ISSN: 0975-833X

Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 15, Issue, 05, pp.24810-24814, May, 2023
DOI: https://doi.org/10.24941/ijcr.45252.05.2023

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

RESEARCH ARTICLE

COMPUTED TOMOGRAPHY SCANNING PARAMETERS AND RADIATION DOSES IN PAEDIATRIC PATIENTS

Japo M. Lukali, Merchris Mango, Ramadhan R. Kazema and Vicent Malika

Ilala City Council, Tanzania

ARTICLE INFO

Article History:
Received 11th February, 2023
Received in revised form
27th March, 2023
Accepted 03rd April, 2023
Published online 30th May, 2023

Key words:

Computed Tomography. Radiation dose. Scanning parameters.Tube potential. Tube current

Corresponding Author:
Japo M. Lukali

ABSTRACT

To determine Computed Tomography (CT) scanning parameters and radiation doses for pediatric patients according to age and body size. **Methodology:** This was a hospital based cross sectional study which was conducted at Radiology department, Muhimbili National Hospital from September 2021 to March 2022. One hundred and seventy four children underwent CT scan examination were recruited. Demographic information clinical indication and scanning parameters were obtained using structured questionnaires. CT doses estimation were calculated from CT dose calculator computer software supplied by Imaging Performance and Assessment of CT scanners (ImPACT). **Results:** Majority of children who underwent CT examination were males, from age group of 1-5 years. Head trauma was the commonest indication comprising sixty four percent. The tube potential and tube current for head examinations were higher than for the chest and abdominal examinations. The mean tube potential and tube current for the head were 115.4 kVp and 209.45 mA respectively. The doses for Head CT examinations were higher compared to the chest and abdomen, the mean CTDIvol (mGy) 11.78, DLP (mGy.cm) 231.42 and CTDIw (mGy) 16.6, but relatively lower than other international values. The calculated mean CTDIvol 11.8, 0.89, 1.79 and DLP 232.6, 36.5, 86.5 for head, chest and abdomen respectively were significantly lower than the values displayed on the console i.e. 36.7, 2.7, 2.6 CTDIvol and 731.7, 78.6, 114.8 DLPs. **Conclusion:** The use of large tube potential and tube current for head examinations has led to large doses for head examinations. The radiation dose mean values for CTDI vol, and DLP were significantly lower than those from other countries. We still have the chance to further reduce our doses to much lower levels.

Citation: ***Japo M. Lukali, Merchris Mango, Ramadhan R. Kazema and Vicent Malika.*** **2023.** "Computed tomography scanning parameters and radiation doses in paediatric patients*". International Journal of Current Research*, 15, (05), 24810-24814.

INTRODUCTION

Computed Tomography (CT) is an imaging modality that uses x-rays and computer processing to produce rapid, consistent and detailed information (through images) of the tissue density in slices through the patient's body. X-rays are one form of ionizing radiation used in computed tomography (CT) scanners and other x-ray devices. Since its introduction in 1970's, the use of CT has increased rapidly; this is because it is noninvasive and has high contrast resolution. Despite the fact that CT produce high contrast resolution, it uses larger doses of ionizing radiation compared to conventional x-ray resulting in a marked increase in radiation exposure in the population (1). Exposure to ionizing radiation may induce two types of effects namely Stochastic and Deterministic. Deterministic effects results from short term, high level (large dose) radiation exposure referred to as ''acute exposure". These effects usually appear quickly and include burns, hair loss, cataract and radiation sickness. These occur only if the radiation dose exceeds a certain threshold, and the magnitude of effect is directly proportion to the size of the dose. Stochastic effects are typically associated with long term, low-level (chronic) exposure to radiation. The effect increases as the radiation dose increases, but the severity of the outcome is independent of the dose. The probability of cancer development will therefore increase with radiation dose even for low dose medical imaging procedures (1). The primary stochastic effects are cancer and genetic defects (mutations). Stochastic risks are of special concern in pediatric imaging because children are more sensitive to the effect of ionizing radiation than adults and have longer life span to develop long- term radiation induced health effects like cancer (2)(3) Fatal cancer induction is the most serious effect of ionizing radiation (4)Most of the quantitative information about the risk of cancer induced by ionizing radiation is obtained from follow-up studies of a cohort of more than 35,000 atomic bomb survivors who had received low doses of radiation comparable to the dose of a single helical CT scan (5) CT is of special interest due to its relatively high radiation dose and wide use. CT use in children has drawn more attention because children are at greater risk of radiation exposure than adults due to their rapidly dividing cells which tend to be more radiosensitive, and also children have a longer expected life time in which potential radiation injury can develop(6). Although the individual radiation risks are quite small, radiation protection in pediatric imaging is a public health problem because of large number of children exposed to those risks (3).

