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Pediatric dose assessment in common CT examination towards establishment of related regional DRL in Mazandaran, Iran

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► ***Short report***

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ABSTRACT

Background: Computed Tomography (CT) is main contributor of population dose from diagnostic X-ray examinations. Children are more radiosensitive than adults, thus optimization of CT examination in these patients is essential. The purpose of this study was to evaluate dose delivered to pediatric patients' undergoing CT examination of the common examinations and also establishing local Diagnostic Reference Levels (DRLs). ***Materials and Methods:*** Questionnaires were designed for data collection at seven public hospitals and information about patient, protocol and CT system were recorded during 2013 and 2014. Dose measurement was performed in four age groups: 0-1, 1-5, 5-10 and 10-15 years old and two CT dose quantity including CTDIw and DLP were calculated. ***Results:*** Values of 40, 48, 59.5, 59.5 mGy; 16.9, 16.9, 17.14, 17.14 mGy; 17, 17, 17, 17 mGy; 17, 17, 19.2, 19.2 mGy in terms of CTDIw and 448, 538, 758, 758 mGy cm; 129, 129, 154, 167 mGy cm; 184, 225, 306, 315 mGy cm; 289, 408, 595, 670 mGy cm in terms of DLP as regional DRL for brain, sinus, chest, abdomen and pelvic examinations were obtained respectively. ***Conclusion:*** The variations in dose of some examination were considerable. As the role and usage of CT technology continues to expand, it is important that all practitioners adapt optimized protocols, especially for pediatrics scanning, following proposed reference levels.

Keywords: *Computed tomography, pediatric, diagnostic reference level, radiation dosimetry.*

INTRODUCTION

A study performed during 1998-2003 in Switzerland, revealed that the number of Computed Tomography (CT) examinations had increased by about 70% [(1)]. Coren *et al.* have shown that between the years 1991 to 1994, CT examination of children increased to about 63% [(2)]. Children are at the greater risk to the carcinogenic effect of ionizing radiation because their tissues are more radiosensitive than adult [(3)]. Radiation protection of children is of high importance because of the higher radiation risks associated with exposure in childhood. This topic has become more important in the last decade because of new uses of CT in children, with some publications raising questions of appropriateness associated with more frequent imaging of children, as well as a number of studies that indicate that radiation doses to children in CT are not optimized [(4–10)]. Awareness of a lack of radiation protection in CT of children became apparent when it was pointed out that the same scanning protocols are often used for children as for adults, resulting in higher than necessary doses to children [11, 12]. Two major principles of radiation protection as established by the International Commission on Radiation Protection (ICRP) are justification and optimization. Most efforts have been directed at optimization and there is a paucity of information on justification or on the use of appropriateness criteria established by professional bodies such as the American College of Radiology (ACR) [13]. International Commission on Radiological Protection (ICRP) introduced Diagnostic reference level (DRL) in ICRP Publication 60 [14], and in more detail in ICRP Publication 73 [15] as a tool for optimization of radiological procedures. In practice, DRLs are set at the 3rd quartile of the dose distribution in a broad survey that includes different CT machines, users and protocols [16]. Studies revealed that in CT examination, there are variations in doses for the same examinations between different departments [17, 19]. Therefore, choosing a quantity as a national or regional reference dose for an examination helps finding situation where patient dose is higher than elsewhere. The aim of this article was to assess the population dose received by the different CT procedure, to set of reference dose values for some pediatric CT examinations as regional DRL in pediatric CT examination in Mazandaran province.

MATERIALS AND METHODS

Data collection

This study was performed during 2013-2014 at seven public hospitals in different cities over Mazandaran province. A questionnaire was developed and patient related data (age, sex, and weight), CT scan machine's specification (type, manufacturer, number of detector row) and protocol (kVp, mAs, and slice thickness, number of slices, pitch, and table increment) were recorded. Four CT examinations including: brain, sinus, chest and abdomen and pelvic were examined. In this study, patients were separated into four age groups (0-l years, 1-5 years, 5-10 years and 10-15 years).

