http:// ijp.mums.ac.ir
Original Article (Pages: 13437-13444)

Evaluation of Volume CT Dose Index (CTDIvol) and Dose Length Product (DLP) in Routine CT scan Protocols among Children under 15 Years of Age Admitted to Imam Khomeini Hospital in Ahvaz, Iran, during 2019

Mohammad Ghasem Hanafi[1], *Maryam Farasat[1], Mohsen Cheki[2], Hoda Pakzadi[1]

[1]Department of Radiology, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran.

[2]Department of Medical Imaging and Radiation Sciences, Faculty of Paramedicine, AhvazJundishapur University of Medical Sciences, Ahvaz, Iran.

Abstract

Background

The computed tomography (CT) scan is a valuable tool in the diagnosis of various diseases, but the absorbed dose causes concern, especially for children. The present study aimed to evaluate the absorbed dose of volume CT dose index (CTDIvol) and dose length product (DLP) in routine CT scan protocols in children under 15 years of age admitted to Imam Khomeini Hospital of Ahvaz, Iran.

Materials and Methods

The present descriptive-analytical epidemiological study was carried out on children under 15 years of age admitted to Imam Khomeini Hospital of Ahvaz during the first 6 months of 2019. CTDIvol and DLP values were measured using a pencil ionization chamber. Universal dosimeter fire ware 2, 20, and single scan standard phantoms were done on children in a single scan for several routine CT scan protocols. Data were analyzed using SPSS software version 16.0.

Results

Significantly different ($P < 0.05$) CTDIvol values were obtained for head, chest, and pelvis (2.14 ± 0.93, 0.93 ± 0.07, and 1.20 ± 0.53, respectively). The obtained DLP values for head, chest, and pelvis (28.46 ± 0.93, 23.91 ± 2.26, and 38.14 ±2.52, respectively) were significantly different ($P <0.05$). Mean CTDIvol and DLP values calculated for head, chest, and pelvic protocols were significantly different by month.

Conclusion

The mean CTDIvol and DLP values for the head, chest, and pelvic protocols, which are within the allowable range and will not be associated with the risks mentioned in this test on children, are less than the values suggested by various guidelines and other studies.

Key Words: CT scan, Child, CTDIvol and DLP.

*Please cite this article as: Hanafi MG, Farasat M, Cheki M, Pakzadi H. Evaluation of Volume CT Dose Index (Ctdivol) and Dose Length Product (DLP) In Routine CT scan Protocols among Children under 15 Years of Age Admitted to Imam Khomeini Hospital in Ahvaz during 2019. Int J Pediatr 2021; 9(4): 13437-444. DOI: **10.22038/IJP.2021.53585.4258**

Corresponding Author:

Maryam Farasat, Department of Radiology, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran.

Email: fr.ajums@gmail.com

Received date: Aug.23, 2020; Accepted date: Feb.22, 2021

1- INTRODUCTION

Computed tomography (CT) scan or was first introduced for medical imaging in 1972. It has undergone many advances in both technical and clinical aspects and today has many research and therapeutic applications in diagnostic sciences and medical physics (1). The national council on radiation protection and measurements (NCRP, 2006) stated that CT scans, with 67 million scans per year, accounted for 15% of all X-ray medical examinations and about 50% of the cumulative radiation exposure dose. It is also the largest source of medical radiation in the United States (2). The above figure increased to about 85 million in 2011, with 5-11% of these scans performed on children (3). CT scans are commonly used among children to diagnose the causes of abdominal pain, assess the post-traumatic injury, diagnose and determine stage cancer, monitor response to cancer treatment, and diagnose and monitor infectious or inflammatory disorders (4).

CT scans are mostly performed on the heads of children, and traumas are the most common reason for CT scans. This imaging technique is often used to diagnose and manage brain injuries in children because it is readily available and accurately and quickly detects injuries that require immediate intervention in an acute care center (3). However, the increasing CT usage has led to increased concerns about the absorbed radiation, especially in children (5). United Nations scientific committee on the effects of atomic radiation (UNSCEAR) 2013 report on the effects of radiation exposure on children states that children may receive far higher doses than adults if the technical parameters are not adjusted (6). Researchers from the British Cancer Society have also announced that children and adolescents exposed to X-rays are much more likely to develop cancer than adults (7). According to the foregoing, the present research project aims to investigate the radiation absorbed dose during CT scans among children admitted to the Imam Khomeini Hospital in Ahvaz and to determine whether or not its range is within the allowable range.

