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Techniques to Optimize the Exposure of Pediatric Patients on Adult Scanners

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Abstract: This report proposes techniques for optimizing the radiation exposure of pediatric patients to adult CT scanners in developing countries. A prospective method was carried out. Most hospitals in this country have older generations of adult CT scanners without a functioning pediatric (software) protocol. A study was done in 2015 and 2018 on 161 pediatric patients to verify improved practices in the hospitals studied through the proposed strategies. In 2015, the principles of radioprotection were not rigorously respected, but in 2018, the practice improved. The sensitization of medical staff in terms of radioprotection today is visible. Dose parameters decreased in 2015 to 2018 for skull examinations. The activation of the pediatric protocol option in the software used for adult CT scanner in hospitals, the reduction of high tube voltage (kV), the tube current-time product (mAs) and the respect of the immobilization measures proposed in this work according to the ages are factors contributing to the improvement of pediatric examinations in this emerging country. The use of radiological protocols and procedures that are not suitable for pediatric examination delivers great scan lengths resulting in exposure to ionizing radiation of some unnecessary parts in an examination.

Keywords: Pediatric CT Scanner, Optimization of Protocols, Dose of Ionizing Radiation

1. Introduction

Computed tomography (CT) is now a very used diagnostic tool for the evaluation of various pathologies in children and adults. CT scanner is the medical imaging device giving a good quality of image in radio-diagnostic. It is the most used device in most hospitals in this country to diagnose certain pathologies difficult to diagnose in the head by conventional radiology for example. The use of magnetic resonance imaging is more effective in preventing children from being exposed to ionizing radiation. But the developing countries have a small number (2 for all the country) of them. In this country, older generation CT scanners for adults are the most used. Children are exposed to ionizing radiation (IR) on adult CT scanners. Their examinations are done with the adult protocol.

As the child is very small in front of adults, the adult protocols that these children receive are inappropriate for their morphologies. In this context, the optimization of the irradiation dose and pediatric patient protocols should not be neglected on these machines. Radiosensitivity of children to ionizing radiation is greater than that of adults [1, 2]. This radiosensitivity is due to their growing organisms, to the large proportion of their young cells, to their high life expectancies than to adults. Strategies are proposed to improve the practice of pediatric CT scan in developing countries and still using older generation CT scanners.

2. Materials and Method

2.1. Eligibility Criteria

After conducting a prospective and observational study for a 6-month period (February to July 2015) 3 years ago, we conducted another 2-month study (from September to October 2018) on pediatric patients aged 0 to 15 years in a public (H1), parapublic (H2) and private (H3) hospital in this developing country. The characteristics of the CT scanner in these hospitals during these years are presented in Table 1. Patients who mainly underwent a skull scan (trauma) were selected. The age groups are: <1 year, 1-4 years, 5-9 years and 10-14 years. A total of 161 patients were recorded. Table 2 presents the number of acquisitions according to the different age categories. In this study, $CTDI_{Vol}$ and DLP are recorded on the 16 cm phantom for all examinations of the head. This study was approved by the research ethics board of the three hospitals studied.

Table 1. *Characteristics of scanner devices in the three hospitals.*

Hospital	Model	Serial	Date of Manufacture	Date of installation	CT technique
H_2	GE Bright Speed[8]	26058HM4	November 2010	2012	4-rotation helical
H_3	GE Light Speed[16]	55957HM5	Mars 2003	2009	16- rotation helical
H_1	HITACHI ECLOS Speed[16]	225761HM6	Mars 2009	2009	16- rotation helical

Table 2. *Total number of skull acquisitions and age groups in 2015 and 2018.*

Years	Examination	Number of acquisitions			
2015	Age	<1 year	1-4	5-9	10-14
	Skull	14	24	21	39
2018	Age	<1 year	1-4	5-9	10-14
	Skull	12	9	27	15

2.2. Statistical Analysis

Parameters such as Product Dose Length (DLP), Volume Computed Tomography Dose Index ($CTDI_{Vol}$), tube current-time product (mAs), High tube voltage (kV), Age, Gender, slice thickness (T), the mode and the pitch of each child for each type of scan were noted during the various examinations and processed in the Microsoft Excel software. In 2015, hospitals used the helical mode and the same 120 kV for all age groups. The tube current-time product used ranged from 57.75 to 283.33 mAs, the slice thickness (T) from 1.25 to 2.5 mm according to the default values offered by the CT scanners. In 2018, the high tube voltage ranged from 100 kV to 120 kV, tube current-time product from 100 to 250 mAS, and slice thickness from 2 to 2.5 mm.

