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Evaluation of Local Diagnostic Reference Levels for Paediatric and Adult Patients Undergoing Head Computed Tomography Examination in Amhara Regional States, Ethiopia

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ABSTRACT

Introduction: During computed tomography examinations variation of dose for pediatric and adults has been increasing widely, even when automated exposure control is used. Hence, the objective of this study was to assess the computed tomography head local diagnostic reference levels in the Amhara region.

Material and Methods: Active computed tomography scanners in the Amhara region were identified and then both retrospective and prospective technique was used to collect data for pediatric and adult head examinations. Scan parameters, patient profiles, and CT dose indicators were collected from 334 patients. Pediatric patients were grouped into three age (years) groups of (1-5, 5-10, and 10-15). The local diagnostic reference levels were established from third quartile values of computed tomography dose index and dose length product. SPSS software version 26 and Microsoft Excel 2016 were used for the entire data analysis.

Results: The calculated 3rd quartile values of computed tomography dose index and dose length product, for adult head examinations, were 49 mGy and 1806 mGy.cm respectively. Similarly, for pediatric head CT scan, computed tomography dose index (mGy) and dose length product (mGy.cm) values for age (years) groups (1-5, 5-10, and 10-15) were (30, 2015); (35, 1221); and (43, 2051) respectively.The investigated 3rd quartile values of computed tomography dose index and dose length product were higher than other national and international reported values.

Conclusion: For all pediatric and adult patients , there are differences in the local diagnostic reference levels between the CT centers and the same scanners, indicating the need for dose optimization.

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Introduction

Computed tomography (CT) is an imaging technique, which generates cross-sectional slices of the body with integrated use of X-rays and computers. This technique is not risk-free since it uses ionizing radiation in medicine. CT utilization has been increasing steadily and the recent data shows that more than 30%ionizing radiation doses in the United States came from CT scans [1].

Numerous CT dosage surveys have shown significant variations in practices for the same kind of scan [2, 3] suggesting that some exposures may not be optimally optimized. The degree of variation indicates that these variations can be attributed to factors more than only the equipment, including patient characteristics like size and weight as well as the exposure parameters and protocols that were utilized.

Modern CT scanners have utilized automatic exposure control (AEC) systems that use tube current (mA) to behave to the attenuation variations within the patient for different spatial projections or at specified times based on user-defined adjustments [4]. Although the dose reduction technique is used, significant differences in radiation dose for comparable CT examinations from different departments have been reported [5]. Evidence has shown that the effective dose of similar CT examination varied up to 32-fold between different cities [6]. For a pediatric cervical Spine CT examination, more than 2.5-fold dose variation between different hospitals was recorded [7]. When automated exposure control is employed in clinical routines, it is generally expected to result in a considerable change in radiation dose on the same CT scanner, even during follow-up CT examinations.

The second and serious one is that users' selectable exposure factor and underestimation of personnel towards the risk of ionizing radiations [8]. Evidence shows that the level of management of risk to patients and awareness of the user to explain this technology in sub-Saharan Africa is almost poor [9]. Research conducted in Ethiopia at Tikur Anbessa Specialized Referral and Teaching Hospital among senior medical students and interns has shown that most of the

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respondents knew the risk of CT, but they failed to implement their protocols [10]. Again surprisingly, research conducted in Jima University Specialized Hospital (JUSH) has shown that doses delivered to pediatric patients were not according to the ALARA principle and suggested that optimization of service and patients 'radiation exposure was needed in JUSH in particular and in Ethiopia in general [11].

In addition to these, underestimation of personnel towards the risk of ionizing radiation results, examination of children equally with adults, and repetitive examination without justification on the area of pathology has increased [12].Hence, constantly, assessing patients received dose per examination is required to estimate the variation of dose delivered to pediatric and adult patients. Although evaluating the influence of exposure parameters on the dose delivered to pediatric and adult head patients is imperative, no study has conducted research in the Amhara region, Ethiopia, regarding the variation of doses between pediatrics and adult head patients.Therefore, this research was one of the major concerns regarding the issue in general, particularly in the Amhara region, Ethiopia.

