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Estimation of Radiation Dose from Most Common Pediatrics Radiographic Examinations within Main Central Hospitals in Najaf City, Iraq

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Abstract:

In this study the Entrance Surface Dose (ESD) received by pediatrics patients undergoing chest, abdomen and skull X-ray examinations was estimated. The study was conducted in two hospitals in Najaf city where three radiographic systems were considered. The study participants were classified into four age groups 0-1, 1-5, 5-10 and 10-15 years. Calculations were performed using exposure factors, kVp, mAs and focal-skin distance, together with patient data age. The ESD was calculated for the involved patients who underwent an Antero-posterior (AP) chest, abdomen and skull X-ray examination. The resulted data were analyzed and compared with international dose references. For all studied radiographic examinations and all X-ray machines, the ESD increases with age. The lowest recorded radiation dose was from hospital 1 machine 2. In this facility ESD ranged from 19.93 μGy to 67.66 μGy for chest X-ray, from 39.03 μGy to 82.63 μGy for abdomen (AP), and from 35.47 μGy to 94.27 μGy for skull (AP). In contrast the highest dose levels are recorded from hospital 2 machine 1; the minimum ESD for chest X-ray is 247.51 μGy and the maximum is 2393.12 μGy ; for abdomen X-ray the lowest ESD is 269.05 μGy and the highest value is 5106.15 μGy ; and for skull X-ray minimum values is 430.96 μGy and the maximum value is 3072.77 μGy . In conclusion, for the considered pediatrics examinations, most of ESD values are within the international acceptable level and some are higher >100%.

Keywords: Children, Dose calculation, Dosimetry, Radiation risk, Surface dose

Introduction:

Since the discovery of X-ray by William Roentgen in 1895, medical imaging has become an indispensable mean for patient care¹. While radiological examinations are an undoubtedly powerful tool for the proper diagnosis of many diseases, they can increase the unnecessary exposure to ionizing radiation. The biggest late adverse effect of radiation is cancer incidence especially in pediatric patients². It has been documented that pediatric patients are two to three times more sensitive to radiation than adults^{3, 4}. The higher radio-sensitivity of pediatric individuals is due to the cancer incidence per unit dose in children is higher than in adults. Also, the longer expected lifetime of children making them at higher risk of cancer development^{5, 6}. It has been found that the risk of radiation induced cancer in children under age of 10 years increase by 15% per 1 Sievert of radiation, while in adults it increase by

1% per 1 Sievert². This was also confirmed by epidemiological studies which revealed that the solid cancers and leukemia incidence in children are related to radiation exposure⁷. Accordingly, the radiation protection of pediatric patient was the focus of many national and international communities. These communities aim to create awareness on the importance of pediatric radiological procedures justification minimizing the risk of radiation-induced cancer from unnecessary radiation^{7, 8}.

The rapid developments of different medical imaging procedures, which involve ionizing radiation, lead to an increase in the level of radiation exposure to pediatric population. This is especially for conventional radiography because of the widely spread of digital radiography systems which may be associated with possibility of acquiring patient overdose due to the built-in image

processing^{9, 10}. As a sequence, the pediatric examinations constitute 10% of radiological examinations giving evidence that the pediatric examinations are not well justified^{11, 12}. To address this, many radiation protection committees manage to introduce recommendations for pediatric radiography^{5, 13}. In radiologic procedures, many factors can result in undesirable radiation exposure effects. These factors include: clinical case complexity, type of radiologic procedure, operator's skill, characteristic of X-ray machine whether it is designed for pediatric or for adult patients, number of required radiographic images and imaging parameters (kV and mAs)¹⁰.

