

## Original Article

### Dose Reference Levels in Radiography for the Most Common Examinations in Sudan

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#### ABSTRACT

**Background:** The aim of this study was to establish national diagnostic reference levels (DRLs) for the first time in Sudan. This is done through evaluation of entrance surface dose (ESD) to patients undergoing selected X-ray examinations.

**Materials and Methods:** ESD per examination was estimated from X-ray tube output parameters in 15 hospitals comprising 20 rooms and a sample of 8 most common X-ray examinations with 11 basic views and a total of 1490 projections. Third quartile was calculated from the resultant distributed mean ESDs in each hospital surveyed.

**Results:** The results obtained in mGy were, 1.9 for PA skull, 1.2 for lateral Skull, 0.539 for PA chest, 3 for abdomen and pelvis, 4.9 for AP lumbosacral spine, 18.5 for lateral lumbosacral spine, 1.35 for AP cervical spine, 1.67 for lateral cervical spine 0.4 for AP knee joint and 1.4 for AP shoulder. With exception of PA chest in all hospitals, mean ESDs were found to be within the international reference dose the major drawback is the large variations in hospitals for the same procedure.

**Conclusions:** The results are valuable for establishing a solid base for national ESDs and can provide a data base for future dose measurements.

**Key words:** Incident air Kerma, Entrance Surface Dose, Diagnostic Reference Levels.

The medical X-ray imaging is ever increasing and it contributes markedly to population dose from artificial sources<sup>1</sup>. Dose limits for radiological examinations are designated for occupational and public but not for the patient. The international studies have shown that there is wide variation in patient dose during diagnostic examination for the same procedure<sup>2</sup>. Such variations indicate the need for dose reduction without compromising image quality. Dose reduction which is a main pillar in radiation

protection system is governed by principles of justification and optimization including reference value. Justification relies on the concept that benefit should outweigh the possible risks, and optimization is based on dose reduction, that the dose should be as low as reasonably achievable (ALARA concept)<sup>2,3</sup>. There are other main approaches of patient dose reduction such as, time, and collimation. Therefore using appropriate technique with suitable x-ray equipment, together with an appropriate film/screen combinations are of prime importance in reducing the radiation dose to the patient. In order to accomplish the goal of reducing the dose to the patient, there must be some guidance on appropriate levels of patient exposure. The international commission on radiological protection (ICRP), the International Atomic Energy Agency

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(IAEA) and European community have recommended the use of diagnostic reference levels (DRLs)<sup>2, 3, 4</sup>.

The international Commission on Radiological Protection (ICRP)<sup>1</sup> defines the DRLs as: dose levels in medical radiodiagnostic practices for typical examinations for groups of standard-sized patients or standard phantoms for broadly defined types of equipment. These levels are supposed to be guidance levels and expected not to be exceeded for standard procedures when good and normal practice regarding diagnostic and technical performance is applied.

In Sudan, so far there is scarcity of data concerning patient dose. Some informal trials of establishing DRLs in specific areas had been carried out such as pediatric patients undergoing chest X-rays by Nadia & Altahir 2013 and interventional radiography, by N. Abbas *et al* (2013)<sup>4</sup> and by Suleiman *et al.*<sup>8</sup>. In light of these information's, the need to fill the gap of establishing guidance levels emerged. Establishing such levels will lead to optimization of the procedure both in terms of image quality and radiation protection. The study provided data of Entrance Surface Dose (ESD) values by adopting a calculation method. The radiographic examinations to establish the DRLs were purposely selected because they represent the most frequent examinations and entail the relatively high dose in conventional radiography

#### **MATERIALS AND METHODS:**

The survey took place at 20 radiological departments distributed in 15 major hospitals, 4 military, security and private Hospitals, 7 governmental hospitals, and 4 University hospitals. 8 X-ray examinations were sampled (11 standard projections) which constitute 1490 projections in total.

Both adult female and male were equally subjected to the study. The representative sampled of hospitals was the largest hospitals in Khartoum State in terms of number of beds and workload. A small private sector (Al Roomi) hospital was included to broaden the scope of the study. Apart from Al Roomi, each hospital workload is approximately 100 patients every day.