Materials and Methods

Study design

A retrospective and prospective cross-sectional hospital-based study was conducted to study pediatric and adult head CT examinations in the Amhara region from July 2020Gc to October 2020Gc.Of11 administrative zones in the Amhara region, only three administrative zones had a computed tomography scanner in their referral hospital. The hospitals from which the study was conducted were; Gondar University referral hospital (GURH), Felege-Hiwot referral hospital (FHRH), and Desie referral hospital (DRH). All CT scans performed in Amhara regions were the source populations. All head CT scans performed during the study period for which their scan parameters available the study populations. All head and neck CT scans were excluded from the research.

Sample size and sampling technique

A hospital-based retrospective cross-sectional study was conducted on a total of 334 (150 adult and 184 pediatric) head patients of all age groups during the study period. A convenience sampling technique was used and the sample size was determined based on ICRP-135 recommendations [13].To determine the local diagnostic reference level (LDRL), pediatrics were stratified into three age groups of (1–5, 5–10, and 10–15) years based on computed tomography availability in the region.

Data collection and analysis

During CT exams, almost all scanners today show the patient Computed Tomography dose index volume and dose length product. Recording patient dose descriptors and scan protocols allowed us to know whether the dosage is below or above the recommended value. Hence, the data collection format includes quantities for assessing routine technical parameters such as; scanning mode, sequence number, usage of contrast materials, and exposure parameters like; kilovolt (kVp), milli - ampere (mA), milli ampere second (mAs), gantry rotation time, pitch, beam width, scanning range and dose indicators like; computed tomography dose index (CTDIvol (mGy)) and dose length product (DLP (mGy.cm)) was prepared in English. The data collection format had also socio-demographic characteristics like age and sex. Data entries were done in Microsoft Excel2016 and exported to SPSS version 26 software for analysis. We checked each piece of data for precision, clarity, and consistency. From the collected data mean, standard deviation (±SD), and third quartile were generated. Finally, the results were compared with other studies.The 3rd quartiles of CTDIvol (mGy) and DLP (mGy.cm) were used to compare the findings with other international diagnostic reference levels (DRLs) of adult and paediatric head CT examinations.

Ethical consideration

The rights of the study group were respected, considering ethical aspects.The study was performed post-approval of the Hospital's Research and Ethics Committee of the Radiology Department, in the Amhara Region. All information was kept confidential by withholding the names of the respondents.

Results

In this study, a total of 334 (150 adult and 184 pediatric) head patients of all age groups were investigated during the study period.

Table 1. CT scanners presented and involved in the participating centers for study

CT scanners data	Participated centers in the study		
	GURH	FHRH	DRH
CT manufacturer	Phillips-Health care	GE-Health care	GE-Health care
CT model	Brilliance CT 64	Optima CT 540	Optima CT 540
Year of installation	2017G.C	2018G.C	2020G.C
Year of manufacturing	2015G.C	2017G.C	2018G.C
Number of detector rows	64	16	16
Automatic exposure controller (tube current modulations) available?	Yes	Yes	Yes
CTDI for pediatric body displayed for which phantom (16 cm or 32 cm)?	16	16	16

Table 2. Mean (±SD) value of technical factors, CT dose descriptors and third quartile of (CTDIvol, DLP) all adult and pediatric patients undergoing head CT examination in all three hospitals