The use of computed tomography in pediatric patients continues to grow despite evidence on known risks of CT- related radiation including induction of fatal cancers in children. About 4 million pediatric CT scans of the head, chest, abdomen and spine are performed each year in United States, and these are projected to cause 4870 future cancers (7). In African countries the number of pediatric CT examinations per year is relatively higher compared to Asia and Eastern Europe (8). In one of the largest teaching hospital in Nigeria, the records show that the proportion of CT studies that are currently performed in children range between 14% and 18%(9).A study done in Uganda in 2014 revealed that the frequency of pediatric CT is increasing with majority of examinations being performed in children 0-4 and 10-14 years(10). A study conducted by Muhogora *et al* in 2010 showed that the frequency of CT scan examinations per year in Tanzania was 3828, of which 587 were performed in children constituting about 13% of total CT scan examinations (8). Since the frequency of pediatric CT examinations is rapidly increasing and estimates suggest that quantitative lifetime radiation risks for children are not negligible, efforts should be made towards more active reduction of CT exposure parameters in pediatric patients. In recent years, radiation protection from pediatric CT revealed increased attention in international medical community. The United States Food and Drug Administration (FDA) published asset of recommendations in order to keep radiation doses during CT as low as reasonably achievable, especially for pediatric and small adult patients. They insisted on the importance of adjusting CT scanner parameters appropriately for each individual's weight and size, and for the anatomical region being scanned. The Image Gently Alliance for radiation safety in pediatric imaging was formed in 2007 US, with the primary objective of raising awareness about methods to reduce radiation dose during pediatric imaging. It recommended the ten steps of image optimization and lowering CT dose for pediatric patients (11).

The AFROSAFE campaign on radiation safety made by PACORI and Radiation health workers in Africa was also formed with the purpose of identifying and addressing issues arising from radiation protection in medicine in Africa. Its goal is that all radiation – based procedures are appropriately justified and optimized for maximum benefit to the patient. This was stressed out during PACORI meeting in Dar es salaam 2017. Various studies in Tanzania were conducted addressing the issue of Radiation protection on CT examination, but none of the study talked about pediatric age group which is the most important one, as children are more vulnerable to the effects of ionizing radiation.

MATERIALS AND METHODS

This was a descriptive hospital based cross sectional study which was conducted at Radiology department, Muhimbili National Hospital from September 2021 to March 2022. Children referred for CT scan for studies were assessed for scanning parameters and radiation doses were included in the study following informed consent from the parents/guardians. Children underwent CT examination by using a Siemens Somatom Definition Flash, Frank furt, Germany model dual tube with 128 slices, 64 slices each tube. Structured questionnaires were used for recording patients' demographic data, clinical indication of CT, and scanning parameters. CT dose estimation was calculated from CT dose calculator computer software supplied by Imaging Performance and Assessment of CT scanners (ImPACT). Data analysis was done using the Statistical Package for Social Sciences (SPSS) version 20. Statistical Association was done by using cross tabulations. P value of < 0.05 was considered statistically significant.

Data collection: Data collection was done through structured questionnaire which were filled by principal investigator. Data collected included socio-demographics, indications of particular CT examination, scan parameters i.e. kVp, mAs, pitch, slice thickness, number of slices, scan length, field of view (FOV), total scan time, rotation time, displayed CTDIvol and displayed DLP.

CT dose calculation: CT dose index is considered as dose descriptor in CT. CTDI is machine inbuilt and is displayed in CT scanner console, but this does not represent the actual absorbed or effective dose for the patient. Radiation dose estimation was therefore determined using the calculated Volume CT dose index (CTDIvol) in mGy the dose- length product (DLP) in mGy and CTDIw. The CTDOSE computer software supplied by Imaging Performance and Assessment of CT scanners (Im PACT) was used to obtain the calculated dose for comparison with those from scanner console and Kvp, mAs, pitch, slice thickness, start and end positions of each scan was used as input data.