2- MATERIALS AND METHODS

2-1. Method

The present descriptive-analytical epidemiological study aimed to evaluate the effective cumulative radiation dose among patients under 15 years of age admitted to the CT Scan Ward of Imam Khomeini Hospital in Ahvaz during the first 6 months of 2019. DLP and CTDIvol values were measured using a standard pencil ionization chamber and standard phantoms in a universal dosimeter fire ware 2. Besides, 20 single-dose dosimeters for several routine protocols used in routine CT scans including brain, lung, abdomen, and pelvis CT scans were done on children under 15 years of age. Data were analyzed using SPSS software version 16.0.

2-2. CT scanner

Quality control tests include the accuracy and reproducibility of the parameters of each scan applied to the device under clinical conditions, including distance from the center in two consecutive sections, section thickness, milliampere (mA), peak kilovoltage (kVp), and the number of sections, pitch factor, scan area length, and total acquisition length. These parameters were then recorded for each protocol for an average of 10 patients under 15 years of age each month. The dose rate was then measured, and finally, the CTDIvol and DLP values were compared after applying the values to the device. To measure the dose rate, a pencil ionization chamber (model TM30009) with an active length of 10 cm, a UNIDOS dosimeter (Universal Dosimeter Fire Ware 2,20), and a standard phantom (PTW

Company, Germany) were used to measure absorbed dose to head and body tissues.

2-3. CTDIvol measurement

At first, head phantom to measure the head dose and PNS and body phantom to measure chest, abdomen, and pelvis doses on CT bed surface were positioned at headrest and bed of CT. Then, the ionization chamber was placed on the central bore of the phantom, other bores were filled by an acrylic bar, and the dose values were measured through three scans and implementing clinical parameters on phantoms. Afterward, the same process was repeated for side bores of the phantom at 9, 6, 3, and 12 o'clock positions. The same steps were repeated for the 10 patients in each protocol. Afterward, CTDI of each position was obtained using the following CTDI (1) Equation:

$$\text{CTDI}=1/\text{NT}\int D(Z)d(Z)$$

Where, D (z) is radiation dose at Z direction, N is the number of active detectors at each 360° rotation of X-ray bulb, and T is the slice thickness. Then, CTDIw was calculated using Equation (2):

CTDIw equation (2)

CTDIw=1/3 CTDIc + 2/3 CTDIp (mGy)

Where CTDIc is the obtained value of CTDI at the central bore of head and body phantom, and CTDIp is the average value of CTDI measured at 9, 6, 3, and 12 o'clock positions of head and body phantom.

CRDIvol was then obtained using the following formula:

1/pitch*1CTDIw: CTDIvol

2-4. DLP calculation

Equations (3) and (4) were used to calculate the DLP, which represents patients' total dose received during a complete process of CT scan.

For axial scan (where the bed is fixed during the rotation of the tube around the patient):

DLP = ΣnCTDI.T.N.C (mGy, cm) (3)

For helical scans (where the bed is fixed during the rotation of the tube around the patient):

DLP = ΣnCTDI.T.A.t (mGy, cm) (4)

Where, nCTDI is CTDIw divided by mAs, T is the thickness of slice (cm), N is the number of slices of each protocol, C is the X-ray bulb, a current over radiation term (mAs), A is the X-ray bulb current (mA), and T is the total time of data collection during a specific protocol(s) (8).

A sample size of 278 people was estimated using the Morgan table, which obtained the largest possible sample size for a limited study population, taking into account the results of previous years, when approximately 1000 people needed a CT scan each year, and considering the following formula, type I error = 0.05, and d = 0.1s. Finally, 120 people entered the study.

$$n=\frac{\left(z_{1-\alpha/2}\right)^2 s^2}{d^2}$$

Where, n indicates sample size, z is the confidence interval, s is prevalence, and d is accuracy.

The present study was conducted from January 2019, to the end of December 2019. The data collection process lasted for one year (2019). Quality control tests include the accuracy and reproducibility of the parameters of each CT scan that is applied to the device under clinical conditions, including the distance between the centers of two consecutive sections, section thickness, mAs, kVp, number of sections, pitch factor, scan area length, and total acquisition length. After applying the obtained values to the device, the dose value was measured to obtain the mean CTDlvol and DL P-value.

