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Estimation of Radiation Dose for Adult Patients Undergoing Diagnostic X-ray Examinations of the Skull and Cervical Spine

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Abstract: *The aim of this study was to estimate the Entrance Skin Dose (ESD), the eye lens dose and the thyroid gland dose for adult patients undergoing diagnostic X-ray examinations of the skull and the cervical spine in some hospitals in Sudan. A total of 120 patients were evaluated. The ESD was calculated using the relationship between the X-ray tube output and the exposure parameters. The eye lens dose and the thyroid gland dose were calculated from the ESD using Xdose software (Version 2). The results showed that the mean ESD was 0.636 mGy, 0.589 mGy and 0.694 mGy for the antero-posterior (AP) cervical spine, lateral cervical spine and lateral skull respectively. The mean eye lens dose was (0.0148) mGy, (0.0007) mGy and (0.27) mGy for antero-posterior (AP) cervical spine, lateral cervical spine and lateral skull respectively. The mean thyroid gland dose was (0.416) mGy, (0.0132) mGy and (0.0104) mGy for antero-posterior (AP) cervical spine, lateral cervical spine and lateral skull respectively. The estimated ESD values were within the range of the international diagnostic dose reference levels and lower than the range at some previous studies and the dose to the eye lens less than the threshold dose of detectable lens opacities and the thyroid gland dose less than that cause damage.*
Keywords: *ESD, eye lens dose, thyroid gland dose, reference dose levels.*

I. Introduction

Patient radiation dose is an important parameter to control the quality of the X-ray services within the hospital. Dose monitoring helps to ensure the best possible protection of the patient and provides an indication of incorrect use of technical parameters or equipment malfunction [1]. During recent years, patient dose has become a major issue [2]. The radiation dose to patients should follow the ALARA principle "as low as reasonably achievable [3]. With increasing awareness of the need for radiation protection, a paradigm shift can be absorbed from the principle of "image quality as good as possible" to "image quality as good as needed" [4]. The establishment of the quality criteria for diagnostic radiology images started in 1984 when the first Directive on Radiation Protection of the Patient was adopted by the Member States of the European Union [5]. Patient radiation dose from conventional radiographic procedures ranges from 0.1 mSv to 10 mSv, resulting in a collective dose to the population that can be significant [6]. The ESD is defined as the absorbed dose to air where the X-ray beam intersects the skin surface of the patient including the backscatter [8]. The reasons for evaluating ESD is that; the physical parameter recommended for monitoring the Diagnostic Reference Levels (DRLs) in conventional radiography was the ESD and the dose is greatest at the surface where radiation enters the body of the patient therefore the skin is the main organ for which there is a possibility of deterministic effect i.e., skin burn [7] another reason the organs equivalent dose can be estimate from the ESD and that very important especially in case where the part of the body to be imaged contain sensitive organ to the effect of radiation.This study was aimed to estimate the ESD, the eye lens dose and the thyroid gland dose for adult patients undergoing diagnostic X-ray examinations of the skull and the cervical spine in some hospitals in Khartoum, Sudan to help applying optimization of radiation protection of the patients.

II. Materials and Methods

A total of 120 patients were enrolled in this study. The examinations chosen for this study are the cervical spine antero-posterior projection (AP), lateral projection (LAT) and lateral skull projection (LAT). For each studied examination, personal data (sex, age, weight and height) and technical parameters (kVp, mAs and FSD) were recorded. The Standard FFD of 100 cm for the cervical spine AP and 110 cm for the cervical spine LAT and the skull LAT were used as routine. The patients were randomly selected from adult patients of both sexes attending medical investigations in three radiological centers namely Antalya Medical Center (AMC), Bahery Accident & Emergency Hospital (BAEH) and Sharg Alneel Hospital (SAH). For each hospital, available machine specific data such as type, model, filtration, focal spot size, year of manufacture were recorded from the manufacturer information

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written on the machine, all imaging systems are computed radiography based system and all X-ray machines are fixed. These data are presented in table 1.
The ESD for each patient was calculated using real examination data, according to Eq. 1 [9][10].

$$ESD = OP \times \left(\frac{kV_p}{80}\right)^2 \times mAs \times \left(\frac{100}{FSD}\right)^2 \times BSF \qquad (1)$$

