Egyptian Journal of Radiology and Nuclear Medicine

RESEARCH Open Access

Estimation of dose and cancer risk to newborn from chest X-ray in South-South Nigeria: a call for protocol optimization

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Abstract

Background: The use of X-ray as a diagnostic tool for complication and anomaly in the neonatal patient has been helpful, but the effect of radiation on newborn stands to increase their cancer risk. This study aims to determine the mean, 50th percentile (quartile 2 (Q2)), and 75th percentile (quartile 3 (Q3)) entrance surface dose (ESD) from anteroposterior (AP) chest X-ray and to compare our findings with other relevant studies. The study used calibrated thermoluminescent dosimeters (TLDs), which was positioned on the central axis of the patient. The encapsulated TLD chips were held to the patients' body using paper tape. The mean kilovoltage peak (kVp) and milliampere seconds (mAs) used was 56.63(52–60) and 5.7 (5–6.3). The mean background TLD counts were subtracted from the exposed TLD counts and a calibration factor was applied to determine ESD.

Results: The mean ESDs of the newborn between 1 and 7, 8 and 14, 15 and 21, and 22 and 28 days were 1.09 ± 0.43, 1.15 ± 0.50, 1.19 ± 0.45, and 1.32 ± 0.47 mGy respectively. A one-way ANOVA test shows that there were no differences in the mean doses for the 4 age groups ($P = 0.597$). The 50th percentile for the 4 age groups was 1.07, 1.26, 1.09, and 1.29 mGy respectively, and 75th percentile were 1.41, 1.55, 1.55, and 1.69 mGy respectively. The mean effective dose (ED) in this study was 0.74 mSv, and the estimated cancer risk was 20.7×10^{-6}.

Conclusion: ESD was primarily affected by the film-focus distance (FFD) and the patient field size. The ESD at 75th percentile and ED in this study was higher compared to other national and international studies. The estimated cancer risk to a newborn was below the International Commission on Radiological Protection (ICRP) limit for fatal childhood cancer ($2.8 \times 10^{-2}Sv^{-1}$).

Keywords: Newborn, Entrance surface dose, Thermoluminescent dosimeter, Back scatter factor

Background

Pediatric radiography is increasing as the world population increases [1]. There is also concern about the danger and effect of radiation on a newborn if imaging processes are not optimized. Although the radiation dose in routine diagnostic radiology investigation is considerably low, radiation stochastic effect may cause serious damage. The risk of pediatric patients developing long-term biological effects following exposure to ionizing radiation is higher than that for adults because of the sensitivity of their body organs [2, 3].

Chest X-ray is one of the primary examinations for children with respiratory disorders of various etiologies. In order to aid diagnosis, it is one of the first examinations performed in newborns admitted to the intensive care units (ICU) or in the neonatal units [4, 5].

The principle of "as low as reasonably achievable (ALARA)" suggest that even if it is a small dose and has no direct benefit to the patient, it should be avoided. It is however necessary that radiation dose to newborns be

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properly optimized with emphasis on collimation (field size) and the appropriate selection of kVp and mAs. The latter has been shown to have a significant effect on the patient dose outcome [6–10].

In most developing countries like Nigeria, there are no national guidelines on diagnostic reference levels (DRL) to checkmate radiography services in the country. Some of the problems faced are the poor legislature, inactiveness of regulatory bodies, paucity in manpower (like the medical physicist), and the lack of dosimetry equipment to evaluate patient dose [11–13].

DRL is an investigational level used to identify unusually high radiation doses for common diagnostic medical X-ray imaging procedures. DRLs are suggested action levels above which a facility should review its methods and determine if acceptable image quality can be achieved at lower doses [14–17]. The International Commission on Radiological Protection (ICRP) emphasizes that DRLs "are not for regulatory or commercial purposes, not a dose restraint and not linked to limits or constraints." DRLs are usually determined with either a standard phantom or from patient data with thermoluminescent dosimeters (TLDs) or through patient anthropomorphic parameter and tube outputs [18]. DRLs are usually set at the 75th percentile of the measured patient or phantom data. The ICRP also emphasizes that DRLs should not be applied to individual patients [19]. To make meaningful comparisons, aggregate data from different facilities should be compared against the benchmark DRL. There should be consistency in the protocol in this regard.