Hospitals	Tot Pt	Age group (yrs)	Pt age (Yrs) mean (±SD)	kVp mean (±SD)	mA mean (±SD)	mAs, Mean (±SD)	Pitch mean (±SD)	Scan range mean (±SD)	CTDI vol (mGy) mean (±SD)	Total DLP (cm.mGy)mean (±SD)	3rd quartile CTDIvol	3rd quartile Total DLP(cm.m Gy)
GURH	20	1-5	2(1.1)	114 (9.1)	141(88.4)	218(176.1)	0.55(0.1)	30(13.1)	28(5.1)	1911(528.4)	31.2	2173
	14	5-10	7.6(1.5)	113(9.7)	139(89.8)	220(180.6)	0.5(0.01)	36(13.7)	27(5.6)	1708(821.7)	33.9	2679
	28	10-15	13.4(1.7)	116(8.3)	133(89.7)	192(174.7)	0.6(0.3)	38(15.3)	25(6.3)	1980(554.2)	30	2350
	41	adult	52.5(21.8)	114.6(8.9)	302(234.2)	206.6(176.1)	1.25(0.00)	23.1(5.0)	26.6(4.7)	1939.6(941.1)	30.2	2469.7
FHRH	20	1-5	2(1.1)	108(18.8)	195(79.2)	208(84.5)	0.56(0.00)	9.0(1.8)	31(17.7)	920(821.1)	38	1333
	14	5-10	7.6(1.6)	111(14.5)	169(53.0)	181(53.0)	0.56(0.00)	9(3.5)	36(12.9)	804(520)	47	759
	26	10-15	12.8(1.5)	117(11.1)	185(54.2)	199(58.1)	0.56(0.00)	11(9.6)	49(12.9)	1238(520.4)	70	1642
	45	adult	45(17.5)	114.6(8.9)	210.9(45.7)	219(58.5)	0.6(0.2)	6.9(3.4)	51(18.1)	1347.6(690.1)	66.9	1806
DRH	14	1-5	1.9(0.7)	120(0.00)	141(41.5)	114 (31.5)	1(0.00)	8(4.3)	28(18.9)	953(743.4)	29	971
	20	5-10	6.6(1.4)	120(0.00)	120(0.00)	120 (0.00)	1(0.00)	6.4(4.4)	26(6.9)	684(294.1)	31	898
	28	10-15	13(1.6)	120(0.00)	213(51.5)	213(51.5)	1(0.00)	4.6(3.1)	38(6.4)	952(495.2)	39	884
	43	adult	48.6(20.5)	120(0.00)	238(60.6)	238(60.6)	1(0.00)	5.4(3.3)	42.3(6.4)	949.3(308.5)	48.8	878.8

Table 3. Paediatrics Head CT: Comparison of values of CT dose indicators of this study with DRLs given in some other studies

	This study		Ataç GK et al. 2015		Verdun et al, 2008		Järvinen etal, 2015		Supika Kritsaneepaiboon et at 2012	
Patient Group	CTDIvol(mGy)	DLP(cm.mGy)	CTDIvol(mGy)	DLP(cm.mGy)	CTDIvol(mGy)	DLP(cm.mGy)	CTDIvol(mGy)	DLP(cm.mGy)	CTDIvol(mGy)	DLP(cm.mGy)
1-5	30	2115	13.1	125	30	520	25	370	30	570
5-10	35	1221	14.3	179	40	560	29	420	40	610
10-15	43	2051	13.7	210	60	1000	36	560	45	800

Table 4. Adult patients: Head CT: Comparison of values of CT dose indicators of this study with DRLs given in the international standards

Dose parameters	This study	Other Studies					
	UOGCSTRH,FHCSRH, and DCSTRH	Sahknini et al, 2017	Ekpo et al, 2018	Salama et al , 2017	Korir et al, 2016	Nyathi M et al, 2018	Kharuzhyk SA et al, 2010
CTDIvol(mGy)	49	44	20	31	12.2	3 2	60
DLP(cm.mGy)	1806	760	1486	1425	890	767	730

As shown in Table1, the CT scanners chosen for inclusion were all multi-detector-row systems and there were single CT units per participating center of which, one had a different model from the three participating centers. Table 2, shows - mean and standard deviation (±SD) values of technical factors, and CT dose indicators of all adult and paediatric patients underwent head CT examination in all three hospitals.