CTDlvol and DLP were calculated based on formulas 1/pitch*CTDlw=CTDlvol and DLP=∑nCTDI.T.A.t, respectively. Data were collected by a checklist consisting of the patient's personal information (age, sex, height, and weight) and the main variables of the study, including age, sex, DLP, and CTDlvol.

2-5. Data analysis

The collected data were analyzed using SPSS software version 16.0 and a P-value < 0.05 was considered as the significance level. Mean ± standard deviation was used in the case of quantitative variables, and distribution and frequency were used for qualitative variables. The normality of data was evaluated using the Kolmogorov-Smirnov test and t-test was used to investigate quantitative data (8, 9).

3- RESULTS

This study was performed on 180 children under 15 years of age (90 females and 90 males) who were candidates for a CT scan in Imam Khomeini Hospital in Ahvaz, Iran, during 2019. In the present study, the KVp value was 80 for the head, chest, and pelvic protocols, and the mAs values were 25, 6.75, and 11.80, respectively. The mean CTDIvol values calculated for the head, chest, and pelvic protocols were 2.14 ± 0.93, 0.93 ± 07, and 1.20 ± 0.53 (mGy), respectively, which were significantly different based on the Kruskal-Wallis test (**Table.1**).

Table-1: The average absorption dose within the scanned volume of CTDIvol (mGy) for head, chest, and pelvic protocol among children under 15 years.

Absorption dose		Mean ± SD	Minimum standard sample	Maximum standard sample	P-value
CTDI(vol), (mGy)	Head	2.14 (0.93)	1.11	4.94	<0.001
	Chest	0.93 (0.07)	0.28	2.22	<0.001
	Abdominal and pelvis	1.20 (0.53)	0.32	1.96	<0.001

SD: Standard deviation, CTDI: CT dose index. Table.1 shows the average absorbed dose within the scanned volume under CT scan for patients under 15 years of age.

DLP values of the head, chest, and pelvis were 28.46 ± 0.93, 23.91 ± 26 2.26, and 38.14 ± 2.52 (mGy*cm), respectively, which were significantly different based on the Kruskal-Wallis test (**Table.2**).

Table-2: Average absorbed dose within the length of scan area DLP (mGy/cm).

Absorption dose		Mean ± SD	Minimum standard sample	Maximum standard sample	P-value
DLP (mGy*cm)	Head	28.46 (0.93)	33	42	<0.001
	Chest	23.91 (2.26)	4	67.30	<0.001
	Abdominal and pelvis	38.14 (2.52)	6	81	<0.001

SD: Standard deviation, DLP: Dose length product. Table.2 shows the average absorbed dose along the length of the scan area for patients under 15 years of age.

Based on the results of **Tables 2 and 3**, the mean values of CTDIvol and DLP calculated for the head, chest, and pelvic protocols were significantly different according to the month.

Table-3: Mean CTDIvol calculated for head, chest, and pelvic protocol among patients under 15 years of age by month.

Month	Protocol		
	Head, Mean ± SD	Chest, Mean ± SD	Pelvic, Mean ± SD
March	2.05± 0.18	0.68± 0.37	1.14± 0.27
April	1.88± 0.17	0.86± 0.56	1.23 ±0.52
June	2.48+0.61	0.87± 0.61	1.23±0.52
July	1.99±0.20	1.19±0.52	0.76± 0.25
August	1.96± 0.38	1.36± 0.42	1.67±0.21
September	2.46±1.17	0.61± 0.46	1.20± 0.39
Total	2.14± 0.60	0.93± 0.55	1.20± 0.41
P-value	0.087	0.011	<001

SD: Standard deviation.

Table-4: Mean DLP values for head, chest, and pelvic protocols among patients under 15 years of age by month.

Month	Head, Mean ± SD	Chest, Mean ± SD	Pelvic, Mean ± SD
March	33.50 ± 6.62	17.40± 12.67	34.30± 17.18
April	24.20 ± 3.39	20.10 ± 15.24	43.20 ± 20.37
June	27.60 ± 4.14	20.10 ± 14.94	38.80 ± 12.02
July	28.50 ± 6.65	31.20 ± 17.39	18.30 ± 9.58
August	29.30 ± 8.44	39.20 ± 15.47	59.50 ± 16.30
September	27.67± 10.16	15.46 ± 19.36	34.75 ± 17.27
Total	28.46 ± 7.22	23.91 ± 17.51	38.14 + 19.58
P-value	0.114	0.01	<0.001

SD: Standard deviation.