Although phantoms can be helpful in assessing the performance of X-ray units operating in an AEC mode, they are recommended not to replace surveys of actual patient examinations. Data from patient examinations provide the only definitive method for determining values of DRL quantities during clinical use [19].

DRLs and achievable doses (ADs) are part of the optimization process. It is essential to ensure that image quality appropriate for the diagnostic purpose is achieved when changing patient doses. Optimization must balance image quality and patient dose, that is, image quality must be maintained at an appropriate level as radiation doses are decreased [20].

Our pilot study shows that for every 10 radiographs, an average of 8 was chest X-ray from the Neonatal Unit. This study is aimed at determining the mean entrance surface dose (ESD) from chest X-rays to newborns (male and female) between 0 and 30 days with calibrated TLD chips and to determine the effect of kVp, mAs, field size, film-focus distance (FFD), and other parameters on the dose. This study will also determine corresponding 50th and 75th percentiles and compare our findings with relevant studies.

Methods

The study involved 40 newborns from the neonatal wards for routine chest (AP) X-ray in a medical center in Asaba, Delta State. Ethical approval was gotten and consent from parents and guidance was duly obtained. The newborns were divided into 4 groups: 1–7, 8–14, 15–21, and 21–28 days respectively. This study involved two qualified and experienced radiographer, each with 7 years' working experience, a radiologist with 12 years' experience, and a medical physicist with 8 years' working experience. A Digital Radiography system (Radiologa S.A., Spain, Algete, September; 2018) was used with the inherent grid system (Table 1). For each newborn, 4 TLD chips were used. The TLD chip used is a round phosphor called lithium fluoride, doped with magnesium and titanium (LiF:Mg, Ti), with batch number of RS/2146/19, with dimensions and diameter of Ø 4.5 mm and thickness of 0.90 ± 0.05 mm, and with sensitivity spread of ± 3.5% standard deviation.

Prior to this study, the TLD chips calibration factor were obtained from a Secondary Standard Dosimetry Laboratory (SSDL) in the National Institute of Radiation Protection and Research (NIRPB) in the University of Ibadan, Oyo State in Nigeria using a Cesium-137 source [21].

Before usage, the TLD chips were arranged on an annealing tray and were positioned in a TLD Furnace Type LAB-01/400 at a temperature of 400 °C for one (1) hour and were allowed to cool to room temperature. In order to remove lower peaks, they were heated to a temperature of 100 °C for another two (2) hours and were allowed to cool. They were later used after 48 h for this study.

Table 1 Digital radiography specifications

Digital radiography machine specifications	
Manufacturer	**RADIOLOGIA**
Type	Ceiling Mounted Unit (DR System)
Serial number	19030007
Machine model	POLYRAD PREMIUM CS
Power capacity	50 kW
kVp range	40–150 kVp
mAs range	0.1–630 mAs
Maximum current	3.5–1.6A
Minimum filtration	2 mmAl @75 kVp
Focal spot	1.2/0.6
Grid	Yes (14 × 17 inches)
Total filtration	3.3 mmAl
Line voltage	115–240 V
Phase	3, 50/60 Hz
Target	Tungsten
Manufactured date	February 2019

Table 2 Entrance surface dose (ESD) and other parameters for newborn between 1 and 7 days

Patient	Mean ESD (mGy)	Field size (cm^2)	kVp	mAs	FFD	Age (days)	Sex	Weight (Kg)	Height (m)
1	0.94 ± 0.01	23 × 23	54	5	100	1	M	4	0.43
2	1.80 ± 0.17	30 × 24	57	6.3	100	7	M	3.5	0.57
3	1.10 ± 0.12	22 × 17	60	5	100	2	M	2.7	0.40
4	0.73 ± 0.03	18 × 12	54	6.3	100	1	M	1.7	0.47
5	0.32 ± 0.15	24 × 18.5	54	5	100	1	F	1.2	0.44
6	1.03 ± 0.01	21 × 18	55	6.3	102	3	F	2	0.39
7	1.19 ± 0.02	21 × 17	56	6.3	100	6	F	3.1	0.51
8	1.33 ± 0.03	20 × 18	57	6.3	100	5	F	2.7	0.42
9	0.83 ± 0.03	24 × 24	57	5	100	3	F	3.1	0.40
10	1.65 ± 0.21	30 × 22	59	6.3	104	7	F	2.3	0.56

Each of the TLD chips was tied in flexible nylon and was wrapped in paper tape and was numbered to avoid mix up. In addition, background TLD chips were kept in a safe place from radiation.