3. Results

The examinations studied at CT Scanner in 2015 and 2018 were mainly traumas for the skull. Pediatric age groups exploited are: <1 year, 1 to 4 years, 5 to 9 years and 10 to 14 years. In 2015, the helical mode and the same high tube voltage of 120 kV for all age groups were used. Tube current-time product (mAs) and slice thickness (T) ranged from 57.75 to 283.33 mAS and 1.25 to 2.5 mm respectively. The principles of radioprotection were partially respected by medical imaging technicians. The restraints used to immobilize the children were the same as the adults (Figure 1). In 2018, after the reduction and optimization techniques recommended in 2015 in these hospitals, the kV are now modified and vary from 100 to 120kV depending on the region explored and the ages of the children. The mAs are modified before the examination. The proposed immobilization techniques are applied. Limiting the number of acquisitions are used. Most exams are limited to acquisition without injection of the contrast medium. Examinations of children whose parents do not have money for sedation are made using the proposed technique. It consists of making the child to sleep late the day before the examination. On the day of the exam, he will feel tired and as soon as he falls asleep, we make his examination. All these techniques recommended in these hospitals improve the practice of the pediatric CT scan on the old CT scanners generations.

Figure 1. *Scout view of an examination of the skull and brain of a child taken in hospital number 2 (H_2). This image shows the patient's length of scan in relation to his height, area to be explored and in relation to length recommended in radiation protection.*

Tables 3 and 4 compare the 3rd quartiles of $CTDI_{Vol}$ and the skull DLP of this study (in 2015 and 2018) for an acquisition with the values of an African country [3], other European countries and the literature of comparison. The comparisons are made on the 16 cm ghost for all exams of the head. The $CTDI_{vol}$ values of children <1 year of this study (51.94 mGy) are superior to the comparative literature (20 mGy for Switzerland [4], 22 mGy for Togo). Togo's $CTDI_{vol}$ for children aged 5 to 9 (32 mGy) are below most of this European research (50 mGy for Germany [5] and Ukraine [6]). The mGy.cm DLP in this country (1,200.04 in 2015 and 1,006.04 in 2018) are higher than all these literatures (900 for Shrimpton et al and 813 for Togo) for children aged 5 to 9 years.

Table 3. *Comparison of the 3rd quartiles of $CTDI_{Vol}$ in mGy of this study in 2015 and 2018 with international studies for the skull for an acquisition.*

Examination / Ages	This study (2015)	This study (2018)	Ukraine 2005[6]	Germany 2007[5]	Switzer-land 2008[4]	France 2009[7]	Togo 2016 (Mean)[3]
Skull /<1	51.94	34.2	30	33	20	30	22
Skull /1-4	51.94	36.65	45	40	30	40	36
Skull /5-9	51.94	51.94	50	50	40	50	32
Skull / 10-14	51.94	56.28	-	60	60	-	46

Table 4. *Comparison of the 3rd quartiles of the DLP (mGy.cm) in 2015 and 2018 of this study with international studies for the skull for an acquisition.*

Examination / Ages	Dose (mGy.cm)	This study (2015)	This study (2018)	DRL (2012)[9]	DRL (2019) [15]	Shrimpton and al [6]	Togo 2016 (Mean)[3]
Skull/<1	DLP	1044.55	670.1	420	320	420	546
Skull /1-4	DLP	1141.63	766.63	600	360	600	800
Skull /5-9	DLP	1200.04	1006.65	900	470	900	813