It has been reported that there were significant differences in published pediatric radiation dose for the same radiological procedure carried out in different facilities⁶. Yakoumakis, Tsalafoutas¹⁴, used 289 TLDs to assess the ESD and the effective dose (E) for five common pediatric radiological examinations at two hospitals in Greece. The examinations include: chest AP and PA projections, skull AP and LAT projections, pelvis AP and LAT projections, lumbar spine AP and LAT projections and full spine AP and LAT projections. Their obtained dose results were higher than DRLs documented by the NRPB-R318¹⁵ and European Commission (EC)¹⁶. A mathematical simulation using DosCal software was conducted in Sudan by Suliman and Elshiekh¹⁷ to evaluate the radiation doses received by 459 pediatric patients from common X-ray examinations in three hospitals in Khartoum state. The resulted data from Suliman's study were slightly higher than that published by NRPB-R318 for the UK. Moe recently in 2010, a national survey was conducted in Australia to establish pediatric DRL. This survey includes the data for 14 hospitals between September 2006 and September 2007. The examinations considered in this survey include: chest, skull AP/PA/LAT and abdomen. According to this survey the participants were classified into: newborns, 1, 5, 10 and 15 year olds¹⁸. Another national survey was conducted in Ireland by Matthews, Brennan¹⁹ to evaluate the pediatric radiography in 18 hospitals. The evaluated examinations were chest, mobile chest, pelvis, skull, abdomen, lumbar spine and full supine. Matthews, Brennan¹⁹ found that the recorded pediatric DAP readings in Ireland are comparable with other published data. Also, they highlighted the essential role of the radiographer in optimization process.

In general, International Atomic Energy Agency (IAEA)⁶ documented that the pediatric dosimetry is considered as a specific area totally different

from adults' dosimetry for many reasons. Firstly, as mentioned above the pediatric patients are more radiosensitive than adults. Secondly, the pediatric dosimetry studies are more complicated than in adults because the sizes of pediatric patients are different and with continuous range. Accordingly, pediatric patients are classified into five age groups: newborn, 1, 5, 10 and 15 years. Finally, there is limited information about pediatric dosimetry and optimization. This motivated us to investigate the radiation dose from most common pediatric examinations in the main two centers for pediatric radiography in Najaf governorate in Iraq. This study tends to be the first multi-central study investigating the radiation dose from several pediatric examinations in Najaf, Iraq.

Materials and Methods:

The machines were coded as H1M1, H1M2 and H2M1 referring to hospital number and machine number. A sample of 229 patients was considered and they are classified into four age group; 0-1, 1-5, 5-10 and 10-15 years. The studied radiographic projections were chest AP, abdomen AP and skull AP. A minimum number of 5 patients were considered for each type of X-ray examination. The recorded exposure parameters, which are tube voltage (kVp), exposure current-time product (mAs), and the focus-film distance (FFD), were used to entrance skin dose (ESD) calculation by the following eq²⁰:

$$ESD = \text{output} * (\text{kVp}/80)^2 * \text{mAs} * (100/\text{FSD})^2 * \text{BSF}$$

Where the X-ray tube output was measured at 100 cm from the X-ray tube and 80 kVp and normalized to 10 mAs using Rad-check ionization chamber. BSF is back scatter factor and FSD (focal-skin distance) = FFD – patient thickness. FSD for all examinations and in all facilities was 100 cm. The maximum reported error which may be associated with ESD calculated by the above equation is 20%²⁰. The above equation was formulated into a simple program using MATLAB to facilitate the process of mathematical calculations of patients' skin dose.

Results:

Tabs.1-3 show the ESD results for the considered X-ray examinations which include chest AP, abdomen AP and skull AP with exposure factors (kVp, mAs and FFD). All of the examinations produce radiographic images with acceptable image quality. Analyses were performed on measurements throughout three radiographic facilities. The distribution and mean values of entrance surface dose for each pediatric age group are also presented in Tabs.1-3. For all projections,

the majority of the doses were almost below and some of them were above the corresponding IAEA levels in the two hospitals. Tab.1 demonstrated the

collected data for chest X-ray examinations across the three considered facilities divided into four age groups.

Table 1. presents the exposure factors (kVp and mAs) used for chest X-ray examinations along with ESD across different age groups in the three considered facilities.