After each positioning, 2 TLD chips were positioned centrally on the patient skin before exposure. The essence of the 2 chips is to estimate average values. To avoid movement, either a guardian or caregiver was available to hold the patient. In this case, the guardian or caregiver wears a lead apron for protection.

Patient information that were noted were the age, sex, weight, height, and protocol parameter kVp, mAs, field size, and FFD.

Each TLD chip was read using a RadPro Cube 400 manual TLD Reader (Freiberg Instruments GmbH, Germany) to determine the corresponding TLD count. In order to determine the patient dose, the following mathematical relation was used:

$$\text{Entrance surface air kerma (ESAK)} = (\text{TLD}_i - \text{TLD}_0) \times \text{CF}_{\text{CS-137}} \left(\text{mGy} \Big/ \text{count} \right) \quad (1)$$

The average background count was obtained from a number of TLD chips that were not exposed to radiation denoted as TLD_0. The obtained TLD counts (TLD_i-TLD_0) were multiplied with a pre-determined X-ray calibration factor (CF).

The effective dose was calculated using the relation:

$$E = \sum_T W_T H_T \quad (2)$$

where the effective dose E is a measure of the combined detriment from stochastic effects for all organs and tissues for the reference man, W_T is the tissue weighting factor, and H_T is the equivalent dose. W_T was determined using the International Atomic Energy Agency (IAEA) Human Health Series No. 24.

Radiation risk for the newborn (preterm) was estimated as $2.8 \times 10^{-2} Sv^{-1}$ according to the ICRP-60 recommendations, and it was multiplied by the effective dose to calculate the radiation risk of the 40 patients [22].

Statistical analysis

The data analysis was performed using SPSS for Windows, Version 22.0 (SPSS Inc., Chicago, IL, USA).

Table 3 Entrance surface dose (ESD) and other parameters for newborn between 8 and 14 days

Patient	Mean ESD (mGy)	Field size (cm^2)	kVp	mAs	FFD	Age (days)	Sex	Weight (Kg)	Height (m)
1	1.18 ± 0.15	25 × 23	58	5	102	13	M	3.5	0.55
2	1.73 ± 0.23	30 × 23	57	6.3	100	10	M	3.5	0.57
3	1.05 ± 0.02	16 × 12	58	5	100	9	M	3.2	0.53
4	0.36 ± 0.05	26 × 18	55	5	98	10	M	1.8	0.56
5	0.60 ± 0.16	27 × 20	54	5	100	11	M	2.5	0.47
6	1.39 ± 0.07	21 × 16	54	6.3	108	14	F	4	0.40
7	1.58 ± 0.12	19 × 19	59	6.3	100	8	F	4.5	0.44
8	1.33 ± 0.33	22 × 20	58	6.3	100	14	F	3	0.41
9	0.52 ± 0.03	24 × 22	57	5	100	12	F	2.7	0.52
10	1.74 ± 0.01	25 × 21	60	6.3	104	13	F	3.3	0.58

Table 4 Entrance surface dose (ESD) and other parameters for newborn between 15 and 21 days

Patient	Mean ESD (mGy)	Field size (cm^2)	kVp	mAs	FFD	Age (days)	Sex	Weight (Kg)	Height (m)
1	1.13 ± 0.02	22.5 × 16	54	5	100	15	M	3.3	0.47
2	1.31 ± 0.11	25 × 25	58	6.3	104	15	M	4.0	0.48
3	1.79 ± 0.10	22 × 17	59	6.3	100	17	M	3.6	0.65
4	0.66 ± 0.23	18.7 × 18	52	5.0	100	20	F	2.9	0.47
5	1.04 ± 0.15	26 × 24	54	5.0	100	17	F	2.3	0.42
6	1.90 ± 0.31	30 × 28	58	6.3	102	18	F	2.7	0.50
7	0.72 ± 0.02	21.5 × 17	56	5.0	100	16	F	4.5	0.45
8	0.80 ± 0.04	20 × 18	57	5.0	104	15	F	2.7	0.42
9	1.61 ± 0.09	29 × 27	58	6.3	100	21	F	3.3	0.40
10	0.97 ± 0.20	20.5 × 17	54	5	104	17	F	2.1	0.38

Descriptive statistics and a one-way analysis of variance (ANOVA) were used at a 95% level of significance. $P < 0.05$ was considered statistically significant.