4- DISCUSSION

It is important to note that unnecessary radiation leads to irreversible risks and this attitude is pursued more seriously, especially among children, who are significantly more sensitive to ionizing radiation than adults. As children have a longer life expectancy than adults, there is a longer opportunity to assess the radiation-induced damage in children, which justifies radiation tests, especially CT scans, in children (4). Therefore, the present study aimed to determine the effective cumulative dose and whether or not this dose is within the allowed range among patients under 15 years of age who referred to the CT Scan Ward of Imam Khomeini Hospital in Ahvaz, Iran during 2019. In the present study, KVp was equal to 80 kV in the head protocol and 110 kV in the chest, abdomen, and pelvis protocols. The head KVp was reported to be 120, 120, 121, 130, and 140 kv in studies carried out in Iran (7), in the international atomic energy agency (IAEA) (10), Taiwan (11), Kenya (12) and Iraq (13), respectively. On the other hand, the pelvis Kvp was equal to 120, 121, and 125 kv in studies carried out in Iran (7), Taiwan (11), and Kenya (12), respectively. The chest KVp was equal to 120, 123, and 122, 125, and 120 kV in studies carried out in Iran (7), IAEA (10), Taiwan (11), Kenya, and Iraq (13), respectively. Results of an Australian study showed that head KVp was 120 kV in children of all ages. The Chest KVp was 80, 100, and 120 kV among children under 5, 5-10, and more than 10 years of age, respectively. The pelvic KVp was equal to 80, 100, and 120 kV among children under 5, 5-10, and more than 10 years of age, respectively (5). In the present study, mAs values of the head, chest, and pelvic were equal to 25, 6.75, and 11.80 mAs, respectively. In an Iranian study, mAs values of the head, pelvis, chest, and abdomen were equal to 165, 125, 200, and 180 mAs, respectively (7). In the IAEA study, mAs values of the head, chest, and abdomen were equal to 260, 157.6, and 147.6 mAs, respectively (10). In a study in Taiwan, mAs values of the head, pelvis, chest, and abdomen were equal to 343, 295, 268, and 292 mAs, respectively (11). In a study in Kenya, mAs values of the head, pelvis, chest, and abdomen were equal to 249, 225, 181, and 209 mAs, respectively (12). In a study in Iraq, mAs values of the head, chest, and abdomen were equal to 265.5, 180, and 360 mAs, respectively (13). In a study in Australia, the head mAs were 150 and 200 mAs among children below and above 3 years of age, respectively. The Chest mAs values were equal to 65, 80, and 80 mAs among children under 5, 5-10, and more than 10 years of age, respectively.

The pelvic mAs values were equal to 80, 80, and 60 mAs among children under 5, 5-10, and more than 10 years of age, respectively (5). The present results showed that CTDIvol values of the head, chest, and pelvis were 2.14 ± 0.93, 0.93 ± 0.07, and 1.20 ± 0.53 mGy, respectively. In a study in Australia, the head, chest, and abdomen/pelvis CTDIvol values were 18-4, 3-23, and 4-15 mGy, respectively, among children of all age groups (5). In the United States, Sadigh et al. (2018) showed that the mean CTDIvol values of children were 33 mGy (range: 22-47 mGy) (14). Kanal et al. (2015) reported that the mean head CTDIvol values of children were 27.3 mGy. Estimates of CTDIvol in pediatric hospitals were 19% lower than the figures reported in general hospitals (15). The American College of Radiology (ACR) has also recommended 40 mGy < dose for children (16). The CTDIvol value is lower in the present study than those of other studies, which is due to the lower mAs value in here than the others. The differences in the studies can be due to the differences between the samples in terms of age and body size, which are the effective factors in selecting scan parameters. In the present study, CTDIvol is higher in protocols measured using head phantom (Head and PNS) than protocols measured using body phantom, which is due to the smaller diameter of the head phantom that initiates radiation distribution at a smaller volume. The CTDIvol value of the head protocol is also higher due to the higher mAs value in the head protocol (25mAS) than in the chest (6.75), and pelvis (11.8) protocols. MAs was also higher in the pelvic protocol than the chest protocol (11.80 vs. 6.75); therefore, the pelvic CTDIvol value was higher than the chest CTDIvol (1.20 ± 20.53 vs. 0.93±0.07). In the present study, DLP values of the head, chest, and pelvis were equal to 28.46 ± 0.93, 23.91 ± 2.26, and 38.14 ± 2.52 mGy/cm, respectively, which were significantly different (P < 0.05).