Age (year)	H1M1			H1M2			H2M1			Reference dose (μGy) ⁶
	kVp mean (SD)	mAs mean (SD)	ESD (μGy) mean (SD)	kVp mean (SD)	mAs mean (SD)	ESD (μGy) mean (SD)	kVp mean (SD)	mAs mean (SD)	ESD (μGy) mean (SD)	
0-1	51.40 (1.52)	1.06 (0.09)	27.78 (3.92)	46.57 (7.32)	1.14 (0.27)	19.93 (9.05)	42.80 (2.59)	9.00 (1.00)	247.51 (56.88)	50
1-5	56.40 (1.14)	1.63 (0.18)	54.37 (7.60)	57.20 (7.43)	1.58 (0.31)	43.92 (16.19)	47.20 (0.84)	14.20 (1.49)	499.42 (68.52)	50
5-10	63.20 (2.05)	8.80 (0.66)	382.57 (52.25)	62.20 (2.17)	1.72 (0.16)	56.15 (8.76)	62.20 (1.92)	24.00 (1.58)	1514.96 (193.73)	70
10-15	64.60 (1.82)	8.48 (0.59)	402.04 (51.03)	65.57 (4.24)	1.77 (0.16)	67.66 (13.93)	68.40 (2.30)	30.00 (1.58)	2393.12 (287.70)	120
10-15*	57.80 (2.17)	2.33 (0.24)	88.61 (15.72)	-----	-----	-----	-----	-----	-----	120

* This X-ray examination conducted while the patient in supine position

The data collected for AP abdomen X-ray examination were presented for the four considered age groups in Tab.2.

Table 2. presents the exposure factors (kVp and mAs) used for abdomen X-ray examinations along with ESD across different age groups in the three considered facilities.

Age (year)	H1M1			H1M2			H2M1			Reference dose (μGy) ⁶
	kVp mean (SD)	mAs mean (SD)	ESD (μGy) mean (SD)	kVp mean (SD)	mAs mean (SD)	ESD (μGy) mean (SD)	kVp mean (SD)	mAs mean (SD)	ESD (μGy) mean (SD)	
0-1	52.80 (2.05)	1.82 (0.21)	49.86 (8.80)	57.00 (2.12)	1.58 (0.08)	39.03 (5.00)	42.20 (1.92)	10.20 (1.30)	269.05 (59.45)	400
1-5	58.40 (2.30)	5.50 (1.12)	201.35 (49.26)	63.20 (2.05)	2.23 (0.04)	73.49 (5.08)	48.80 (0.84)	17.00 (2.24)	648.26 (106.68)	400
5-10	58.80 (0.89)	9.13 (0.95)	415.09 (50.23)	66.17 (3.76)	2.25 (0.05)	83.20 (8.22)	49.20 (0.84)	27.00 (2.92)	1070.17 (147.99)	500
10-15	65.80 (2.39)	15.20 (1.13)	758.52 (98.06)	63.88 (3.23)	2.23 (0.05)	82.63 (8.98)	67.20 (1.92)	65.40 (3.97)	5106.15* (598.15)	800

* This facility used grid for this age group.

For AP skull X-ray examinations, the collected data are summarized in Tab.3 for the three facilities and for the each age group.

Table 3. presents the exposure factors (kVp and mAs) used for skull X-ray examinations along with ESD across different age groups in the three considered facilities.

Age (year)	H1M1			H1M2			H2M1			Reference dose (μGy) ⁶
	kVp mean (SD)	mAs mean (SD)	ESD (μGy) mean (SD)	kVp mean (SD)	mAs mean (SD)	ESD (μGy) mean (SD)	kVp mean (SD)	mAs mean (SD)	ESD (μGy) mean (SD)	
0-1	51.80 (1.64)	1.26 (0.24)	35.76 (9.16)	57.00 (2.12)	1.34 (0.08)	35.47 (4.61)	41.20 (1.30)	16.00 (3.16)	430.96 (111.92)	800
1-5	57.00 (2.12)	1.76 (0.15)	66.55 (10.45)	63.00 (2.74)	1.74 (0.22)	62.56 (12.90)	46.00 (1.58)	22.20 (1.92)	819.87 (127.34)	800
5-10	59.20 (1.10)	8.70 (0.45)	367.25 (31.43)	62.67 (2.25)	2.07 (0.19)	76.17 (11.64)	49.60 (0.55)	34.00 (1.58)	1509.95 (100.00)	1100
10-15	63.80 (0.84)	10.38 (0.34)	515.31 (19.59)	64.33 (4.09)	2.40 (0)	94.27 (12.04)	63.00 (1.58)	42.20 (1.92)	3072.77 (294.05)	1100
5-10*	54.20 (0.84)	2.40 (0.22)	84.95.74 (9.86)	-----	-----	-----	-----	-----	-----	1100
10-15*	58.40 (1.67)	3.00 (0.28)	125.35 (17.20)	-----	-----	-----	-----	-----	-----	1100