Results

The mean ESD for 10 newborns between 1 and 7 days was 1.09 ± 0.43 mGy, and the ESD at 50th and 75th percentiles was 1.07 ± 0.05 and 1.41 ± 0.11 mGy respectively. The ESD for the 4 male and 6 female within this age group was 1.14 ± 0.46 mGy and 1.05 ± 0.46 mGy respectively. The mean field size, kVp, mAs, FFD, age, weight, and height for the 10 newborns within the age group were 461 ± 156.46 cm^2, 56.3 ± 2.11kVp, 5.78 ± 0.67mAs, 100 ± 1.35 cm, 3.6 ± 2.46 years, 2.63 ± 0.85 kg, and 0.46 ± 0.07 m respectively. A one-way ANOVA post hoc test shows that doses (mGy) were affected by FFD ($P < 0.001$) and field sizes ($P < 0.001$). Parameters that did not affect the dose were kVp ($P = 0.346$), mAs ($P = 1.000$), age ($P = 1.000$), weight ($P = 1.000$), and height ($P = 1.000$) respectively (Table 2).

The mean ESD for 10 newborns between 8 and 14 days was 1.15 ± 0.50 mGy, and the 50th and 75th percentiles were 1.26 ± 0.11 mGy and 1.55 ± 0.01 mGy respectively. The ESD for 5 male and 5 female within this age group was 0.98 ± 0.53 mGy and 1.31 ± 0.47 mGy respectively. The mean field size, kVp, mAs, FFD, age, weight, and height for the 10 newborns within the age group were 466 ± 141 cm^2, 57 ± 2.05 kVp, 5.65 ± 0.69mAs, 101.2 ± 2.86 cm, 11.4 ± 2.12 years, 3.2 ± 0.76 kg, and 0.503 ± 0.07 m respectively. A one-way ANOVA post hoc test shows that doses (mGy) were affected by FFD ($P = 0.001$) and field sizes ($P < 0.001$). Parameters that did not affect the dose were kVp ($P = 0.209$), mAs ($P = 1.000$), age ($P = 1.000$), weight ($P = 1.000$), and height ($P = 1.000$) respectively (Table 3).

The mean ESD of 10 newborns between 15 and 21 days was 1.19 ± 0.45 mGy, and the 50th and 75th percentiles were 1.09 ± 0.06 and 1.55 ± 0.08 mGy. The ESD for 3 male and 7 female within this age group was 1.41 ± 0.34 mGy and 1.10 ± 0.47 mGy respectively. The mean field size, kVp, mAs, FFD, age, weight, and height for the 10 newborns within the age group were 502 ± 197 cm^2, 56 ± 2.36 kVp, 5.52 ± 0.67mAs, 101.4 ± 1.90 cm, 17.1 ± 2.08 years, 3.14 ± 0.75 kg, and 0.46 ± 0.08 m respectively. A one-way ANOVA post hoc test shows that doses (mGy) were affected by FFD ($P = 0.039$) and field sizes ($P < 0.001$). Parameters that did not affect the dose were kVp ($P = 0.650$), mAs ($P = 1.000$), age ($P = 0.998$), weight ($P = 1.000$), and height ($P = 1.000$) respectively (Table 4).

Table 5 Entrance surface dose (ESD) and other parameters for newborn between 22 and 28 days

Patient	Mean ESD (mGy)	Field size (cm^2)	kVp	mAs	FFD	Age (days)	Sex	Weight (Kg)	Height (m)
1	1.20 ± 0.01	20 × 20	54	5	100	25	M	3.2	0.62
2	1.73 ± 0.17	30 × 23.5	59	6.3	100	28	M	3.7	0.57
3	1.97 ± 0.12	27 × 27	60	5	100	27	M	4.2	0.59
4	1.14 ± 0.03	26 × 18	52	6.3	100	25	M	4.0	0.60
5	1.37 ± 0.15	22 × 20.7	58	6.3	100	28	M	2.5	0.47
6	0.74 ± 0.01	21 × 16	56	5	100	27	M	3.8	0.48
7	0.95 ± 0.02	19 × 19	57	6.3	100	24	F	4.2	0.44
8	2.01 ± 0.03	21 × 15	59	6.3	100	27	F	3.7	0.60
9	1.37 ± 0.03	28 × 24	57	6.3	100	24	F	4.3	0.53
10	0.73 ± 0.21	26.3 × 21	60	5	100	28	F	3.2	0.50