Dosimetry

Dose measurement was performed with pencil ionization chamber (DCT10 RS, Electronics, Molndal, Sweden) connected to X-ray multimeter (Barracuda, RTI Electronics, Molndal, Sweden) and CT dosimetry phantom. The chamber has 100mm active length and designed for CT dosimetry. The CT ion chamber which was calibrated and corrections for temperature and pressure was done according to manufacturer manual. Two cylindrical polymethylmetacrylate (PMMA) phantoms with different diameters are used in CT dosimetry surveys as patients head and body representative with 16cm and 32cm diameter respectively. It is recommended that pediatric dose measurement should be perform on 16 cm phantom regardless of age or scan area (18). Therefore, in this study dose of all examinations were measured on 16 cm phantom. Quantities that used in CT for dose expression are Weighted Computed Tomography Dose Index (CTDIw) which is a quantity to express radiation dose in a single axial rotation, Dose Length Product (DLP) that expresses total dose in a complete examination and Volume Computed Tomography Dose Index (CTDIvol) which has introduced as dose quantity in multi-detector CT systems.

For dose measurement, phantom was placed in iso-center where its axis was paralleled to the gantry rotation axis in the center of scan plane. Then ionization chamber was placed in dosimetry hole and other holes were filled with PMMA plugs. Measurements have been done 3 times. According to questionnaire, a single axial scan was performed. This procedure was repeated for all phantom holes and then CT dose quantities were calculated.

Data analysis

The data were analyzed to assess the number of examinations in a 1-year. The frequency of a particular CT examination was determined as the proportion of that type of pediatric CT examination to all CT examinations and expressed as a percentage. The frequency of pediatric CT for each technique was estimated by averaging the frequencies for all participating centers. The frequency expressed in this way provided the relative proportion of pediatric versus adult CT examinations in each participating center. The mean value, 3rd, standard deviation and p-values of data were calculated by using Matlab software.

RESULTS

The details of pediatric brain examination utilized in each age group are shown in table 1 as an example. The seven hospitals indicated in table 1 use spiral CT systems and are coded alphabetically from A to G. As seen, there are fundamental differences in the scan parameter among the hospitals. These discrepancies observed for three other examinations as well. Most of the hospitals use a consistent tube voltage (kVp) for all age group and the use of lower kVp for the younger patients applied only in hospital C. The variation in the mAs value is also considerable. Hospitals A, C and G, applied lower mAs with decreasing patient age but an opposite trend was observed in hospital B, where the applied mAs for two youngest age groups was higher. Variations in the slice thickness are also observed between the hospitals (from 4 to 10 mm). These variations in scan parameters and also in CT systems led to dose variation of same examination from hospital to hospital. Variation in the dose of same scan area was significant but there was some general trend between radiation dose and patient age. For brain examination, a reduction in the DRL of $CTDI_v$ and DLP were observed with decreasing patients' age. A similar reduction in DRL of DLP was also observed in sinus, chest, abdomen and pelvic examinations. However, all age groups in chest examination, two youngest and two eldest age group in sinus, abdomen and pelvic examination had similar DRL for $CTDI_w$. The error bars that represent the standard deviations indicate large variation in DLP of all examination. The p- value of related results is calculated bellow 0.05. The differences are considerable when comparing the mean value of DLP, particularly in the 10-15 years old age group for brain and chest examinations between this study and Switzerland (figure 3).

Table 1. The details of Protocol which is used in different centers for brain examination.

Age group	Protocol parameters	Hospitals						
		A	B	C	D	E	F	G
0-1	KVp	120	110	110	120	130	110	120
	mAs	70	110	150	140	270	270	120
	T (mm)	10	6	5	10	4, 6	5, 8	7.5
	Pitch	-	1.1	0.85	-	1	0.8	1.2
1-5	KVp	120	110	110	120	130	110	120
	mAs	70	110	170	140	270	270	150
	T (mm)	10	6	5	10	4, 6	5, 8	7.5
	Pitch	-	1.1	0.85	-	1	0.8	1.2
5-10	KVp	120	110	130	120	130	110	120
	mAs	170	100	235	140	270	270	240
	T (mm)	5, 10	4, 6	4, 6	10	4, 6	5, 8	.5
	Pitch	-	1.1	0.85	-	1	0.8	1.2
10-15	KVp	120	110	130	120	130	110	110
	mAs	170	100	235	140	270	270	300
	T (mm)	5, 10	4, 6	4, 6	10	4, 6	5, 8	7.5
	Pitch	-	1.1	0.85	-	1	0.8	1.2

