes, the protection against these provided by LLR may make LLR beneficial rather than harmful. Genes turned on and turned off by LLR are often different from those affected by high doses. Direct studies of cancer risk vs dose are reviewed: animal experiments generally indicate that LNT exaggerates the risk of low level radiation, and the same is true of most data on humans except possibly where dose rates are very high. Data show that the time delay between receipt of dose and cancer death increases with decreasing dose, which means that, with low level radiation, death from natural causes will often occur first. This implies an effective threshold. Responses to this type of information by various official and prestigious groups charged with estimating cancer risks from radiation are reviewed. (Cohen, B. L. (2011) However, children are particularly vulnerable to potential effects from ionizing radiation due their small size, rapid cell division and longer lifetime to manifest changes. It is most important that radiologists ensure that every CT scan is justified by the medical indication, that alternative imaging such as ultrasound or magnetic resonance imaging cannot be substituted and that methods are used to ‘‘child-size’’ the technique for the scan**(**Kenneth, H., *et al.*,2012; Goske, M. J., *et al.*, 2012).

Fortunately, the current generation of meltidetector CT (MDCT) scanners has made the CT examination much shorter and better tolerated by children. A trained CT technologist enlisting the cooperation of the parents is now able to scan the majority of children quickly, painlessly, and without sedating them (Seeram, E. 2015).

Published DRLs can prove useful in allowing comparison of median dose values in your facility, for a particular imaging system, although there are many potential problems in this process include the different in imaging practices and technology, the types of examination or procedure specified for the published DRLs, published dose values may not have been obtained using the same methodology, published DRLs values may not be expressed in a different dose quantity or dose unit, the patient sample and advances in technology, such as post-processing and iterative reconstruction. All these factors will need to be taken into account when updating DRLs (IAEA, 1998–2017; IAEA). A survey before about a year, it found that there are more than 70 CT machines in Sudan with different manufacturers and modalities which ranged from single slice to 128 slices which intended to propose national DRL for paediatrics in Sudan. Examination-specific DRLs for various patient groups can provide the stimulus for monitoring practice to promote improvements in patient protection. Such DRLs can be set not only at a national level (as investigation levels for unusually high typical doses), but also locally by each CT centre (as characterizing its present practice (Roberts, A. *et al.*, 2008). Few data are available regarding the current practice and dose level in different centres in Sudan. This study intended to evaluate paediatrics patient doses during CT brain procedures in order to establish NDRL in Sudan.

MATERIALS AND METHODS:

The data used in this study were collected from 8 radiology departments 7 of them with routine and KUB for each and 4 use contrast for tri-phase procedures, all at Khartoum state during 24 month. Some of departments out of these 8 departments did not receipt paediatrics for CT exams especially whose needs sedation or anaesthesia during the procedure and some machines are not work during this period .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 96 patients include 66 KUB, 22 routine abdomen & pelvis, and 8 tri-phase procedures (30 female and 66 males) were referred for abdomen CT Imaging procedures. 68% of patients were send for renal indications. 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, kilo voltage (kV), tube current (mA), exposure time, slice thickness, table increment, number of slices, contrast agent and start and end positions of scans) on patient dose.

CT dose measurements:

Because most CT applications involve multiple adjacent slices, dose is usually calculated from multiple scans. Measurements are made at the center of the slice and several points around the periphery with plastic phantoms.

This procedure accounts for the effect of scatter from the tails of each slice into the neighboring slices. Again, total dose is the central slice radiation dose, plus the scatter overlap (or tails). This is called the multiple scan average dose (MSAD). The MSAD will increase if slices overlap and decrease if there are gaps between slices.