Table 6 Mean parameters and ranges for the AP chest X-ray

Mean dose (mGy)	Field size (cm^2)	kVp	mAs	FFD (cm)	Age (days)	Weight (kg)	Height (m)
1.19 (0.32–2.01)	482 (192–840)	57 (52–60)	5.7 (5–6.3)	101 (98–108)	14.6 (1–28)	3.2 (1.2–4.5)	0.49 (0.38–0.65)

The mean ESD of 10 newborns between 21 and 28 days was 1.32 ± 0.47 mGy, and the 50th and 75th percentiles were 1.29 ± 0.12 and 1.69 ± 0.03 mGy. The mean ESD for 6 male and 4 female within this age group was 1.36 ± 0.44 mGy and 1.26 ± 0.56 mGy respectively. The mean field size, kVp, mAs, FFD, age, weight, and height for the 10 newborns within the age group were 499 ± 156 cm^2, 57.2 ± 2.62kVp, 5.78 ± 0.67mAs, 100 ± 0.00 cm, 26.3 ± 1.64 years, 3.68 ± 0.57 kg, and 0.54 ± 0.06 m respectively. A one-way ANOVA post hoc test shows that doses (mGy) were affected by FFD (P = 0.004) and field sizes ($P < 0.001$) respectively. Parameters that did not affect dose were kVp (P = 0.331), mAs (P = 1.000), age (P = 0.972), weight (P = 1.000), and height (P = 1.000) (Table 5).

The mean ESD, field size, kVp, FFD, age, weight, and height was 1.19 (0.32–2.01), 482 (192–840), 57 (52–60), 101 (98–108), 14.6 (1–28), 3.2 (1.2–4.5), and 0.49 (0.38–0.65) respectively (Table 6).

The mean ESD, 75th percentile (Q3), minimum, maximum, age range, mode of measurements, and the detector used was compared to other studies are shown in Table 7. Similarly, the technical parameters and anthropomorphic measurements were compared with other studies (Table 8).

The effective dose (ED) was 740 μSv, and the estimated radiation risk from ICRP 60 report was in the range of $20.7x10^6$ (Table 9).

Discussion

This study has used MTS-N (LiF:Mg, Ti) also known as TLD-100 to directly determine ESD from AP chest X-ray in newborn for 0–30 days. The mean ESD from this research was higher compared to other studies. The 75th percentile was 13 and 22 times higher in dose compared to the DRLs and ADs with the use of an anti-scatter grid and was 26 and 39 times higher in dose compared to the DRLs and ADs without the use of anti-scatter grid based on the American College of Radiology-American Association of Physicists in Medicine-Society for Pediatric Radiology (ACR-AAPM-SPR) report [15, 20]. The effective dose (ED) was higher compared to other studies. Similarly, the study shows a cancer risk of 1 to 1353, which was higher compared to other studies, indicating the need for protocol optimization.

Similarly, there was no difference in the mean ESD among the 4 age groups from a one-way ANOVA test, showing that the radiographer used a similar exposure

Table 7 Comparison of this study's ESD with other national and international studies