4. Discussion

Many medical imaging technicians in 2015 were not well built on the concepts of optimizing dose protocols and the notion of radioprotection especially on children. The majority of them have not received training in radioprotection. As the pediatric protocol was not functional in their CT scanner, they validated most of the default values offered by the CT scanner for pediatric examinations. However, the dose ratios of adults and children were therefore identical. Some even did not know that kV could be modified as in conventional radiology. They knew how to introduce the parameters of the patient, to start the acquisition, to reduce the lengths of the scoot view, to stop the examination. Which is not enough to optimize a protocol. This leads to the absorption of large amounts of doses to children. Children are irradiated on CT scanner that are not adapted to their morphology. The scoots view being parameterized for the morphology of the adults causes exposure to ionizing radiation (IR) of the very small ones over a great scan length of scan (figure 1). These great scan length produce a large dose-length product (DLP). Scoot view can not be modified by imaging technicians before the first acquisition is launched. The best way to immobilize the child was by sedation. The restraints used (Figure 2) are not sufficient to immobilize agitated children. For age groups lower than the previous one, the values of this study are higher than those of the previous literature and those of Ukraine [6] and France [7]. For countries such as Switzerland [4] and Germany [5], our values are lower for skull examinations of 10 to 14 years (Table 3). Togo achieved this result because it used the "tube current modulation" mode which allows the doses to be reduced, but only the exposure parameters in this mode are not always adapted appropriately to the problematic or size of the patient, particularly in children [3].

Figure 2. *Inadequate restraint used to immobilize children in hospitals in this country.*

After the report of this research in 2018, children are always exposed to IR on CT scanner designed for adults. Others have recently purchased a new device (2018) that is more efficient for adults but has only the pediatric protocol for the examination of the functional head (H_3). This is an optimization start but it is not enough for the other parts of the body. To immobilize agitated children, aged less than 5 years, we propose, with equipment available at the hospital, to wrap the ends of the studied area (for example the head) with perforated red sticky plaster (roll 18 Cm x 5) making at least three rounds of plasters around the motorized table. For older children, whose parents can not afford a sedation service, we suggest to sleep deeply and add the restraint of the examination table (strap compression) to avoid a possible displacement in case of unexpected awakening. If not, we also suggest having the child sleep late at home the day before the exam. Then bring him early in the morning so that we can do the exam quickly when he is still sleepy. With the motivation of his parent he can easily fall asleep during the exam. For quiet children, we ask parents to motivate or encourage their children to stay calm and not be afraid on the scanner table. For him to be deeply confident, we can admit the parent (the man) in the examination room with a leaded blouse. In the case where none of these methods are applicable, proceed to sedation. For examinations that take practically the whole body of children (abdominal CT), we propose to cover the unnecessary area in the exam with this leaded blouse (Figure 3 [8]) for the protection of organs very radiosensitive to IR (gonads, thyroid, eyes). The activation of the pediatric protocol option in the CT scanner software used in hospitals is one of the key factors in optimizing the practice of CT scanner. The improvement of practices in this country is evolutionary and the sensitization of the personnel of the medical service in term of radioprotection of these days is visible. The knowledge and skills of medical imaging technicians and even radiologists today are already updated through seminars, continuous and regular training in medical imaging and the concept of radiation protection.

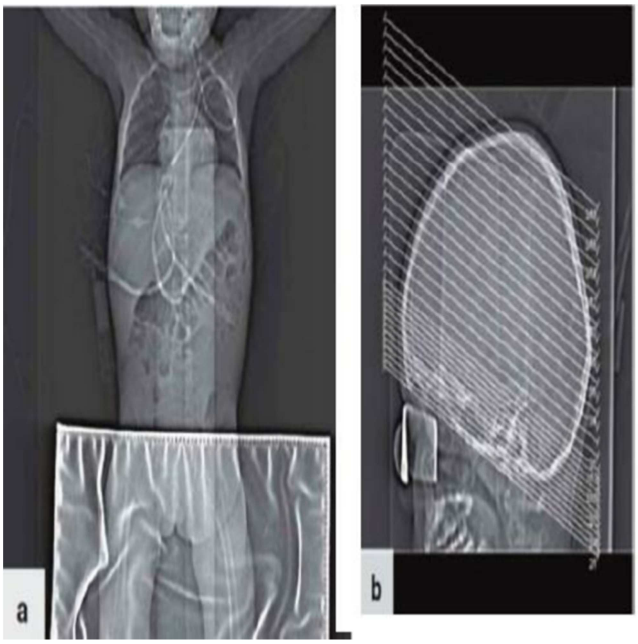

Figure 3. *Radioprotection of a child's scanner [8]: a) Scout view of a chest scanner with unnecessary exposure of additional body parts but using a shielded shield when the scout is for example very large compared to the size of the child. b) Slicing of a cranial parallel of CT at the base of the skull to protect the orbits. The scout view also shows a band of eye protection.*