Single slice dose + amount scattered = total exposure

MSAD: dose calculated from multiple scans

CTDI: dose reported to the FDA; slices must be contiguous

When there is no overlap or gap between slices, the MSAD equals the CTDI. Another type of radiation dose measurement in CT is the computed tomography dose index (CTDI). This allows an estimate of the MSAD to be accomplished with a single scan. The CTDI is what manufacturers report to the U.S. Food and Drug Administration (FDA) and prospective customers regarding the doses typically delivered for their machines. The CTDI can only be calculated if slices are contiguous, that is, there are no overlapping or gapped slices. If there is slice overlap or gaps, the CTDI is multiplied by the ratio of slice thickness to slice increment. This would technically be the MSAD, because the CTDI conditions would no longer exist. Equipment manufacturers report CTDI doses for typical head and body imaging techniques. These are equivalent to the dose a patient receives if multiple adjacent slices are acquired. Medical physicists usually use a special dosimeter called a pencil ionization chamber to measure the CTDI. This 100-mm-long thin cylindrical device is long enough to span the width of 14 contiguous 7-mm CT slices. This provides a better estimate of MSAD for thin slices than that of the single-slice method. When this method is used it is referred to as the CTDI100. As mentioned earlier, the dose for body scans are not uniform across the scan field of view—the dose at the periphery of the slice is higher than the central dose. The CTDIw adjusts for this by providing a weighted average of measurements at center and the peripheral slice locations (i.e., the *x* and *y* dimensions of the slice). The CTDIvol radiation dose parameter takes the process a step further by taking account the exposure variation in the *z* direction. For helical sequences the CTDIvol = CTDIw/pitch. The CTDIvol is now the preferred expression of radiation dose in CT dosimetry. The CTDIvol is a measure of exposure per slice and is independent of scan length. If the irradiated length of the scan is to be accounted for, the parameter used is the dose-length product (DLP): DLP = CTDIvol × scan length. Although the DLP more closely reflects the radiation dose for a specific CT examination, its value is affected by variances in patient anatomy. Therefore, the CTDIvol is a more useful tool for comparing radiation doses among different protocols.

The CTDIvol is the preferred expression of radiation dose in CT dosimetry (Lois, E., & Romans, R.T. 2011).

Statistical analysis:

Statistical Package for the Social Sciences (SPSS) version. 16.0 Chicago, Illinois, USA, SPSS Inc.), is used to analyze the data. Descriptive statistics, bivariate statistics (t-test, ANOVA). DLP (mGy.cm) and CTDIvol (mGy) were analyzed to obtain the third quartile value as a reference value for DRL for each hospital and the overall average.

Table-1: Demonstrates CT Machines

No	**Hospital**	**Manufacture**	**Modality**
1	Ribat	Neosoft	128
2	Dar Elilaj	Philips	64
3	Bhr Modern	GE	8
4	Alaml	Neosoft	64
5	Bogaa	Toshiba	16
6	Nilain	GE	2
7	Antalya	GE	8
8	Asia	GE	16

RESULTS

A total of 96 CT abdomen procedures were performed over two years in 8 different hospitals, 66 KUB, 22 routine abdomen & pelvis, and 8 tri-phase procedures.

Table-2: Demonstrates the Results of the variables (kVp, mAs, DLP, CTDIvol) according to Hospital

Variables	Hospital	3rd quartile Routine	N	3rd quartile Tri-phase	N	3rd quartile KUB	N
Age	Ribat	12	4	14	6	11.5	5
	Dar Elilaj	10	5			.	2
	Bhr Modern	14	4	15	1	14	17
	Alaml	1	1				
	Bogaa	12	4			12	22
	Nilain	0	1			11	1
	Antalya	.	3			12	4
	Asia			15	1	13.5	5
kVp	Ribat	121	4	120.3	6	120	5
	Dar Elilaj	120	5			.	2
	Bhr Modern	120	4	120	1	120	17
	Alaml	120	1				
	Bogaa	120	4			120	22
	Nilain	110	1			110	1
	Antalya	120	3			120	4
	Asia			120	1	120	5
mAs	Ribat	230.3	4	176.8	6	173.5	5
	Dar Elilaj	250	5			.	2
	Bhr Modern	250	4	250	1	250	17
	Alaml	55	1				
	Bogaa	51.5	4			135	22
	Nilain	144	1			23	1
	Antalya	.	3			132.5	4
	Asia			82	1	155.5	5
DLP	Ribat	906.6	4	719.4	6	343.1	5
	Dar Elilaj	3031.3	5			.	2
	Bhr Modern	1909.2	4	817.4	1	898.8	17
	Alaml	823.4	1				
	Bogaa	501.8	4			143.1	22
	Nilain	358.0	1			47.0	1
	Antalya	.	3			487.8	4
	Asia			1472.6	1	322.9	5
CTDIvol	Ribat	8.9	4	17.9	6	4.8	5
	Dar Elilaj	16.4	5			.	2
	Bhr Modern	22.4	4	19.9	1	19.9	17
	Alaml	10.2	1				
	Bogaa	16.4	4			4.0	22
	Nilain	22.0	1			1.6	1
	Antalya	.	3			60.0	4
	Asia			10.0	1	8.4	5