Table 3 shows: a comparison of 3rd quartile values of paediatric head CT dose index volume (mGy) of this study with DRL values given in some other studies. Table 4 shows the comparison of the 3rd quartile values of the adult head-dose-length product (mGy-cm) of this study with the DRL values of different countries.

Discussion

From this research, variations in CT dose indicators value and utilization of scan parameters for pediatric and adult head CT across different age groups were identified, providing evidence that different protocols were used like [14] to perform the CT procedures for the same anatomical region (Table 2). The substantial variation in CT protocols for the same anatomical region delivers more than two to three folds of DLPs higher than necessary across all three hospitals were identified. Surprisingly, variability of scan parameters and CT dose indicators were also observed from the same CT scanner (FHRH and DRH) and the same age group (Table 2). It is worth mentioning that both GURH and FHRH did not adapt the protocols based on the age of the patient. These leads to a variation of 3.5-fold of DLP values between these two hospitals in the paediatric age (years) groups of 5- 10 (Table 2). This is primarily related to the variation of scan parameters and the 4-fold variation of scan length in the same age groups. There is also more than 2.5 folds of DLP variation between DRH and GURH in adult head examinations because of the same reason specified above. Although all three hospitals were using dose optimization tools such as tube current modulations (Table 1) which can reduce patient dose considerably, large differences in dose indicators in the same anatomical region and for the same CT scanner model were observed (Table 2).The possible explanation for this might be the poor knowledge of technologists about the efficiency of CT scanner and their poor knowledge about the advanced scanning techniques[15] .This difference may be resolved by improving the education of technologists in medical radiation protection focusing on the proper use of dose reduction tools by the application of standardizing acquisition protocols [16].

This study showed that the 3rd quartile values of CTDIvol and DLP of the current adult head patients were higher than other authors [17-22] (Table 4). This difference may be attributed to differences in scan length which is not indicated in most of the research and the usage of scan protocols which vary on the training of technologists in each country. Similarly, when the present study compared with other studies, the DLP of pediatric groups of age (1-5, 5-10, and 10-15 yrs) were substantially higher than other similar studies [23-26] (Table 3). A possible reason for the higher paediatric DLP in this study than in similar studies [23, 24] could be that the pediatrics in this study were receiving adult-sized scan protocols when performing computed tomography scans (Table 2**).** Surprisingly, except for age groups 5-10 years, the 3rd quartile DLP values of all other age groups were higher than the 3rd quartile DLP values of adult patients. For example, in DRH, a kVp of 120 and a pitch of 1 is used for all adults and all paediatric age groups without decreasing potential (kVp) and increasing pitch for pediatric patients result in having the same DLP (Table 2).The finding from these results showed that significant reductions in patient doses would be possible in paediatric CT examinations without adversely affecting image quality. The results of this study indicated that substantial reductions in patient doses could be achieved in pediatric CT examinations without compromising image quality**.** It was observed that exposing pediatric patients to the same dose as adults, resulted in a greater impact of radiation on children [13, 27], likely because of due to their smaller size and some other related factor. This inconsistent use of scan parameters, which resulted in variation of DLP values between all pediatric and adult patients, is a consequence of the lack of standardization within the department. The standardization between the hospitals promote the reduction of dose differences between hospitals[13]**.** A result showed that there is a need to develop diagnostic reference levels in the country to optimize the CT procedure effectively. This variation of scan parameters between participating hospitals can also be solved by adapting documented guidelines and protocols for pediatric imaging [28].

Conclusion

There are variations in the local diagnostic reference levels between the computed tomography centers and identical scanners in all pediatric and adult patients of routine computed tomography indicating the necessity for dose optimization. Hence, the authors of this manuscript recommend, that the regional diagnostic reference levels presented in this document can be used as a baseline against which future dose measurements in the area can be compared. To further minimize the trends of using adult CT protocols for pediatric patients and optimize pediatric radiation dose in the region, a similar type of survey should be undertaken within couple of years.

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