* This X-ray examination conducted while the patient in supine position

Discussion:

The AP chest X-ray examinations Tab.1 achieved in H1M1 demonstrate that the kVp is ranged from 51.40 to 64.60 among different ages 0-15 year, whereas the mAs was ranged from 1.06 to 8.80 across the same ages. The ESD of the corresponding X-ray examination ranged from 27.78 to 402.04 μGy across the same ages. These calculated ESD were within the internationally acceptable range recommended by the IAEA for 0-1 and 1-5 years age groups but they were more than the acceptable level for the other two age groups. A lower exposure factors (kVp and mAs) as well as ESD were recorded for chest X-ray examinations achieved by H1M2. In general, in both H1M1 and H1M2 facilities the ESD from chest X-ray examination was consistent with previously published work^{2, 12}. However, extremely higher ESD ranged from 247.51 to 2393.12 μGy were recorded by H2M1. These high ESD levels can be attributed to the high mAs used in this facility, which ranged from 9 to 30 mAs. ESD data in this facility tend to be comparable to those published by Beremauro, Kahari²¹.

The AP abdomen X-ray examination results can be seen in Tab.2. Regarding the abdomen AP X-ray examination across different ages 0-15 year achieved by H1M1, the kVp was ranged from 52.80 to 65.80, the mAs was ranged from 1.82 to 15.20. The ESD of the AP abdomen was ranged from 49.86 to 758.52 μGy . Similar to chest X-ray examination, the AP abdomen examination achieved by H1M2 facility recorded the lowest mAs 1.58 -2.23 mAs resulting in lowest ESD ranged from 39.03-82.63 μGy . In general the recorded ESD for both H1M1 and H1M2 were within the international acceptable levels recommended by IAEA and lower than that recorded in a sample of Iranian hospitals². On the other hand, the ESD data in these two facilities was comparable to that recorded in Finland¹². With regard to H2M1, the recorded ESD for 0-1 year age group was within the IAEA acceptable level, also. However for other age groups the ESD was higher than levels published by IAEA. The extremely high ESD level recorded for 10-15 years' age group was because the use of grid with this examination.

Regarding the skull AP X-ray examination across different ages 0-15 year Tab.3, the kVp was ranged from 51.80 to 63.80, the mAs was ranged from 1.26 to 10.38 and the ESD was ranged from 35.76 to 515.31 μGy for H1M1. In relation to the same X-ray examinations which were conducted by H1M2, the results demonstrate that the kVp is ranged from 57.00 to 64.33 among different ages 0-15 year, whereas the mAs was ranged from 1.34 to

2.40 and the ESD was 35.47 to 94.27 μGy across the same ages and this is consistent with that recorded by Kiljunen, Tietavainen¹². Similar to other examinations, the AP skull examinations achieved by H2M1 facility recorded the highest exposure factors and consequently cause the highest ESD ranged from 430.96 to 3072.77 μGy . The calculated ESD for this facility (H2M1) was within the internationally recommended range by the IAEA for young pediatrics within the first and second age groups and higher than acceptable range for pediatrics 5-15 years age; 31.4% higher for 5-10 years and 94.5% higher for 10-15 year. However, for the three considered facilities the ESD from skull X-ray examination was comparable to that published by Nahangi, Chaparian².