Table-3: Demonstrates the Results of the variables (kVp, mAs, DLP, CTDIvol) according to Modality

Variables	Modality	3^{rd} quartile Routine	N	3rd quartile Tri-phase	N	3rd quartile KUB	N
Age	M2	8.9	4			11	1
	M8	16.4	5	15	1	13.5	21
	M16	22.4	4	15	1	13	27
	M64	10.2	1			.	2
	M128	16.4	4	14	6	11.5	5
kVp	M2	110	1			110	1
	M8	120	7	120	1	120	21
	M16	120	4	120	1	120	27
	M64	120	6			.	2
	M128	120.8	4	120.3	6	120	5
mAs	M2	144	1			23	1
	M8	250	7	250	1	250	21
	M16	51.5	4	82	1	130	27
	M64	250	6			.	2
	M128	230.3	4	176.8	6	173.5	5
DLP	M2	358	1			47	1
	M8	916.1	7	817.4	1	879.0	21
	M16	501.8	4	1472.6	1	160.0	27
	M64	2861.5	6			.	2
	M128	906.6	4	719.4	6	343.1	5
CTDIvol	M2	22.0	1			1.6	1
	M8	22.4	7	19.9	1	19.9	21
	M16	16.4	4	10.0	1	5.1	27
	M64	16.4	6			.	2
	M128	8.9	4	17.9	6	4.8	5

Table-4: Demonstrates 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 Routine	Sig	N Tri-phase	Sig	N KUB	Sig
Age	Female	9	0.563	3	0.659	55	0.236
	Male	13		5		1	
kVp	Female	9	0.943	3	0.423	55	0.769
	Male	13		5		1	
mAs	Female	9	0.480	3	0.838	55	0.235
	Male	13		5		1	
DLP	Female	9	0.703	3	0.293	55	0.055
	Male	13		3		1	
CTDLvol	Female	9	0.378	5	0.476	55	0.380
	Male	13		3		1	

There are NOT statistically significant differences at the level of significance (0.05) or less in the variable (Age, Kvp, MAS, DLP and CTDI) attributable to the Gender

Table-5: Demonstrates the Results of independent samples T-test to know significance of the difference in the variables (age, kVp, mAs, DLP and CTDIvol) according to CT technique

Variables	CT technique	N Routine	Sig	N Tri-phase	Sig	N KUB	Sig
Age	Helical	17	0.533	7	0.333	55	0.236
	Routine	5		1		1	
kVp	Helical	17	0.297	7	0.736	55	0.769
	Routine	5		1		1	
mAs	Helical	17	0.133	7	0.716	55	0.235
	Routine	5		1		1	
DLP	Helical	17	0.181	7	0.015	55	0.055
	Routine	5		1		1	
CTDIvol	Helical	17	0.500	7	0.900	55	0.380
	Routine	5		1		1	

There are NOT statistically significant differences at the level of significance (0.05) or less in the variable (Age, Kvp, MAS, DLP and CTDI) attributable to CT technique.

Table-6: Demonstrates the Results of (One Way ANOVA) to know significance of the difference in the variables (age, kVp, mAs, DLP and CTDIvol) according to Hospital

		Routine		**Tri-phase**		**KUB**	
Variables	Source of variation	Sig	interpretation	Sig	interpretation	Sig	interpretation
Age	Between Group	0.017	significant	0.323	not significant	0.821	not significant
	Within Group						
	Total						
kVp	Between Group	0.210	not significant	0.885	not significant	0.027	significant
	Within Group						
	Total						
mAs	Between Group	0.000	significant	0.345	not significant	0.000	significant
	Within Group						
	Total						
DLP	Between Group	0.013	significant	0.043	significant	0.000	significant
	Within Group						
	Total						
CTDIvol	Between Group	0.001	significant	0.875	not significant	0.001	not significant
	Within Group						
	Total						

Table-7: Demonstrates the Results of (One Way ANOVA) to know significance of the difference in the variables (age, kVp, mAs, DLP and CTDIvol) according to Modality