Sadeghiani et al. (2005) showed that DLP values of the head, pelvis, chest, and abdomen were 362.67, 179.78, 307.33, and 346.07 mGy/cm, respectively, in Iranian children (7). In the IAEA study, the DLP values of the head, chest, and abdomen were equal to 527, 477, and 696 mGy/cm, respectively (10). In a study in Taiwan, Tsai et al. (2007) showed that the DLP values of the head, pelvis, chest, and abdomen were equal to 665, 410, 455, and 453 mGy/cm, respectively (11). Similarly, Wambani et al. (2010) showed in a study in Kenya that the DLP values of the head, pelvis, chest, and abdomen were equal to 1364, 934, 745, and 1143 mGy/cm, respectively (12). In a study in Iraq, Al-Kinani et al. (2014) reported that DLP values of the head, chest, and abdomen were equal to 1094, 477, and 707 mGy/cm, respectively (13). According to European committee guidelines, DLP values of the head, pelvis, chest, and abdomen are recommended to be 1050, 570, 650, and

780 mGy/cm (17). In an Australian study, Brady et al. (2012) also demonstrated that head DLP values were equal to 300, 650, 700 mGy/cm among children aged 6 months to 3, 3-6, 6-10, and more than 10 years, respectively. Chest DLP values were equal to 100, 300, and 800 mGy.cm among children aged less than 5, 5-10, and more than 10 years of age, respectively. Pelvic DLP values were equal to 150, 400, and 750 mGy/cm among children aged less than 5, 5-10, and more than 10 years of age, respectively (5). Kanal et al. (2015) showed in a study on children that the mean DLP value was 390.9 mGy/cm (15). In the present study, a KVp value of 80 kV was obtained for the head, chest, and pelvis protocols, and mAs values were equal to 25, 6.75, and 11.80 mAs, respectively. The CTDIvol means of the head, chest, and pelvic protocol were equal to 2.14 ± 0.93, 0.93 ± 0.07, and 1.20 ± 0.53 mGy, respectively, which were significantly different based on the Kruskal-Wallis test ($P < 0.05$, Table 1).

DLP estimates of the head, chest, and pelvis were 28.46 ± 0.93, 23.91 ± 2.26, and 38.14 ± 2.52 mGy/cm, respectively, which were significantly different the based on Kruskal-Wallis test ($P < 0.05$, Table 1). The means of CTDIvol and DLP calculated for the head, chest, and pelvic protocol were significantly different by month ($P < 0.05$). In a study entitled "Radiation dose analysis to pediatric patients in computed tomography, Kharbanda (2015) investigated 478 people with a mean age of 8.1 years, among whom 56.9% were boys. The mean effective dose of the head CT was 2.68 mSv and decreased with age. For abdominal CT, the mean effective dose was 5.06-6.03 mSv and increased with age (3.67-11.12 mSv, $p < 0.001$). For abdominal CT, 8% of children aged 5-10 years, 28% of patients aged 10-15 years, and 60% of those over 15 years of age received effective doses above 10 msv (18). The results of this study are not consistent with the present study in the average absorbed dose of the head (2.14), and abdomen (1.20) because our mean absorbed doses of the head and the abdomen were much higher and much lower, respectively. Mazonakis (2004) stated that the effective doses of the head were 8.8-25.4, 8.2-27.3, and 8.4-22.7 µSv for radiography depending on the child's age (19); however, it is not possible to compare the radiation dose with the present study because age was not determined here.

5- CONCLUSION

Our results showed that the DLP and CTDIvol values were lower than those recommended by the European Committee guidelines and previous studies in other countries; therefore, they will not be associated with the risks mentioned in this test on children. This issue may be due to differences in the scan parameters selected in the other studies. The lower DLP and CTDIvol in the present study than those of other studies may be due to differences in the length of the scan area. Moreover, the radiation dose in CT may differ based on the level of trauma, knowledge status, the number of CT scanners, or adherence to the specific CT protocol of children (15). Based on the results of the present study, it is expected to minimize the harmful effects of radiation on children by calculating the dose indices received in children and comparing it with the internationally approved normal dose. Besides, proper training of staff and radiologists, controlling protocols, and adhering to the principles of radiation protection, as well as quality control of devices, are recommendable in this regard. Proper calibration of the CT scan components, examination of the parameters of the devices, and regular quality control of the CT scans can help to improve the image quality to some extent. On the other hand, it finally reduced the patient's dose by reducing mAs, which could be a step in line with the as low as reasonably achievable (ALARA) principle in radiation protection.