	Mean (mGy)	Q3 (mGy)	Minimum (mGy)	Maximum (mGy)	Age range	Mode of measurement	Detector
This study[a]	1.19	1.56	0.32	2.01	≤ 30 days	Direct	TLD
ACR [15][a,b]	–	0.12/0.06	–	–	0–1 years	Direct[d]	TLD
Brazil [23]	0.07/0.05		0.06/0.04	0.09/0.08	0–1 year	Direct	$CaSO_4$:Dy/TLD
Iran [24][a]	0.076	0.07	–	–	< 1 year	Direct	TLD
Nigeria [25][c]	0.64/0.07/1.1	–	–	–	0–1 year	Direct	TLD
Turkey [26]	0.067/0.07	–	–	–	6–112 days	Direct/indirect	TLD/tube output
Ethiopia [27]	1.82	1.37	0.97	2.34	0–1 year	Indirect	Tube output
Kuwait [28][b]	0.074	–	–	–	< 1 year	Indirect	Tube output
Finland [29]	0.06	–	0.01	0.27	0 year	Indirect	Tube output
EC [30]	–	0.08	–	–	0 year	Indirect	Tube output
UNSCEAR [31]	0.041	–	–	–	0–1 year	Indirect	Tube output
UK [32]	0.06	0.07	0.03	0.09	0 year	Indirect	Tube output
Nigeria [33]	0.11	–	–	–	0–1 year	Indirect	DoseCal
Sudan [34]	0.057		0.031	0.368	0– < 1 year	Indirect	DoseCal

[a]Grid system was used
[b]No grid system was used
[c]Comparison was made with 3 hospitals
[d]Phantom was used, *EC* European Commission

Table 8 Comparison of technical/patients' parameters with other studies

Source	kVp	mAs	Height (m)	Weight (kg)	Field size (cm^2)	Age (year)
This study	57 (52–60)	5.7 (5–6.3)	0.49 (0.38–0.65)	3.2 (1.2–4.5)	490 (192–864)	0
Toossi [24]	52 (50–54)	–	0.51	3.3	–	< 1
Olgar [26]	49 (46–51)	1.9 (1.6–3.5)	–	–	–	0
Mesfin [27]	40 (30–45)	8 (6.3–10)	–	6.2 (3.4–1.5)	125 (100–150)	0–1
Kiljunen [29]	84	1.5	0.53	4.0	116	0
Nahangi [35]	46.7 (40–50)	13.3 (12–16)	0.51	3.4	154	0
Allsup [36][a]	62 (60–63)/61 (60–65)	1.5 (1.2–2)/1 (0.5–1.5)	–	–	–	0
BSI [37]	–	–	0.52	3.5	–	0
Freeman [38]	–	–	0.56	4.5	–	0

[a]Computed radiography (CR) and a digital radiography (DR) was used respectively

factor for all age groups, which may be a contributory factor to the increase in dose observed.

Comparison of this study with direct measurements (real patient/phantom)

The use of the "direct approach" as described in ICRP 135 report is still regarded as the best method in determining ESD; one of such was a study in Brazil by Mohamadain et al., who investigated ESD for age 0–1 year. The study showed that the mean ESD with CaSO4:Dy and TLD-100 was 0.07 and 0.05 mGy. These values were significantly lower compared to this study with similar TLD elements. The variation in ESD was 126 and 130% respectively. The kVp variation between both studies was 10.2%. Possible discrepancies may be due to dosimetry uncertainties, differences in field sizes, and FFD. Parameters like kVp and mAs were not considered different [23].

Furthermore, a study in Iran to access the ESD from chest AP X-ray for < 1-month patients by Bahreyni Toossi et al., shows that the mean ESD was 0.076 mGy and the 3rd quartile value was 0.07 mGy using LiF:Mg Ti (TLD-100). Toossi's study was lower compared to our study. The variations in the mean and 3rd quartile dose against this study were 124% and 126% respectively. The weight and height from both studies were considered the same with a variation of 2.2% and 2.8% respectively. A critical look shows that anthropomorphic data like weight and height do not usually affect ESD [24]. In a similar study in Nigeria by Egbe et al., who used TLDs, the mean ESD from AP chest X-ray from 3 facilities studied between the age group of 0–1 years was 0.64, 0.07, and 1.1 mGy [25]. The variation between Egbe's work and this study was 70, 126, and 5.6%. Dose discrepancies are likely due to the total tube filtration which ranged from 2.5 to 2.7 mm Al, against this study which was 3.3 mm Al. This study used a flat panel system and Egbe's study used a film-screen system. Other factors may be associated with the expertise of the radiographers, and the TLD uncertainties may affect the dose [25]. Also, TLDs were used in a study in Turkey by Olgar et al., where the obtained mean ESD was 0.07 mGy. The variation between both studies was 126% [26].

