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Determination of Diagnostic Reference Levels for Chest Examination for Windhoek, Namibia

E.L.M David[1*], E. Daniels[2] and V. Uushona-Mikka[3]

[1]Department of Physics, University of Namibia, Windhoek, Namibia
[2] Allied Department -Radiography, University of Namibia, Windhoek, Namibia
[3]National Radiation Protection Authority, Ministry of Health and Social Services, Windhoek, Namibia

*Author for correspondence: email: esterdavid82@gmail.com; Cell: + 264 81 4970247

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ABSTRACT

The widespread use of X-ray examination has improved lives worldwide and this evolution of imaging has also resulted in a significant increase in the population's exposure to ionizing radiation. This exposure can be minimised by the setting up Diagnostic Reference Levels (DRLs). DRLs are exposure level that serve as guide for standard regions of interest and are recommended by the International Atomic Energy Agency for member states to apply within the context of the national legislation. Namibia Radiation Protection and Waste Disposal Regulations also mandate the National Radiation Protection Authority to determine guidance levels as a condition of a license. Management of patient dose and determination of DRLs are important part of quality control programs in X-ray diagnostic departments as it forms an efficient and powerful standard for minimising radiation dosage to patients. Since Namibia has not yet established DRLs, the aim of this study was to develop DRLs for posterior anterior (PA) chest examination in Windhoek, Namibia. Quality control tests were done on the X-ray machines using a Xi-Unfors radiation meter. Entrance skin doses (ESDs) were obtained from 120 patients that were referred for chest examination at the six selected facilities in Windhoek. The following parameters were measured: kilovoltage peak (kVp), milliampere seconds (mAs), the focus to bucky distance (FBD) and focus to surface distance (FSD). The ESDs were then calculated. The average ESD was found to be 0.47 mGy, ranging from 0.14 to 1.3 mGy. The study provided baseline information on ESD's for PA chest radiography. The ESD's in this study was above the ESD's recommended by the IAEA which is 0.2mGy. This was attributed to the use of high kVp and mAs and a short FBD at some facilities. The results of this study, with more data expected to be collected by the National Radiation Protection Authority (NRPA) will provide a useful baseline to establish Namibia's DRLs.

1. Introduction

The widespread use of X-ray examination has improved the lives worldwide and this evolution of imaging has also resulted in a significant increase in the population's exposure to ionizing radiation. When using X-rays for medical imaging, low energy from X-rays is always absorbed by the body which might lead to the high radiation dose that the body will absorb without contributing to the image. The amount of radiation people are exposed during an X-ray depends on the tissue or organ being examined. The basic requirements for radiation protection against exposure to ionizing radiation of workers, members of the public and patients, known as 'The International Basic Safety Standards for Protection against Ionising Radiation and for the safety of Radiation Sources (BSS) was published by the International Atomic Energy Agency (IAEA) in 1996. To ensure that the exposure to patients is minimal as necessary to achieve the required diagnostic objective relevant guidance levels for medical exposure must be established (Organization & others, 1996).

Diagnostic reference levels (DRLs) refers to the dose levels in the medical diagnostic procedures for a typi-