Compared with 2015, radiation dose results for 2018 are lower $CTDI_{Vol}$ decreased by 34.15% for children <1 year, 29.43% for children 1-4 years, and Dose Length Products (DLP or $CTDI_{Vol}$) also decreased by 35.84%, 32.84% and 16.11% for children <1 year, 1-4 years and 5-9 years respectively for skull examinations. $CTDI_{Vol}$ of the skull of children aged 1-4 in 2018 (36.65 mGy) are below some comparator countries (45 mGy for Ukraine, 40 mGy for Germany and France). For children aged 10 to 14 in the same year, $CTDI_{Vol}$ (56.28 mGy) are also above the data for Ukraine (60 mGy) and Germany (60 mGy). The doses of this study are very high in front of the diagnostic reference levels of France of 24 October 2011 [9].

Optimization of radiological protocol parameters at the pediatric CT scanner

The need to optimize protocols has always existed but is not rigorously taken into account in our hospitals. This is why improvements in that domain is a necessity in this country. Most recommendations are not yet put into practice. Among other things, the scan length can be reduce; pediatric protocol can be activated in CT scanners, reconstruction algorithm for dose reduction can be use, in contras enhanced CT scanner do not forget to reduce the kV. It is important also to choose the optimal acquisition mode for an examination forgetting the notion of time (helical or axial), to be rigorous in the introduction of radiological parameters so as not to forget anything, to use adequate time even if we work in a private hospital and focus on the health of the patient and to look forward by the purchase of a CT scanner, to include functional adult and pediatric protocol option in this country. The United States offers 10 optimizations strategies from the Gently image campaign [10] to adapt protocols to patient morphology: 1. Increase awareness and understanding of radiation issues among radiologists; 2. Use the services of a qualified medical physicist; 3. Get accreditation from the American College of Radiology for your action strategy 4. If applicable, use an alternative imaging strategy that does not use ionizing radiation; 5. Determine if the CT scan is justified for the clinical indication; 6. Establish DRL; 7. Establish pediatric dose levels based on morphology; 8. Optimize the parameters of the pediatric examination (Center the patient; Reduce the doses during the scout view; Choose axial or helical mode; Reduce the size of the detector in the z axis during acquisition; Adjust the current product of the tube/exposure time; Set the kV; Increase the pitch; Manual or auto MACT) 9. Analyze only the indicated area: An acquisition; 10. Prepare a child-friendly environment.

The decrease in the voltage is at the origin of a significant reduction of the dose (for example, keeping the other constant parameters, the decrease of the kV of 120 to 80 reduces the dose delivered by a factor 2.2 [11]) but causes an increase in noise [12]. Heliot C., Mestdagh P., Opsomer H., Chaffiotte C., in their document proposes that the choice of a relatively low value should be preferred (one can use 80 kV for newborns) because it helps to reduce the dose [13]. As for the International Commission on Radiological Protection [14] (ICRP), for children weighing between 5 and 50 kg, it is possible to use 100 kV in the routine.

DRL of $CTDI_{Vol}$ of France 2019 [15] (320, 360, 470 mGy.Cm) are lower than those of France 2011 (420, 600, 900 mGy.Cm). Therefore, it is possible to increase the dose in those hospitals. We have to adjust radiological parameters.

This report was disrupted by certain device failures.

5. Conclusion

The practice of pediatric CT scan should be improved in our hospital training by decreasing the scan lengths, applying during the evaluation of the sedation dosage, using a more adequate compression (plexi board plus bandage) to prevent any movement the patient; By favoring the choice of the radiological parameters recommended in the literature according to the weight of the patient. Hospitals must equip themselves with pediatric CT scanner in case adjustment is not possible. A common protocol for the use of CT scanner in this country should be set up to avoid random work in order to promote the use of a common procedure following the principles of radiation protection. The radiological practices must consist of delivering the least possible dose while providing a satisfactory result in terms of image quality and diagnostic information.

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Compliance with Ethical Standards

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Disclosure of Potential Conflict of Interest
The authors declare that there are no conflicts of interest.

Ethical Approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent

Informed consent was obtained from all individual participants included in the study.

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