		Routine		**Tri-phase**		**KUB**	
Variables	Source of variation	Sig	interpretation	Sig	interpretation	Sig	interpretation
Age	Between Group	0.006	sig	0.323	not sig	0.671	not sig
	Within Group						
	Total						
kVp	Between Group	0.132	not sig	0.885	not sig	0.192	not sig
	Within Group						
	Total						
mAs	Between Group	0.052	not sig	0.345	not sig	0.000	sig
	Within Group						
	Total						
DLP	Between Group	0.014	sign	0.043	sig	0.000	sig
	Within Group						
	Total						
CTDIvol	Between Group	0.268	not sig	0.875	not sig	0.000	sig
	Within Group						
	Total						

Table-8: Demonstrates the Results of correlation and its significance in the variables (kVp, fov and scan) with DLP and CTDIV

		Routine			**Tri-phase**			**KUB**		
		kVp	fov	scan	kVp	Fov	scan	kVp	fov	scan
DLP	Pearson Correlation	-0.060	0.408	0.252	0.140	0.360	0.734*	0.137	0.295*	0.526**
	sig	0.059	0.059	0.258	0.741	0.381	0.038	0.314	0.027	0.000
CTDIV	Pearson Correlation	0.039	0.127	0.703**	0.908**	0. 176	0.042	0.089	0.153	0.286*
	sig	0.862	0.573	0.000	0.002	0.677	0.922	0.514	0.262	0.033

(**) Means the difference is statistically significant at the level of significance (0.01) or less (CTDI according to the Scan Time)

(*) Means the difference is statistically significant at the level of significance (0.05) or less

Table-9: Demonstrates the Results of independent samples T-test to know significance of the difference in the variables (DLP and CTDIvol) according to age group

		Routine			Tri-phase			KUB		
Variables	Age group	N	sig	interpretation	N	sig		N	sig	interpretation
DLP	0 – 5	5	0.529	Sig	3	0.178	not sig	19	0.004	Sig
	6 – 10	5			1			13		
	11 - 16	12			4			24		
CTDIvol	0 – 5	5	0.658	not sig	3	0.230	not sig	19	0.053	not sig
	6 – 10	5			1			13		
	11 - 16	12			4			24		

DISCUSSION

CT Abdomen- pelvis procedure Routine

In this study a total of 22 CT abdomen-pelvis procedures were performed for CT abdomen-pelvis procedures over two year in 7 different hospitals equipped with dual, 8, 16, 64 and 128 CT slices. According to the hospital in Table (2) , Dar Elilaj with the machine modality 8 slices shows high radiation dose, but according to modality as in Table (3) it shows lower dose and similar with 128 slices DLP= 907 , the high doses with the different modalities it remains to the helical technique used for the most abdominal CT scans. When comparing the dose in 2015 when using 64 with 2018 we found it very high in 2018 although the latter with the kids unlike the first (Fig (2)). The Kvp is constant in all. There is no significance differences at the level of significance 0.05 or less in the variables age, Kvp, mAs, DLP, and CTDI attributable to the Gender, and also same variables shows no significance at the same level attributable to the CT technique used and the modality of the machines, as demonstrated in the Tables 4, 5 and 7, although there are significance of the modality according to the age variable is noticed. Table 6 shows statically significant differences at the level of significance 0.05 or less in the variables Age, MAS, DLP and CTDI attributable to the Hospitals and shows no significance with the variable Kvp. Table 8 shows that there is statically significant differences at the level of significance 0.05 or less of the Scan time according to the CTDI and no significance to the FOV and Kvp, also DLP showed no significant for the both FOV and Scan time. When take different age groups, it showed no significant differences with the variables DLP and CTDI. When compared, it was found that Sudan, like Japan, less than Ireland and Australia, and is higher by 1.3% of The National Radiation Safety Committee (NRSC) November 2007 (Figure (1))

CT Abdomen: Tri-phase

According to the hospital in Table-2 showed the higher DLP = 1472 and the lower CTDI = 10. As general the Kvp is constant and the higher MAS = 250 in BHR Morden. In fact the increasing the x-ray tube potential increases both the radiation dose and penetration of the x-rays through the body. In general, increases beyond 120 kVp should be avoided, except when imaging obese patients. However, an increase in kVp could be accompanied by a reduction in tube current to offset the increased dose (Step by step). According to the modality in Table (3) M16 showed the higher DLP and the higher CTDI in M8 with the constant Kvp. According to Gender statically significant differences at the level of significance 0.05 or less in the variables Age, Kvp, MAS, DLP and CTDI. Also there is not statically significant different with the same variables attribute to the CT technique, Modality and hospital and for the all three DLP showed significant different at the level of 0.05 or less for the same variables see Tables (5), (6) and (7) Statically there is significant at the level of significance 0.01 or less for CTDIV with kvp and no significant with FOV and Scan time, but DLP showed significant at the level of 0.05 with Scan time and no significant with Kvp and FOV, See Table 4.8. According to the age group there is not statically significant differences of the variables DLP and CTDIV.