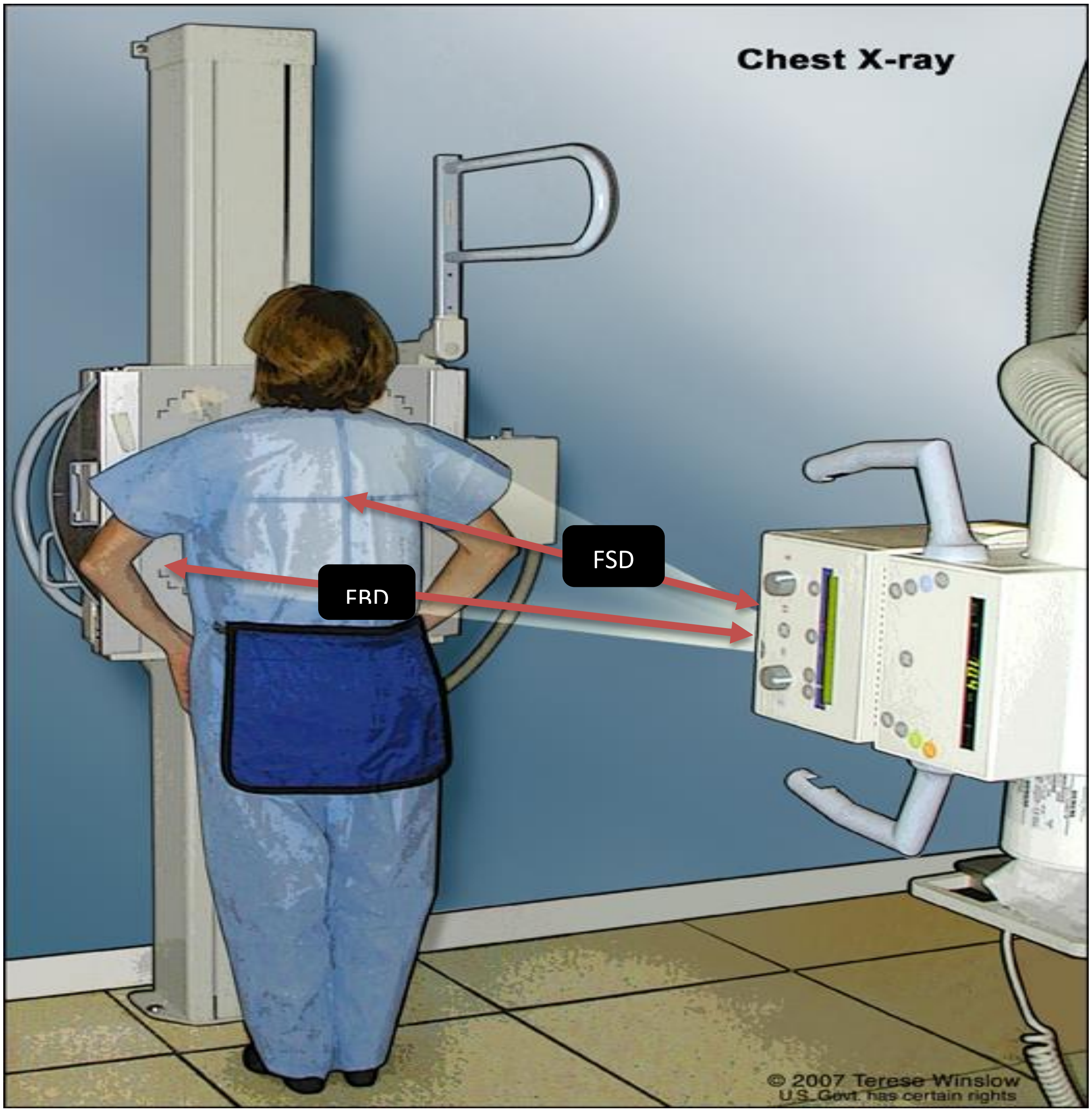

Figure 1: Diagram showing the position of patient undergoing Chest PA examination illustrating the FSD and FBD ***(Adapted from Junying & Thomsom, 2006)*** **.** *PA Chest projection: distance from the X-ray source to the surface of the patient in the midline at the level of the 7th thoracic vertebra where the radiographer centres the X-ray beam (Junying & Thomsom, 2006).*

cal examinations for standard sized patients for broadly defined types of equipment. These levels are not expected to be exceeded for standard procedures when good and normal practice regarding diagnostic and technical performance is applied (Perníčka & McLean, 2007). Due to this effect, the DRLs is intended to be used as a simple test for identifying circumstances where the levels of patient dose are below or above the average. It was found that the diagnostic procedures are consistently leading to exceeding the desired DRL; however there should be a local review of procedures and equipment in order to determine whether the protection has been adequately optimised, and if not, measures aimed at reduction of doses should be taken (Malone et al., 2014).

According to an article by National Radiological Protection Board in 2002, the use of DRLs in the United Kingdom and appropriate optimization resulted in a 50% reduction in average patient radiation doses from their first publication in the mid-

1980s until 2000 (Pernička & McLean, 2007). Therefore it is important for each country to establish its own DRLs that are appropriate to their own radiological techniques in order to optimise patient radiation dose. DRL can be obtained by comparing national or regional data and the mean value of patients doses observed in practice for a suitable reference group of patients (Hart & Wall, 2002).