#### **Dosimetry:**

To establish reference dose the quantity of exposure is measured for each X-ray tube. In line with international recommendations<sup>1</sup> concerning application of appropriate dose quantity, the measurements of entrance service dose (ESD) were carried out using RAD-CHECK<sup>TM</sup>PLUS model 06-526 (Standard Units) X-ray exposure meter (Nuclear Associates Victorian Division, NY, USA). The RAD-CHECK PLUS<sup>TM</sup> (Fig. 1) is recalibrated at Sudan Atomic Energy Commission (SAEC) Secondary Standard Dosimetry Laboratory (SSDL). The minimum number of patients per each examination considered were 10 for each room, based on ICRP guidelines<sup>14</sup> for each radiographic projection, a standard-sized patient was selected which is normally at 70 kg  $\pm$  10 kg. In order to collect data for each patient, a specially designed form was given to the chief technologist and kindly asked to fill the required parameters. Only images that yielded satisfactory diagnostic quality was considered. This is usually verified by radiologist, and chief technologist. The form includes the hospital name, the room number, patient data, type of examination and radiographic data. To calculate focus-to-surface distance (FSD) from focus-to-film distance (FFD), object-film distance (OFD) of 20 cm for AP abdomen projection and 30 cm for lateral abdomen or chest and 20 cm

for AP/PA skull and 15 cm for lateral skull were chosen. The deduction of object film distance (OFD) from (FFD) to get (FSD) using standard patient size is more suitable than measuring source-surface distance (SSD) directly, which otherwise might be inconvenient for the patient. Anatomical parts sampled to undergo radiological examinations were: chest, skull, abdomen pelvis, spine (cervical and lumbo-sacral joint), AP shoulder and AP knee joint. Each X-ray tube of the aforementioned X-ray equipment has its output measured. This type of dose measurements is time effective and doesnot involve the patient directly. The meter is placed at 100 cm from X-ray tube focus. The radiation area is collimated to the effective area on the meter with fixed mAs normalized to 10 mAs. Different readings were recorded with a varying tube potentials, that is as from 40 kV to 110 kV, with 5 or 10 kV added systematically and the output is measured each step. The reading obtained by the ionization chamber

is incident air kerma which is free of back scatter. To calculate the ESDs the following formula is used:

$$ESD = \frac{O}{P} \times \left(\frac{kV}{80}\right)^2 \times mAs^2 \times \left(\frac{FFD}{FFD - SSD}\right)^2 \times BSF \quad (1)$$

Where O/P is the X-ray tube output, kV is the actual kV, FFD is the focus film distance, SSD is the source-surface distance and BSF is backscatter factor<sup>8</sup>. The X-ray tube output is converted from mR/mAs to mGy/mAs by multiplying it by 1/113<sup>9</sup>. The values of the X-ray tube output per mAs were plotted against tube potential and the resulting curve was fitted using Microsoft Excel power function for data manipulation<sup>9</sup>. Data analysis was performed using the SPSS version 12 software (SPSS INC. Chicago, IL)

**RESULTS:**

Not all examinations were assessed in each radiological department, because some X-ray machines were designated for specific examinations. Table 1 shows the parameters

Table 1: Parameters descriptive of the distributed ESD for each radiological examination, with exposure factors.

Examination	kV (min/Max)	mAs (Min/Max)	Min.	Max.	Mean	Range	SD	3rdQ
Chest	60 -80	8 - 32	0.114	1.623	0.525	1.509	0.247	0.539
Abdomen	66- 80	32 - 50	0.483	13.28	2.828	12.797	0.396	3
Pelvis	74 - 78	30 -36	0.715	22.002	3.691	21.287	1.076	3
Knee	52 -60	5 - 12	0.123	6.608	0.382	6.485	0.18	0.4
PA Skull	62 - 70	18 - 36	0.235	3.286	1.287	3.051	0.164	1.9
Lat. Skull	56 – 77	12 - 24	0.197	2.642	1.027	2.407	0.193	1.2
AP LS/S	76 - 90	40 - 90	0.538	14.518	4.399	13.98	0.625	4.9
Lat. LS/S	90 - 110	40 - 80	1.294	31.614	11.268	30.32	1.661	18.5
AP CS	66 - 70	14 - 20	0.252	4.546	1.159	4.293	0.267	1.35
Lat. CS	66 - 86	22 - 50	0.243	5.722	2.926	5.479	1.130	1.67
Shoulder	60 - 74	24 - 40	0.254	4.110	1.203	3.855	0.360	1.4

descriptive of the exposure conditions. These are the minimum, mean, maximum of the kV and mAs together with the range of each for each examination. The focal film distance is also shown.