6- CONFLICT OF INTEREST: None.

7- REFERENCES

1. Fearon T, Vucich J. Pediatric patient exposures from CT examinations: GE CT/T 9800 scanner. Am J Roentgenol. 1985;144(4):805-9.

2. Mettler FA Jr, Thomadsen BR, Bhargavan M, Gilley DB, Gray JE, Lipoti JA, McCrohan J, Yoshizumi TT, Mahesh M. Medical radiation exposure in the U.S. in 2006: preliminary results. Health Phys. 2008 Nov;95(5):502-7.

3. Kanal KM, Graves JM, Vavilala MS, Applegate KE, Jarvik JG, Rivara FP. Variation in CT pediatric head examination radiation dose: results from a national survey. Am J Roentgenol. 2015;204(3):W29-W301.

4. Shah NB, Platt SL. ALARA: is there a cause for alarm? Reducing radiation risks from computed tomography scanning in children. Current opinion in pediatrics.2008;20(3):243.

5. Brady Z, Ramanauskas F, Cain T, Johnston P. Assessment of paediatric CT dose indicators for the purpose of optimisation. Br J Radiol. 2012;85(1019):1488-98.

6. Linton OW, Mettler Jr FA. National conference on dose reduction in CT, with an emphasis on pediatric patients. Am J Roentgenol. 2003;181(2):321-9.

7. Sadeghiani T, Hashemi B, Hashemi H, Sharafi A. Evaluating CT scan dose in children in common methods and quality control characteristics in a CT scan system. Iranian Journal of Medical Physics. 2005;2(8):31-44.

8. Treier R, Aroua A, Verdun FR, Samara E, Stuessi A, Trueb PR. Patient doses in CT examinations in Switzerland: implementation of national diagnostic reference levels. Radiat Prot Dosimetry. 2010;142:244-54.

9. Hatziioannou K, Papanastassiou E, Delichas M, Bousbouras P. A contribution to the establishment of diagnostic reference levels in CT. Br J Radiol. 2003;76:541-5.

10. Tsapaki V, Aldrich JE, Sharma R, Staniszewska MA, Krisanachinda A, Rehani M, et al. Dose reduction in CT while maintaining diagnostic confidence: diagnostic reference levels at routine head, chest, and abdominal CT—IAEA-coordinated research project. Radiol. 2006;240(3):828-34.

11. Tsai H, Tung C, Yu C, Tyan Y. Survey of computed tomography scanners in Taiwan: dose descriptors, dose guidance levels, and effective doses. Medical Physic. 2007;34(4):1234-43.

12. Wambani J, Korir G, Onditi E, Korir I. A survey of computed tomography imaging techniques and patient dose in Kenya. East African Med J. 2010;87(10):145-53.

13. Al-Kinani A, Saddam A. Radiation doses from computed tomography in Iraq. Arab J Nuclear Sci Applic. 2014;47(1):114-24.

14. Sadigh G, Kadom N, Karthik P, Sengupta D, Strauss K, Frush D, et al. Noncontrast head CT in children: national variation in radiation dose indices in the United States. Am J Neuroradiol. 2018;39(8):1400-5.

15. Kanal KM, Graves JM, Vavilala MS, Applegate KE, Jarvik JG, Rivara FP. Variation in CT pediatric head examination radiation dose: results from a national survey. Am J Roentgenol. 2015;204(3):293-301.

16. American College of Radiology. CT accreditation program requirements. Am Coll Radiol. 2013;2(1):77-89.

17. Menzel H, Schibilla H, Teunen D. European guidelines on quality criteria for computed tomography. Luxembourg. 2000;2(2):123-43.

18. Anupam B. Kharbanda, Ernest Krause, Yi Lu, Karen Blumberg, MD. Analysis of Radiation Dose to Pediatric Patients During Computed Tomography Examinations. Academic Emergency Medicine. 2015 doi: 10.1111/acem.12689

19. M Mazonakis, J Damilakis. Radiation dose and cancer risk to children undergoing skull radiography. Pediatric Radiology. 2004; 34: 624–29.