RESULTS

Demographic findings: A total of 174 patients were participated in this study, of which 95(54.6%) were male and 79(45.4%) female as shown in the Table 1 below. The patients' mean age was 6.3(±4.7) years old. Age ranged from 0.01-15 years old. Majority of the patients were age group of 1-5 years old 55(31.6 %%) as Table 1 below shows.

Table 1. Sociodemographic factors among paediatric patients undergoing CT examination at MNH.N=174.

Demographic characteristics		Sex		
		Male	Female	Total
Age group	<1	18 (58.1%)	13 (41.9%)	31 (100%)
	1-5	31 (56.4%)	24 (43.6%)	55 (100%)
	6-10	26 (59.1%)	18 (40.9%)	44 (100%)
	11-15	20 (45.5%)	24 (54.5%)	44 (100%)
	Total	95 (54.6%)	79 (45.4%)	174 (100%)

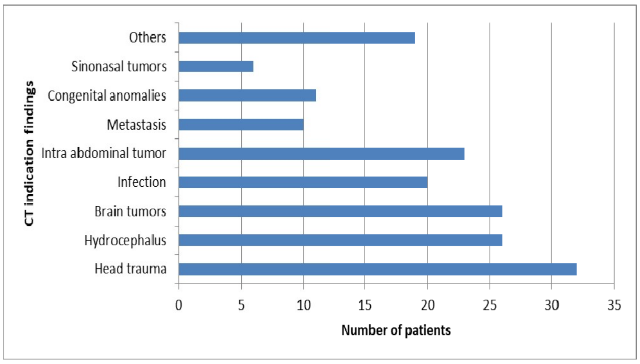

Figure 1. Distribution of the indications of Computed Tomography imaging in pediatric patients at MNH. N= 174

The results shown that head trauma was the most common indication found, followed by hydrocephalus and brain tumors; the third was intra-abdominal tumor as depicted in the Figure 1 above, Sino nasal tumors were the least prominent indications found. Others include Lymphoma, retinoblastoma, intestinal obstruction, chest masses, osteosarcoma of the hip and parotid tumors. Most of paediatric CT examinations were performed at tube potential ranging from (80-120) kVp for the head, and (80-100)kVp for the chest and abdomen. Tube current ranges of (76-32) mAs for head and (52-14) mAs (4, 45-245) mAs for chest and abdomen respectively. Pitch ranged from (0.6-1.5) mm for all examinations. Slice thickness ranged from of (0.5-10)mm for head,(5-10)mm for chest and(0.75-10)mm for the abdomen. These ranges are within the recommended values, except for the slice thickness of which the range exceeds 5mm which is not recommended for paediatric examinations.

The calculated CT doses for head and chest were higher in body weight less than 10kg compared to other weight groups. For abdominal examinations, the doses increased with weight. The CT doses were relatively higher for the head compared to chest and abdomen. The calculated CT doses for head were higher in age group less than 1 year compared to other age groups, however the doses increase with age for abdominal examinations.

Table 2. Values of CT scanning parameters in paediatric patients at MNH N=174

Type of examination	Abdominal CT (N=45)		Head CT (N=112)		Chest CT (N=17)	
	Mean ± SD	Range (Min-Max)	Mean ± SD	Range (Min-Max)	Mean ± SD	Range (Min-Max)
Tube Potential	83.6±7.7	80-100	115.9±9	80-120	91.8±10.1	80-100
Tube current	130.8±41	45-245	209±34.5	76-325	89.1±30.4	52-144
Effective mAs	109.5±68.3	18.5-345	164.3±55.1	61-350	105.1±58.3	56-255
Pitch	1±0.4	0.6-1.5	1.6±1.3	0.5-15	1.2±0.0	1.2-1.2
Slice Thickness	4.9±4.1	0.75-10	3.3±1.6	0.5-10	9.4±1.7	5-10
Total Scan Time	6.7±2.6	2.65-11.5	2.7±0.8	0.5-5.19	3.1±0.7	2.23-4.16
Rotation Time	0.5±0	0.5-0.5	0.5±0.1	0.28-1	0.5±0.1	0.28-0.5

Table 6: Calculated Computed Tomography radiation doses by weight groups amongpediatric patients at MNH