CT KUB

A total of 66 CT KUB procedures were performed for CT in 7 different hospitals with the machine modalities dual, 8, 16, 64, and 128 slices. According to the hospitals in Table (2) Bhr Modern showed the highest in of DLP = 899 while CTDIV in this hospital = 20. On the otherwise Antalya showed the highest in CTDIV = 23, while DLP in this hospital = 488. The kvp is constant. Age is above 7 years. According to modality in Table (3) higher DLP and CTDIV with 8 and 64 slices. According to the gender in Table (4) there is no significant differences at the level of significance 0.05 or less in the variable (Age, Kvp, MAS, DLP and CTDI). Also there is not significance with the same variables according to the technique used as in table (5). Hospitals showed significant differences at the level of significance 0.05 or less with the age, while no significant differences with the remained variables. Also modality showed significant differences at the level of significance 0.05 or less with the age and Kvp, while no significant differences with the remained variables as in Table (6). When we take DLP and CTDIV with the variables Kvp, FOV and Scan time in Table (8), the significance at the level of 0.01 or less is found for the DLP with Scan and at the level 0.05 or less with FOV. Also it found at the level of 0.05 or less for CTDIV with Scan. In the Table (9) according to the age groups with DLP and CTDIV there is not statically significant differences.

Taking into consideration all CT scans of the abdomen, it was found that the KUB were the most exams, which were represented 69%. This means that most of the patients were sent to CT abdomen for the purpose of urinary system problems and most of these problems were kidney and ureteral stones as was noted. In the second stage, Routine abdomen and pelvis which was represented 23%, and only 8% was the percentage of abdominal tri-phase cases. The DRLS in 75% value was 658, 1003 and 366 mGy.cm sequentially, for KUB, Routine abdomen and Tri-phase. By ignoring the Tri-phase cases, and take an average of KUB and Routine cases, DRLs was established for paediatric CT scan in Sudan 675 mGy.cm.

Table-10 Comparison of patient Radiation dose in terms of DRL (CTDIvol (mGy) and DLP (mGy cm)) for certain countries paediatrics patients for Abdomen and pelvis CT scan

Country	year	CTDI mGy	DLP mGy cm
NRSC	2007		130-400
Australia	2012	4– 15	150–750
Ireland	2012	12	600
Japan	2015	16-17	220-530
Present study	2018	5-22	160-916

The National Radiation Safety Committee (NRSC)

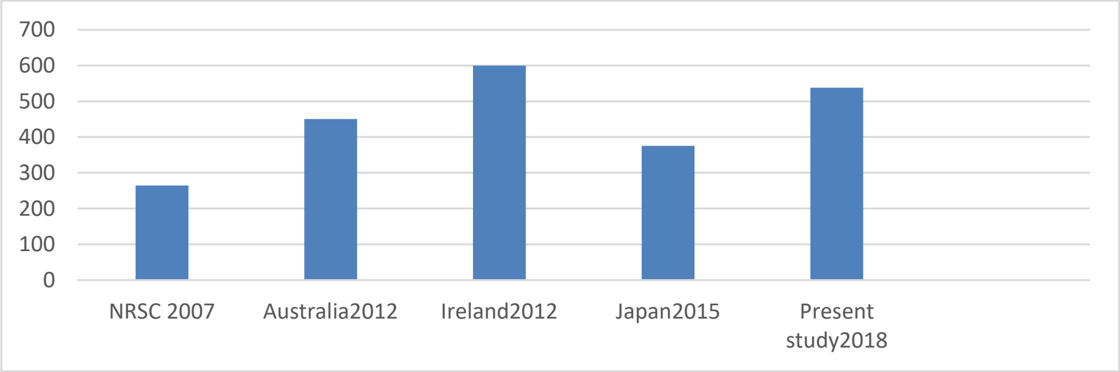

Fig.-1. Comparison of patient Radiation dose in terms of DRL (DLP (mGy cm)) for certain countries paediatrics patients for Abdomen and pelvis CT scan