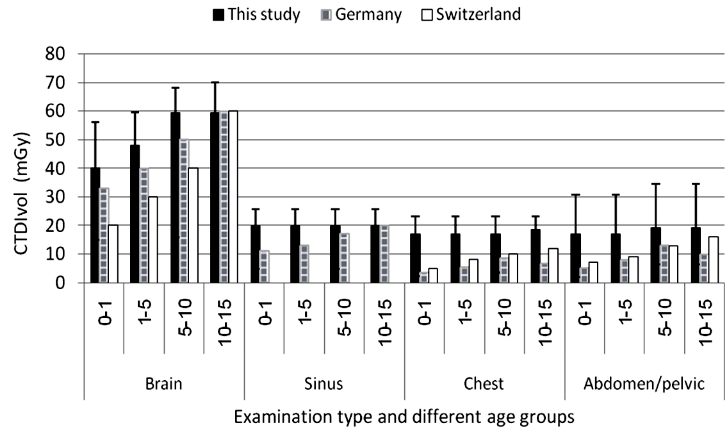

Figure 1. Comparison of the 3rd quartile of dose distribution for one single axial scan of this study with the international reference levels (Germany [19] and Switzerland [17]). Error bars describe the standard deviation of the mean value.

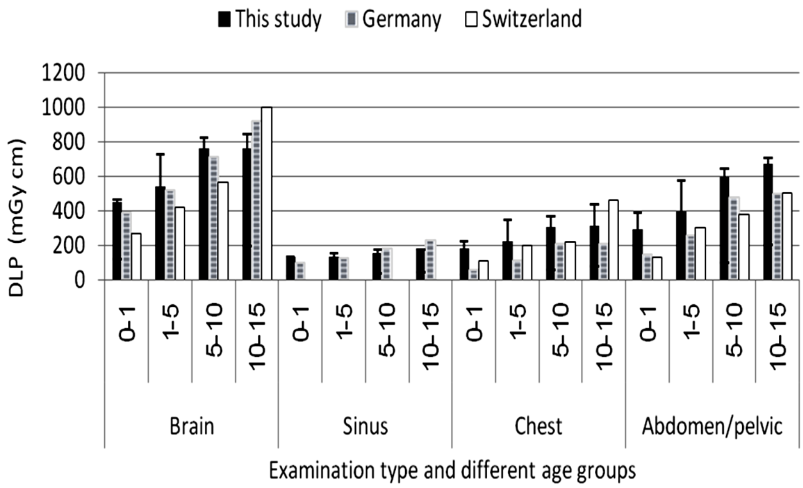

Figure 2. The 3rd quartile of dose length product (DLP) of this study in comparison with the international reference levels (Germany [19] and Switzerland [17]). Error bars describe the standard deviation of the mean value.

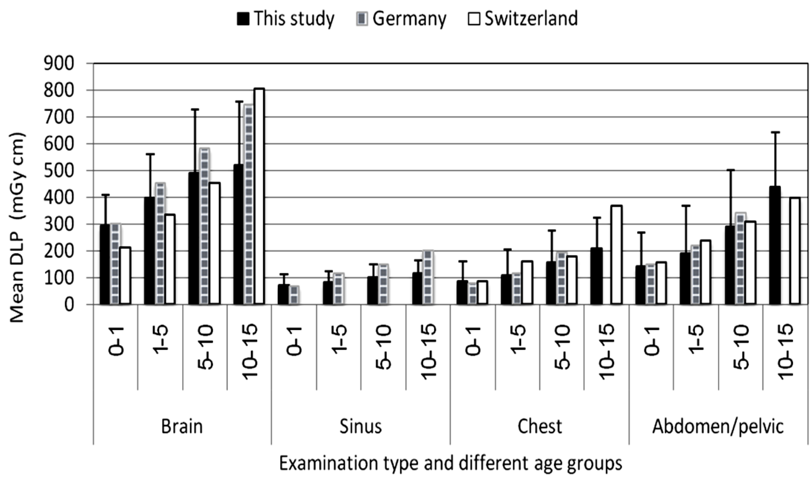

Figure 3. Mean DLP value of this study in comparison with Germany [19] and Switzerland [17]. Error bars describe the standard deviation of mean values. Data of chest and abdomen & pelvic examination for 10-15 years old in German study were not recorded (Error bars describe the standard deviation of the mean value).