	Weight group	N	Calculated CTDIvol	Calculated DLP	CTDIw
			Mean (Range)	Mean (Range)	
Head CT	<10	18	12.9(4.9-33.4)	252.4(83-767)	14.9(3.9-31.6)
	10-15	31	11.3(4.6-16.4)	220.8(107-393)	16.6(4.9-24.5)
	15-30	48	11.9(2.1-27.7)	235.3(57-567)	17.2(2.7-30.5)
	30-45	15	11.6(5.5-19.3)	224.9(103-376)	17.4(8.3-28.3)
Chest CT	<10	3	0.9(0.7-1)	35.7(28-41)	1.1(0.8-1.2)
	10-15	4	0.8(0.5-0.9)	31.3(24-37)	0.9(0.6-1)
	15-30	4	0.7(0.4-1)	27.8(20-44)	0.8(0.6-1.2)
	30-45	6	1.2(0.4-1)	46.3(33-56)	1.4(1.1-1.5)
Abdominal CT	<10	5	1.3(0.6-2.1)	68.2(26-106)	1.1(0.4-1.8)
	10-15	11	1.2(0.5-3.7)	36-89)	1.4(0.7-2.3)
	15-30	22	1.7(0.5-3.7)	81.9(24-171)	1.6(0.7-3.5)
	30-45	7	3.4(2.1-6.7)	158.1934-316)	2(0.7-3.5

Table 7. Calculated Computed Tomography radiation doses by age groups among pediatric patients at MNH. N=174

	Age group	**N**	**Calculated CTDIvol**	**Calculated DLP**	**CTDIw**
			Mean (Range)	**Mean (Range)**	**Mean (Range)**
Head CT	<1	23	12.5(4.9-33.4)	246(83-767)	15.4(3.9-31.6)
	1-5	31	11.5(4.6-15.2)	219.6(107-312)	17.1(4.9-22.7)
	6-10	36	12.2(3.3-27.7)	248(57-567)	17.5(2.7-30.5)
	11-15	22	10.9(2.1-19.3)	212.1(93-376)	16.4(3.1-28.3)
Chest CT	<1	2	1(1-1)	39.5(38-41)	1.2(1.2-1.2)
	1-5	6	0.7(0.5-0.9)	29.3(23-37)	0.8(0.6-1)
	6-10	2	0.8(0.6-1)	34(24-44)	1(0.6-1)
	11-15	7	1(0.6-1)	42.6(20-56)	1.3(0.7-1.2)
Abdominal CT	<1	6	1.3(0.6-10)	64(26-106)	1.1(0.4-1.3)
	1-5	18	1.3(05-2.4)	65.2(24-126)	1.3(0.7-1.8)
	6-10	6	1.8(1-2.9)	90(44-147)	1.8(1.1-2.3)
	11-15	15	2.6(0.8-6.7)	119.8(41-316)	1.9(1.2-4)

Table 8: Calculated CT dosimetry values compared with displayed dosimetry values

Values	Displayed CTDI volmGy	Calculated CTDIvol mGy	Displayed DLPmGy.cm	Calculated DLPmGy.cm
Head CT	36.7816	11.8196	731.798	232.6518
Chest CT	2.7218	0.8941	78.6118	36.5294
Abdominal CT	2.6082	1.7978	114.8089	86.5556
TOTAL	42.1116	14.5115	925.2187	355.7368
P value at 95%CI	0.001	0.0001	0.0001	0.0001

Table 9: Mean CTDI vol by age compared with data reported from other international values

Types of examination	CTDIvol	This study		Australia		European	
	Age group (years)	CTDIvol	DLP	CTDIvol	DLP	CTDIvol	DLP
Head CT	<1	12.5	246	10.5	100	25	300
	1-5	11.5	219.6	10.5	100	38	505
	6-10	12.2	248	12	120	53	700
	11-15	10.9	212.1	15	150	60	900
Chest CT	<1	1.0	39.5	1.5	25	3.3	45
	1-5	0.7	29.3	1.5	55	5.6	115
	6-10	0.8	34	2.0	100	5.7	180
	11-15	1.0	42.6	2.5	150	6.9	200
Abdominal CT	<1	1.3	64	1.5	25	5.7	160
	1-5	1.3	65.2	1.5	55	5.7	170
	6-10	1.8	90	2.0	100	7.0	290
	11-15	2.6	119.8	2.5	200	14	580

Table 10. Comparison of the mean values of CTDIvol for head and Chest CT with minimum CTDIvol reported from IAEA

Types of examination	CTDIvol		
	Age group (years)	This study	IAEA
Head CT	<1	12.5	2.3
	1-5	11.5	2.7
	6-10	12.2	5.0
	11-15	10.9	14.5
Chest CT	<1	1.0	0.4
	1-5	0.7	0.5
	6-10	0.8	0.5
	11-15	1.0	0.5