The number of rooms (X-ray equipment) used were: 10 rooms for cervical spine projections and shoulder joint. For chest X-ray and lumbosacral spine examinations 16 rooms were used. This was intentionally selected because the chest examination is the most frequent and the lumbosacral comes next. Besides, it entails the highest patient dose. Other examinations were also done in 10 rooms each. The last column in the same

table shows the third quartile (75<sup>th</sup> percentile), which will be the basis of our mean ESD calculations. Other parameters descriptive e.g. minimum, maximum, mean, range and standard deviations are of paramount importance in providing dose data-base for future large-scale patient dose survey.

Figures 1 to 5 show descriptive statistics and represents the mean value of the minimum, maximum, mean, standard deviation and third quartile for each examination done in this survey. The big gap between the standard deviations; reflects the wide variations in each projection. It is also

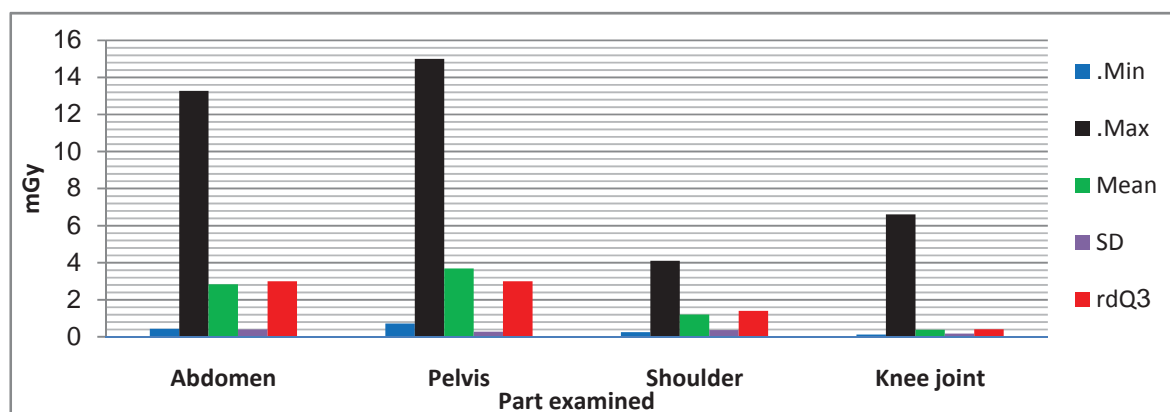


Figure 1: Parameters Descriptive of the distributed mean ESD in mGy for AP Abdomen, Pelvis, shoulder and Knee joint.

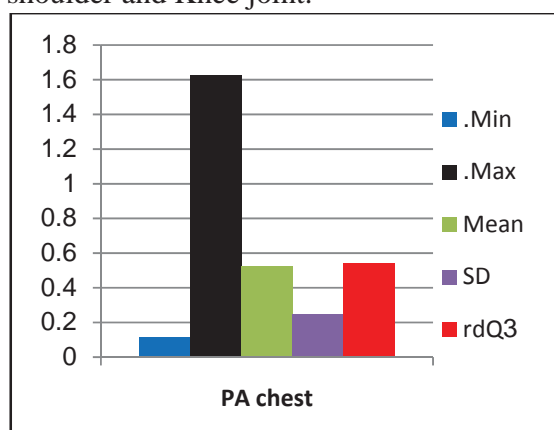


Figure 2: Parameters Descriptive of the distributed mean ESD in mGy for PA Chest X-ray.

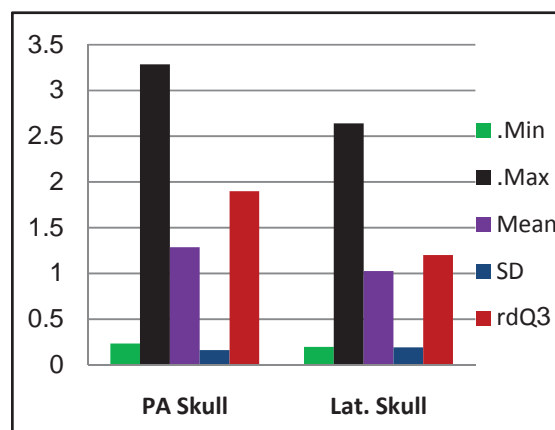


Figure 3: Parameters Descriptive of the distributed mean ESD in mGy for Skull X-ray.