In summary, the entrance surface dose at H2M1 was the highest for all X-ray examinations; this in fact could be due the high tube output of the machine combined with low tube filtration. Also, this could be attributed to the relatively high exposure parameters used in this facility (H2M1). Moreover, the radiographers experience may have some impact. Similar statement can be made for other hospitals where high entrance surface dose values were observed. Based on the results recommendations will be made on how to bring the doses below the international recommended dose levels.

Conclusions:

Entrance surface dose (ESD) of pediatrics patients undergoing chest, skull and abdomen (AP) examinations at two hospitals in Najaf are observed to be in general consistent with the reference levels values that have been reported in past studies with some slight decrease and increase in certain values at certain radiological positions and hospitals. This is evidence that there is inconsistency in radiation dose data recorded in different hospitals in Najaf. Radiation dose variations may be primarily attributed to radiographers' experience. Accordingly, regular radiation dose evaluation is necessary to avoid high radiation dose to pediatric patients which are more radiosensitive than adults.

Authors' declaration:

- Conflicts of Interest: None.
- We hereby confirm that all the Figures and Tables in the manuscript are mine ours. Besides, the Figures and images, which are not mine ours, have been given the permission for re-publication attached with the manuscript.
- The author has signed an animal welfare statement.

- Authors sign on ethical consideration's approval
- Ethical Clearance: The project was approved by the local ethical committee in University of Kufa.

Authors' contributions statement:

R.M.K. M.Ali and H.A.A.B. Mraity contributed to the design and implementation of the research, to the analysis of the results and to the writing of the manuscript

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تقييم الجرعة الإشعاعية لفحوصات التصوير الطبي للأطفال الأكثر شيوعاً في مستشفيات محافظة النجف في العراق

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الخلاصة:

تضمنت هذه الدراسة تقييم جرعة الدخول الإشعاعية المستلمة من قبل المرضى الأطفال الذين يجرون بعض فحص التصوير الطبي للصدر، البطن، والجمجمة. تمت الدراسة في مستشفيين رئيسيين في محافظة النجف حيث تضمنت الدراسة ثلاثة اجهزة شعاعية للتصوير الطبي. تم تقسيم عينة الدراسة الى اربعة فئات عمرية 0-1 ، 1-5 ، 5-10 و 10-15 سنة. اجريت الحسابات باستخدام عوامل التعرض الاشعاعي والتي تشمل فرق الجهد والتيار الكهربائي لأنبوبة الأشعة السينية والمسافة بين مركز الأشعة و سطح جلد المريض بالإضافة الى عمر المريض. وقد حسبت جرعة الدخول الإشعاعية لكل من الفحص الامامي الخلفي للصدر والبطن والجمجمة. وتم تحليل النتائج ومقارنتها مع الحدود المسموحة دولياً لكل فحص شعاعي. وقد وجدت الدراسة ان الجرعة الإشعاعية الناتجة عن أي فحص تزداد بزيادة عمر الطفل. وقد سجلت المستشفى رقم 1 بجهازها رقم 2 اقل الجرعة الإشعاعية حيث كانت جرعة الدخول الإشعاعية لها 67.66-19.93 ملي كري لأشعة الصدر، 82.63-39.03 ملي كري لأشعة البطن، و 94.27-35.47 ملي كري لفحص الجمجمة. بينما اعلى الجرعة الإشعاعية سجلت في المستشفى رقم 2 بالجهاز ذو الرقم 1 وكما يلي: بالنسبة لأشعة الصدر كانت اقل جرعة 247.51 ملي كري واعلى جرعة 2393.12 ملي كري، ولأشعة البطن كانت اقل جرعة 269.05 ملي كري واعلى جرعة 5106.15 ملي كري، اما لأشعة الجمجمة كانت اقل جرعة 430.96 ملي كري والاعلى كانت 3072.77 ملي كري. وقد استنتجت الدراسة ان معظم الجرعة الإشعاعية المسجلة للأطفال ضمن الحدود المسموح بها دولياً مع بعض القيم اعلى من ذلك.

الكلمات المفتاحية: الاطفال، حساب الجرعة، قياس الجرعات، مخاطر الاشعاع، جرعة السطح