The mean values of CTDIvol, DLP, and CTDIw for the head were significantly higher than for the chest and abdomen as demonstrated in Table above. The calculated CTDIvol were significantly lower than the values displayed on the scanner console (p - value = 0.0001, 95%CI). The calculated DLP were significantly lower than the values displayed on the scanner console (p – value = 0.0001, 95%CI. The mean CTDIvol and DLP for the head were higher compared to Australian values but relatively lower compared values reported by European study. For the chest and abdominal examinations, the mean CTDIvol and DLP from this study were relatively lower compared to those of Australia and Europe. The mean CTDIvol for head and chest were relatively higher compared with the minimum CTDIvol reported to International Atomic Energy Agency.

DISCUSSION

The study involved a total of 174 patients from age 0 to 15years. The majority of paediatric CT scan examinations were performed on under five children of 1-5 years (31.6%) Similarly, a study done in Switzerland by Francis R.et al, showed that most children underwent CT examinations was younger than 5 years of age (12). However a study by Kisembo *et al* noted the highest frequency of CT scan examinations to be in the age group 10-14(10). The lack of awareness about the hazards of CT radiations in children can also be the reason for the high number of CT scan examinations performed on the very young children as noted in this study. Males had higher number of CT examination compared to females in this study (62.9%). Similar findings were noted in a study by Nasoor *et al.* (13) and a study done in Uganda (10). Head CT were the commonest examination performed (64.4%) than chest and abdomen. Similar findings were noted in a study done by Brady *et al* (14) and Buls *et al* (15). This is caused by more number of head injury found in this study which warrants CT scans. Ultrasound and plain radiograph are still the main stay modalities of choice for abdominal and chest imaging for paediatrics respectively. With regard to CT scanning parameters, the mean values of tube potential, tube current and pitch for the head were more than for the chest and abdomen. Similar findings were noted by a study done in Portugal (16) and in Australia (17). The mean tube potential and tube current for the head were 115.4kVp and 209.45mA respectively with no evidence of adjustment based on body size and age of the patient. The mean tube potential and tube current for chest and abdomen were adjusted for paediatric body size and age with the mean value of 84.52 kVp and 90.42kVp for the tube potential and 126.5mA and 91.25mA for tube current respectively. Most of abdominal and chest examination were conducted using slice thickness of 10mm, this is very large for children due to their small body sizes. The Slice thickness of 5mm is recommended by WHO for paediatric examinations (3). There doses for Head CT examinations were higher compared to the chest and abdomen, CTDIvol (mGy) 11.78, DLP(mGy.cm) 231.42 and CTDIw (mGy) 16.6, similar findings were noted by(16) and (12) . This is due to the use of adult scanning parameters such as 120 kVp for head examinations. We therefore need to adjust the parameters for head examinations in order to minimize the radiation dose inflicted to our children. The calculated CT doses for head were higher in age group less than 1 year and weight group less than 10 kg compared to other age groups, This shows that the doses are not adjusted according to age and weight and therefore we really need to adjust them accordingly. There is also a great need to adjust our scanning parameters in order to further reduce the radiation doses to the very young ones. The principles of radiation protection in paediatrics require use of less radiation doses to younger age. The mean CTDIvol and DLP for the head were higher compared to Australian values(17) but relatively lower compared values reported by other international values (16)(12)(18) study. Although these presented data were lower than the values presented by most literature, lower values were reported by International Atomic Energy Agency(18). As the Afrosafe campaign insist on promotion of radiation safety in radiological facilities CT examination should be kept safe for paediatric imaging (33). For the chest and abdominal examinations, the mean CTDIvol and DLP from this study were relatively lower (3.4) mGy.and (153)Mg.cm respectively, compared to those reported from other countries (18)(16), this is caused by the use of large slice thickness(10mm) and the use of low tube current. Although some pathology can be missed because of the use of larger slice thickness in children's small bodies, multi planar multi slice reconstruction technique can provide that information.