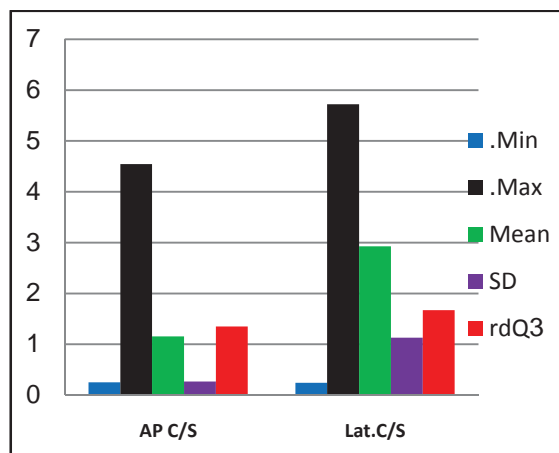


Figure 4: Parameters Descriptive of the distributed mean ESD in mGy for cervical spine X-ray.

apparent that, variation between the minimum and the maximum dose for a standard patient was too big. The third quartile in each hospital can be used as a local DRL for each examination. Figure 2 shows posterior-anterior chest and displays large variations in patient dose which reached 14 fold. The general impression is that, the variations shown in these graphs are unreliable. In fact, it is much greater between different health facilities. Figure 3 shows the skull radiological examination for AP and lateral and both show patient dose variation which is more than 13 fold. Figure 4 displays the cervical spine AP and lateral. The variation in patient dose concerning the anterior-posterior is about 18 fold and that of the lateral is more than 23 folds.

#### DISCUSSION:

The survey to propose national DRLs was done in Khartoum state. The methodology adopted to collect the information was non-invasive i.e. by calculation of ESD through usage of X-ray tube output. This is measured by a dosimeter and associated exposure parameters were included in the calculations. The data were obtained from

standard-sized patients male and female Undergone conventional radiological examinations. DRLs were inferred from distribution of mean ESD values to standard-sized patients 70 kg.±10, for each type of radiograph considered. Furthermore the information about the hospitals (distribution of equipment and number of radiological examinations) was considered and the exposure parameters were recorded, that is tube potential (kV), tube current and time (mAs), focus-film distance (FFD).

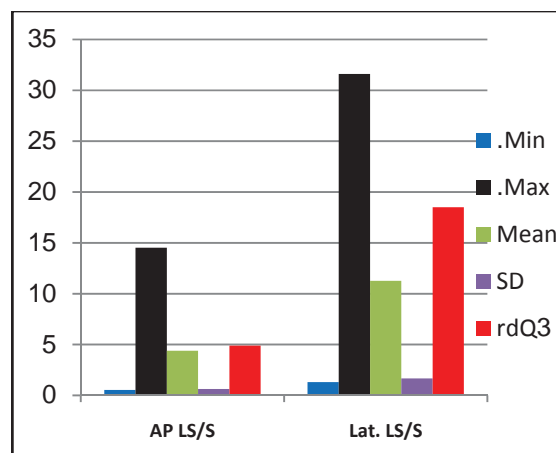


Figure 5: Parameters Descriptive of the distributed mean ESD in mGy for Lumbosacral Spine X-ray.

Tube specifications were also included, i.e. filtrations. The technique adopted in each hospital has led to identification of great variations in ESD for the same procedure. Other parameters are of paramount effect on patient dose such as equipment calibration and processing conditions. If the processing conditions are not optimal, the film will require higher radiation dose in order to provide an acceptable film density. This was one of the major factors of high patient dose in some X-ray departments surveyed. The large variations in ESD values indicate that, much can be done to decrease patient doses by changing exposure parameters, kVp and

mAs and by adopting a quality assurance program, through which the performance test is carried out periodically and should cover every facility aspects including X-ray film processing conditions. The eight examinations sampled showed large variations which reached up to 27 folds. This is a strong indicator of suboptimal performance in one or more of the many variables in diagnostic arena. These variables include – but not limited to- technique, film screen combination and processing facilities. Although patients represented here were standard-sized patients and the weight varied between 60 and 80 kg, yet, this will not justify such great variations which is, as mentioned before, reached several folds. The first impression of such consistently wide variations is that the film-screen combination was most likely the major cause. But in fact this is not exactly true. Because all the screen speed used is speed 400, but some of them were overused. Other main causation of great variations in patient dose was the type of the chemicals in use and their frequency of renewal. To overcome such an obstacle there must be a regular test for the efficiency of the chemical, through using of sensitometer strip. In case this kind