Where ESD is the entrance surface dose, OP is the output of the X-ray tube (in µGy mAs $^{-1}$) at 80 kV_p at a distance of (100 cm) normalized to 20 mAs, kV_p is the tube potential (in KV), mAs is the product of the tube current (in mA) and the exposure time (in ms), FSD is the focal spot-to-skin distance and BSF is the backscatter factor. The backscatter factor was 1.35 suggested in European guidelines (EC, 1996) [7]. The FSD was calculated using Eq .2

$$FSD = FFD - (b + d) \qquad (2)$$

Where FFD is tube focus-to-image receptor distance, b is the patient thickness and d is image receptor-to-top table distance. b and d were measured using meter ruler. The eye lens dose and thyroid gland dose for each projection were calculated using Xdose software (Version 2). The X-ray tube output was measured at a distance of 100 cm from the tube focus using 80 kVp and 20 mAs using the DIAVOLT universal (Model T43014-01292).

Table 1: Specifications of X-ray machines used

Hospitals	AMC	BAEH	SAH
Manufacturer	Toshiba	Shimadzu Corporation	Philips
Model	E7239X	P18DE-85	9890 000 86101
Focal spot size	2.0/1.0	0.6/1.2	NA
Total filtration	1.9 mm AL at 75 kV_P	2.5 mm AL at 75 kV_P	2.5 mm AL at 75 kV_P
Generator Manufacturer	Allengers	Shimadzu Corporation	Philips
CR reader	Fujifilm FCR PRIMA 35×43cm 14×17Inch	Fujifilm FCR PRIMA 35×43cm 14×17Inch	Fujifilm FCR PRIMA 35×43cm 14×17Inch
Tube output (µGymAs $^{-1}$)	33.9	47.58	54.28

III. Results

Table 2: Characteristics of the patients and technical parameters selected for various examinations

Hospitals	Projection	KV_P mean±SD	mAs mean±SD	FSD (cm) mean±SD	Grid
AMC	C/S* AP	67.6±1.45	15±0.0	85.2±1.41	No
	C/S LAT	70±1.06	15±0.0	88.13±3.58	Yes
	Skull LAT	70.06±3.12	14.26±1.57	83.23±1.33	Yes
BAEH	C/S AP	62.6±1.45	12±0.0	85.2±1.41	Yes
	C/S LAT	57.6±2.13	9.06±0.7	87.2±2.67	Yes
	Skull LAT	51.53±2.66	4.96±0.12	83.2±1.53	Yes
SAH	C/S AP	64.46±1.72	9.66±0.48	84.66±1.55	No
	C/S LAT	68.93±1.38	9.73±0.88	87.93±3.34	Yes
	Skull LAT	69±1.195	14.8±1.2	83.56±1.68	Yes

C/S*: Cervical Spine.

Table 3: The mean ESD (in mGy±SD) in the three Hospitals

Hospitals / Examination	ESD (mGy) mean±SD		
	C/S AP	C/S LAT	Skull LAT
AMC	0.676±0.032	0.679±0.053	0.731±0.135
BAEH	0.69±0.056	0.399±0.0561	0.192±0.0278
SAH	0.544±0.0536	0.691±0.107	1.161±0.152

Table 4: The (mean±SD) eye lens dose and thyroid gland dose (in mGy) in the three Hospitals

		C/S AP	C/S LAT	Skull LAT
AMC	Eye lens dose mean±SD	0.0165±0.001	0.00076±0.0001	0.283±0.054
	Thyroid dose mean±SD	0.436±0.022	0.0159±0.0012	0.0113±0.003
BAEH	Eye lens dose mean±SD	0.0145±0.001	0.0003±0.0007	0.07082±0.01
	Thyroid dose mean±SD	0.456±0.063	0.00716±0.001	0.00162±0.0004
SAH	Eye lens dose mean±SD	0.0136±0.001	0.0009±0.0001	0.457±0.061
	Thyroid dose mean±SD	0.356±0.043	0.0177±0.003	0.0185±0.003