Table 9 Comparison of effective dose and radiation risk with other studies

Sources	Effective dose (μSv)	(Radiation risk) $x10^{-6}$
This study	740	20.7
Olgar et al. [26]	15	2
Brindhaban and Eze [28]	12	–
Ward et al. [39]	20	–
Aliasgharzadeh et al. [40]	45.52	1.27–5.91
Jones et al. [41]	15.4	2
Bouaoun et al. [42][a]	31.6	0.9–4.1

[a]Comparison was with chest and abdomen

Comparison of this study with indirect measurement (software/tube output)

The mean, 1st quartile, 3rd quartile, maximum, and minimum ESD from chest (AP) X-rays from Mesfin et al. was slightly comparable to our study with a variation of 30, 38, 9, 10.7, and 71% respectively. This study used TLD chips for ESD measurement, but Mesfin's study used the tube output parameters to estimate pediatric dose, which was considered a factor that would affect ESD. The variation in field size between both studies was 84%. The field size in our study was noticed to be 4 times higher [27]. The mean ESD from 2 related studies in Kuwait and Finland using the tube output approached was 0.074 and 0.067 mGy, which was far lower than this study [28, 29]. The mean ESD in this study was higher compared to EC, UNSCEAR, and the UK report [30–32]. It was worthy to note that the tube output approach has been recommended in resource-low areas, and it has been found to reduce ESD accuracy by 20–30% because the output varies with voltage waveform, anode angle, and filtration [19].

Some studies have used the DoseCal software to estimate ESD; one of such study was carried out by Egbe et al. in Nigeria and Alatts et al. in Sudan for AP chest X-ray between the ages of 0 and < 1 year. The mean ESD from both studies was 0.11 and 0.057 mGy, which was lower compared to this study [33, 34]. Since the DoseCal software is a mathematical human model, the ESD obtained may vary with our study.

The outcome of the effective dose (ED) and estimated cancer risk was high compared to other studies. The variation in ED between this study and those in Table 9 was 125%. However, this study was below the ICRP estimated fatal cancer risk with a low dose for newborns [22].

There was no statistically significant differences in kVp, mAs, height, weight, and field size [26, 27, 29, 35, 37, 38], but the field size in this study was significantly higher compared to other studies, which may have accounted for the unusual high dose observed in the 4 age groups [26, 29, 35].

Conclusion

A study to determine the mean ESD, 50th and 75th percentile ESD, ED, and cancer risk for AP chest X-ray for a newborn has been determined using the direct method as indicated in the IAEA TRS-457 report, using TLD chips. There is a strong indication that newborn ESDs were considerably high in the studied area, which additionally affected ED and cancer risk. Factors that have been identified from this study were field size and FFD. This study strongly suggests a review of the exiting protocol to reduce newborn dose to the barest minimum.

Abbreviations

ESD: Entrance surface dose; TLD: Thermoluminescent dosimeter; ED: Effective dose; FFD: Film-focus distance; ICRP: International commission on radiological protection; ICU: Intensive care unit; DRL: Diagnostic reference level; SSDL: Secondary standard dosimetry laboratory; NIRPB: National Institute of Radiation Protection and Research; IAEA: International Atomic Energy Agency; UNSCEAR: United Nations Scientific Committee on the Effects of Atomic Radiation

Acknowledgements

We sincerely want to thank the staffs of the Department of Radiology, Federal Medical Centre Asaba, who gave their time and support for this study.

Authors' contributions

ADO conceived the topic and made provisions for the materials used for the research. He designed the template consent and for data collection and did the TLD readout, data analysis, manuscript preparation, and manuscript editing. MOA did a critical review on the dose values measured to see their validity, reviewed the manuscript, and did a follow-up after submission. SOA did a thorough search of the literatures used; he also edited the manuscript for possible errors and vetted the data analysis. IOA took part in the manuscript preparation and material search. AAA administered the consent form and was involved in the data collection. All authors read and approved the finial manuscript.

Funding

No funding whatsoever

Availability of data and materials

The data sets used and/or analyzed during the current study are available from the corresponding author on request.

Ethics approval and consent to participate

This study was approved by the ethics committee of Federal Medical Centre Asaba with approval number FMC/ASA/A90. Written informed consent was obtained from parents or guardian before the commencement of the study

Consent for publication

Approval for publication was granted.

Competing interests

No competing interest

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Received: 1 October 2020 Accepted: 17 February 2021
Published online: 02 March 2021

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