CONCLUSION

Scanning parameters for head CT examinations are not adjusted for paediatric examinations. The use of large tube potential and tube current for head examinations has led to large doses for head examinations. The radiation dose mean values for CTDI vol, and DLP were significantly lower than those from other countries, however lowest doses have been reported to IAEA. We therefore still have the chance to further reduce our doses to the lower levels than these so as to reduce the level of radiation to our children**.**

REFERENCES

1. Brenner DJ, Hall EJ. 2007. Computed tomography-an increasing source of radiation exposure. *N Engl J Med*., 357(22):2277–84.
2. Alzen G, Benz-Bohm G. 2011. Radiation Protection in Pediatric Radiology. Dtsch Arztebl Int [Internet].108(24): 40714. Availablefrom:http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3132617/%0Ahttp://www.ncbi.nlm.nih.gov/pmc/articles/PMC3132617/pdf/Dtsch_Arztebl_Int-108-0407.pdf
3. W.H.O 2016. Communicating radiation risks in paediatric imaging [Internet].W.H.O. geneva:W.H.O;2016.2231p.Availablefrom:http://www.who.int/about/licensing/copyright_form/index.html
4. Shah NB, Platt SL. 2008. ALARA: is there a cause for alarm? Reducing radiation risks from computed tomography scanning in children. *Curr Opin Pediatr*., 20(3):243–7
5. Brody AS, Frush DP, Huda W, Brent RL, Care P. 2007. Radiation Risk to Children From Computed Tomography.120(3).
6. Hwang J-Y, Do K-H, Yang DH, Cho YA, Yoon H-K, Lee JS, et al. 2015. A Survey of Pediatric CT Protocols and Radiation Doses in South Korean Hospitals to Optimize the Radiation Dose for Pediatric CT Scanning. Medicine (Baltimore) [Internet]. 94(50): e2146.Availablefrom:http://www.ncbi.nlm.nih.gov/pubmed/26683922%0Ahttp://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC5058894
7. Miglioretti DL, Johnson E, Williams A, Greenlee RT, Weinmann S, Solberg LI, et al., 2013. The Use of Computed Tomography in Pediatrics and the Associated Radiation Exposure and Estimated Cancer Risk. JAMA Pediatr [Internet].2013;167(8): 700. Availablefrom: http://archpedi.jamanetwork.com/ article.aspx? doi=10.1001/ jamapediatrics.311

8. Muhogora WE, Ahmed NA, AlSuwaidi JS, Beganovic A, Ciraj-Bjelac O, Gershan V, et al., 2010. Paediatric CT examinations in 19 developing countries: Frequency and radiation dose. *Radiat Prot Dosimetry*.140(1):49–58.
9. Ogbole GI. 2010. Radiation dose in paediatric computed tomography: risks and benefits. Ann Ibadan Postgrad Med [Internet].8(2):11826.Availablefrom:http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=4111023&tool=pmcentrez&rendertype=abstract
10. Kisembo H. 2015. A survey of paediatric CT radiation doses in two selected hospitals in Kampala, Uganda: a radiation safety concern. Int J Cancer Ther Oncol [Internet].3(3):3327. Available from: http://ijcto.org/index.php/ IJCTO/article/ view /ijcto.33.27
11. Strauss KJ, Goske MJ, Kaste SC, Bulas D, Frush DP, Butler P. et al. 2010. Image gently: Ten steps you can take to optimize image quality and lower CT dose for pediatric patients. *Am J Roentgenol.,* 194(4):868–73.
12. Verdun FR. CT radiation dose in children : a survey to establish age-based diagnostic reference levels in Switzerland. 2008; 1980–6.
13. Article O, Nsoor N. 2009. Factors that can be attributable to radiation dose reduction among pediatric age group. 25(4):669–73.
14. Brady Z. 2012. Radiation Doses and Risks from Paediatric Computed Tomography. PhD Diss., (February).
15. Buls N, Bosmans H, Mommaert C, Malchair F, Clapuyt P, Everarts P. CT. 2010. paediatric doses in Belgium : a multi-centre study. (February).
16. Santos J, Foley S, Paulo G, Mcentee MF, Rainford L. 2014. The establishment of computed tomography diagnostic reference levels in Portugal.158(3):307–17.
17. Mohammed K, Al S, Kin C, Ng C, Sun Z. 2015. Pediatric Computed Tomography Dose Optimization Strategies : A Literature Review. J Med Imaging Radiat Sci [Internet].;46(2):241–9. Available from: http://dx.doi.org/10.1016/j.jmir.2015.03.003
18. Guidelines P. European Guidelines on DRLs for Paediatric Imaging. 2015;(September):1–105.
19. Nyabanda R. 2015. Championing radiation safety in Africa. Afrosafe kenyan champion.

****