Table-11 Comparison of patient doses with different CT modalities for CT abdomen and pelvis with Abdurrahman research for adults Sudan 2015 and this research for paediatrics

Modality	DLP (mGy.cm) Adult Sudan 2015	DLP (mGy.cm) paediatrics Sudan 2018
2S	447.22	358
4S	926.70	-
16S	572.93	473.9
64S	1018.98	1974.6
128S	978.92	556.2

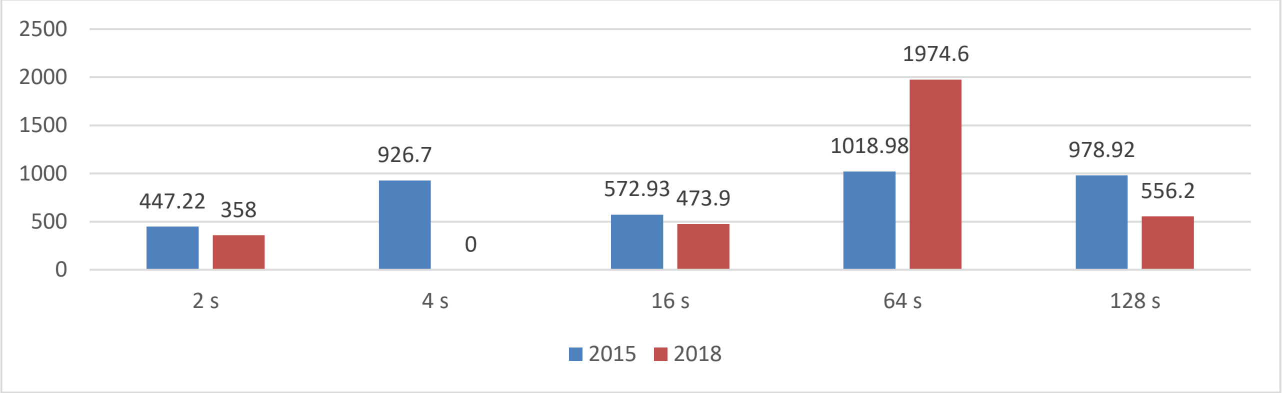

Fig.-2 Comparison of patient doses with different CT modalities for CT abdomen and pelvis with Abdurrahman research for adults Sudan 2015 and this research for paediatrics

Table-12.A: DRLs Diagnostic Reference Levels (DRLs) in Europe for paediatric CT examinations in terms of DLP, mGy cm. (DDM2 Project, 2010)

Age	Range	Mean	Countries with the most common DRL
0 years	27-130	78	Austria, Switzerland
1 year	70-160	115	Switzerland, France, Ireland
5 years	125-230	222	Switzerland, Ireland
10 years	240-400	320	Switzerland, France, Ireland
15 years	400-500	450	Switzerland, Ireland

Table-12.B: DRLs Diagnostic Reference Levels (DRLs) in Europe for paediatric CT examinations in terms of DLP, mGy cm. (DDM2 Project, 2010)

Age	Range	Mean	Countries with the most common DRL
0-5 years	27-230	128	Austria, Switzerland, France, Ireland
5-10 years	125-400	262	Switzerland, France, Ireland
10-15 years	240-500	370	Switzerland, France, Ireland

Table-13. DRLs in Sudan 2018 for paediatric CT Abdomen in terms of DLP, mGy cm.

Age	Mean Routine	Mean Tri-phase	Mean KUB
0 - 5 years	795	397	221
6-10 years	1398	530	225
11-16 years	926	943	476

CONCLUSION

Fortunately, 69% of the patients were send for KUB in which doses were the lowest compare with routine and tri-phase, However, it is necessary to take a lot of precautions to reduce the radiation dose of children, especially direct exposure to the genital areas, by means of appropriate radiation protection, and the appropriate examination after consultation between the technician, the doctor and radiologist, and the existence of a reasonable interval between the examination and return. The level of reference dose for the abdomen was performed for children and was the highest compared to European doses. Extra topics are highly suggested in this section in a certain chosen departments after special training for the technicians to deal best with the children and are able to adapt to the various devices to choose the ideal dose for the CT scan, taking into consideration the correct rules for radiation protection.

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