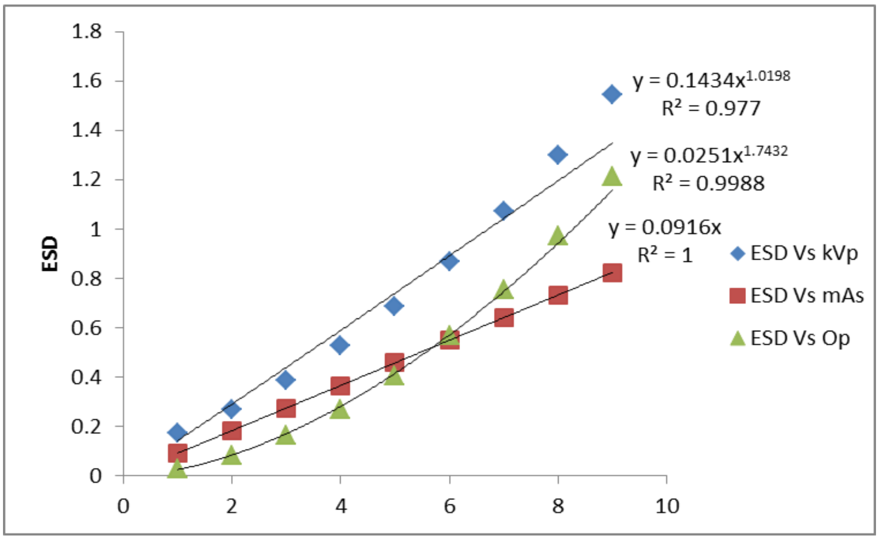

Figure 2: Illustration of the relationship between the ESD and the kV_p, mAs and the X-ray tube output

Table 5: Comparison of ESD (in mGy) with the DRLs and some previous studies

The Studies	Cervical spine (AP)	Cervical spine (LAT)	Skull (LAT)
This study	0.636	0.589	0.694
Abu KhiarA A (2016) [13]	1.35	1.67	1.2
Olivera Ciraj et al (2004) [14]	1.3	1.03	0.95
A. Beganović et al (1997) [15]	0.9	0.2	0.909
Damijan Škrk et al (2014) [17]	1.4	1.4	1.73

IV. Discussion

The highest kVp and mAs for the cervical spine AP and cervical spine LAT were observed in AMC. BAEH observed lowest kV_p and mAs for cervical spine LAT and the skull LAT. This variation in the exposure parameters may be due to the variations in the patient's weights, thicknesses and radiographic techniques employed by the operators. Table 3 showed that, the highest ESD for the cervical spine AP (0.676 mGy) was observed in AMC, the highest ESD for the cervical spine LAT (0.691 mGy) and the skull LAT (1.161 mGy) were observed in SAH. The lowest ESD for the cervical spine LAT (0.399 mGy) and the skull LAT (0.192 mGy) were observed in BAEH. Table 2 showed that, The FSD was almost constant for the same test between the three hospitals. AMC and SAH used approximately the same exposure parameters (kV_p, mAs and FSD) although it was noted a different ESD for the lateral skull. This difference may be due to the difference in the X-ray tube output between the two hospitals. The ESDs values compared with the international diagnostic dose reference levels (DRLs) [11] and other studies in the Sudan [1][9][10][12][13] and other countries [14][15][16][17], the results showed that; all estimated ESDs values within the range of the DRLs and lower than the range of some previous studies.

Table 4 showed that, the eye lens dose and thyroid gland dose increases with increase the ESD for the same projection. The maximum eye lens dose (0.457) mGy was observed for the skull LAT in SAH that may be due to manual exposure control settings, patient size and other equipment-related factors. The maximum thyroid gland dose (0.436) mGy was observed for cervical spine AP in AMC that may be due to the position of thyroid gland at the center of the beam entry. The mean ESD compared with published works are shown in Table 5; the mean ESD for the examinations were lower than those of published works elsewhere. This could generally be attributed to good radiographic techniques employed during the procedures. Therefore, increasing the tube filtration and proper selection of exposure parameters (kVp and mAs) are effective methods for reducing patient dose during radiographic procedures. The improvement in image receptor technology provides potential for dose reduction but requires proper adjustment of exposure parameters and operator skills.

V. Conclusion

The study estimated the ESD for patients underwent skull and cervical procedures in three hospitals in Sudan. The results of this dose survey provide essential data for patient dose levels for radiography and the performance of the equipment used. Dose values were accepted as compared with previous studies in Sudan or other countries. ESD values depend on exposure parameters and number of exam performed as well as patient demographic data. These findings support the importance of the ongoing quality assurance program to ensure that doses should be kept to a level consistent with optimum image quality.

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