DISCUSSION

This study represents the first survey of dose measurement in pediatric CT examination of the brain, the sinus, the chest, and the abdomen & pelvic and four age groups were evaluated. The hospitals involved in the study use a wide range of CT systems from different manufacturer. Most hospitals are using multi-slice CT (MSCT): three 16-slices and two 6-slices from two manufacturers (Siemens and GE). However, single-slice CT (SSCT) and conventional (third generation) CT are still using in Mazandaran province. These discrepancies in CT systems could be a reason for dose variation for same examinations. The seven hospitals that provided frequency data performed approximately a total of 32000 CT examination of brain, sinus, chest and abdomen & pelvic in 2013; 3024 CT scans (approximately 9.4%) were performed on children before the age of 15. 12.5% of the pediatric examinations were performed on children before the age of 1, 19% on children between 1 and 5 years old, 29.5% on children between 5 and 10 years old, and 39% on children between 10 and 15 years old. Brain examination had the highest percentage (41.3%) of the total, whereas sinus, chest and abdomen & pelvic account for 19%, 19.2% and 20.5% respectively. Large variations in patient dose were observed for each age group and all examinations. Brain examination had the highest $CTDI_v$ and DLP values for all age groups compared to other examinations because of the particular irradiation condition (such as thinner slice thickness and high level of tube current or mAs).

Figures 1 and 2 compares our DRL with proposed DRLs for Germany [19] and Switzerland [17]. The study done in Switzerland did not include sinus examination. In figure 3, the mean value of DLP compared with the mean values reported for Germany and Switzerland. According to those figures, in brain examination, our reference doses of all age groups were higher than Germany and Switzerland except the eldest age group that our values were lower. In chest, abdomen and pelvic examination, our reference doses were higher except the DLP value of eldest age group in chest examination, where our value was lower than Switzerland data. This was probably because of our lower scanning length in this age group compared to Switzerland. In chest examination, all age groups had same $CTDI_v$ (17 mGy) but DLP increased with age. This is because of the larger scan length in elder patients. Compared with the German data, our corresponding scan length was lower in all examinations except for the abdomen & pelvic examination in two eldest age groups. In the 5-10 years and 10-15 years age group of this study the scan length was 33 and 42 cm, whereas the German scan length was 31.6 and 40 cm respectively. Therefore, there is a possibility for dose optimization by reducing the scan length. The most inter-center variation observed in both $CTDI_v$ and DLP value of abdomen & pelvic examination. It was observed that in some centers, same protocol and irradiation factor utilized for all age groups (table 1). Choosing protocol and irradiation factor adapted to the patient's size could reduce individual doses [20]. Our results show that the variation of children CT dose is substantial.

CONCLUSION

The frequency of CT examinations on pediatric patients and the values of CT dose quantities (CTDIv and DLP) in Mazandaran public hospitals were evaluated. Significant variations were observed in the scan parameter and radiation dose quantities. There is a possibility for dose optimization by reducing the scan length. Also awareness of a lack of radiation protection in CT of children became apparent when it was pointed out that the same scanning protocols are often used for children as for adults, resulting in higher than necessary doses to children.

Therefore, there is an essential need for reconsideration of CT protocols, reducing individual doses and also reducing dose variations between different centers. The proposed DRLs in this study were established appropriate to the current circumstances of Mazandaran province in CT examinations. The set of reference doses are proposed and recommended that these values used as provisional until a comprehensive study is conducted to examine all pediatric CT examinations over the country.

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Conflict of interest: *Declared None.*

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