of test is not available there must be at least a systematic approach of monitoring chemicals efficacy round the clock in terms of strength, temperature and level. One major factor that leads to good practice - hence reduction of the dose to the patient- is the adoption of appropriate technique. For example concerning Posterior-anterior chest for lung field examination, all department surveyed using low kV technique as noted in table 1. This resulted in a higher dose to the patient. Using low kV means to increase the mAs accordingly to maintain the film density which results in higher dose. The remedy for such a problem is to use the high kV technique. In case of cervical spine projections which are shown in Figure 4, a wide variation in ESD is noticed. The reason is that, in case of lateral cervical projection it is routinely done with erect Bucky with anti-scatter grid and due to the anatomical shape there is an air-gap between the object and the receptor. Once the gap exists, it is advisable not to use a grid; for either method is quite enough to do the job of reducing the scatter radiation. None of the departments selected for this study having a cassette carriage to be hanged on the erect Bucky, so the operator can use it interchangeably whenever a lateral view is

Table 2: Proposed Diagnostic Reference Level expressed in third quartile of the mean entrance surface dose (ESD) (mGy) obtained from standard-sized patients undergoing the most frequent examinations carried in Khartoum State.

Radiograph	ESD/View	Radiograph	ESD/View (mGy)
Chest PA*	0.54	Abdomen	3
Skull PA	1.9	Pelvis	3
Skull Lat.***	1.2	LS/Spine AP	6.43
CS AP**	1.35	LS/spine Lat.	18.5
CS Lat.	1.67	Knee joint AP	0.39
		Shoulder Girdle	1.4

\*\* Lateral \*\*\* Anterior Posterior \* Posterior Anterior.

needed. DRLs can be considered as the initial standard in local radiology audit process for identifying situations where patient doses are unusually high<sup>26</sup>. DRLs are consistent with the national reality and reflected the severe lack of such entity of optimization of protection of patient against ionizing radiation in Sudan. The data obtained have added a positive impact on the whole process by providing a base line against which the mean values of patient doses at individual X-ray department may be compared. This is achieved by directing professionals who are actually performing medical exposure, to be familiar with typical doses. Professionals also should be trained on methods of measurements and means of reducing the dose to the patient.

The mean ESD in this study, apart from PA chest, is found to be well below most of the examinations in some countries<sup>25</sup>. This does not mean that the dose level could not be further reduced without compromising image quality. The DRLs, when adopted, are not supposed to be applied as investigation levels for individual patient, but should be compared with measured mean values of representative samples of patient<sup>30</sup>. If the typical dose to a specific type of diagnostic procedure is consistently exceeding the relevant established DRLs, an appropriate corrective action should be taken. This could be achieved through a regular review. In such case an appropriate action either remedial or suspension level, should be taken in order to improve practice and avoid unnecessary risk due to radiation health detriment<sup>22</sup>. Thus it is sound to say that DRLs do provide an effective tool of quality assurance and play a major role

in dose optimization both for patients and radiation workers.

DRLs should be modified as technology improves. A culture of regular dose measurements, film rejection analysis and image quality assessment as recommended by the IAEA<sup>25</sup> need to be adopted in diagnostic radiology in Sudan.

#### **CONCLUSION:**

The data presented in this paper are an initial effort at establishing national diagnostic reference levels in Sudan. Although the survey was focused in Khartoum State, yet the ESD evaluation allows the collected data to be interpolated for the rest of the country. Despite some effort carried out by some authorities to reduce patient dose through carrying out regular quality control, yet the dose for similar examination in different X-ray department still vary substantially. The large variations in different department for the same radiological projection reflected the necessity and urgency to establish national diagnostic reference levels. Because such work of establishing national references is time consuming, therefore it is advisable to adopt an internationally established DRLs until the job is accomplished nationwide. When national DRLs have been adopted, it would be prudent to review them in a regular basis.

Last but not least, this study have paved the way for large-scale dose survey which should cover all other radiological procedures, such as fluoroscopy, interventional radiography, pediatric radiography, mammography and dental radiography

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