The Radiation Protection and Waste Disposal Regulations of 2011 requires for DRLs to be determined and established for basic diagnostic examinations. Namibia has not yet established DRLs, it is for this reason that the research focused on the establishing DRLs for chest examination in selected radio diagnostic facilities in Windhoek, Namibia, which will eventually be part of the national DRLs.

2. Materials and Methods

The study target population was six radiological facilities in Windhoek. Patient thickness was calculated for each projection by subtracting the source to patient distance from the source to bucky top distance. The focus to surface distance (FSD) was measured as such in order to determine patient thickness.

The study population were patients referred for chest PA. Chest examinations have been chosen because they are most commonly performed procedure used in clinical practice, (Verdun et al., 2008). ESD was obtained from a minimum of 20 patients referred for chest examination in each facility. The IAEA, European commission and the dosimetry working party recommended that a minimum of 10 patients per radiographic examination be included during radiation measurements of patients (Verdun et al., 2008).

The entrance surface dose was determined in four steps namely: Performing Quality Control Tests, measuring the entrance surface air kerma (ESAK), completing the data collection form and calculating the ESD.

Quality control (QC) tests were done on the X-ray machines to ascertain if it is performing within the required parameters. Image quality and patient dose are dependents on any variation in the generator kilovoltage (kV) of the X-ray set (Treier et al., 2010). Therefore an accurate kV calibration was needed. A non-invasive tube voltage check over the whole used kV range was performed with electronic device called a Xi-Unfors base radiation meter that was used to measure kVp and the radiation dose. The following tests under quality control were done on the machine:

a) kVp accuracy test

b) kVp Reproducibility test

c) Radiation output linearity and mAs linearity

d) Half Value Layer (HVL)

e) Beam alignment test

The researcher employed a prospective quantitative, descriptive and contextual research design based on the International Atomic Energy Agency (Muhogora et al., 2008) and National Radiological Protection Board (NRPB) of the College of Radiographers in the United Kingdom guidelines on direct dose measurements (Roberts, Drage, Davies, & Thomas, 2009). The NRPB recommends that dose measurement studies be performed on patients, rather than phantoms or free air in order to provide a true measurement of clinical practice.

The incident air kerma is the kinetic energy released per unit mass (kerma) to air from an incident x-ray beam measured on the central beam axis at the position of the patient surface (Faulkner, Broadhead, & Harrison, 1999). Only the radiation incident on the patient and not the backscattered radiation is included. It is measured in J/kg and the name for the unit of kerma is gray (Gy).

A detector (Xi-Unfors) was positioned at 100 cm (1metre) from the x-ray tube focal spot. Then the radiation field was collimated to the size of the detector to prevent backscatter. The incident air kerma was measured at different kVp settings range from (50-150) kVp. The incident air kerma was then divided with the corresponding mAs to give dose/mAs. Finally, a graph of the dose/mAs vs kVp was plotted.

In absence of dosimeter to measure DAP or ESD directly, the reliable estimate of the ESD and consequently of effective dose, was obtained by recording the exposure parameter (mAs, kVp) chest X-ray projection and the focus to bucky distance (FBD), focus to surface distance (FSD) and the absorbed dose to air was measured in combination with BSFs available in literature and for chest PA examination it is said to be 1.35.

The ESD for each exposure was determined by:

$$ESD[mGy]=output\ at\ 1metre \times mAs \times (100/FSD)^2 \times BSF$$

Where output at 1meter (100cm) is the output obtained at a distance of 100cm from the X-ray tube, calculated from the graph of (mGy/mAs) versus kVp during the measurements of incident air kerma and BSF of 1.35 was used (Seeram & Brennan, 2006).

3. Results

3.1 Quality control test

The quality control test was done in all facilities and all facilities passed the tests. This gives an indication that the X-ray machines were performing optimally.

Table 1: Summarising the quality control for all the facilities

Facility	kVp accuracy	kVp reproducibility test (CoV) [%]	Radiation output linearity and mAs linearity	HVL (mmAl)	Beam alignment
1	Passed	0.10	Passed	3.07	Passed
2	Passed	0.19	Passed	2.60	Passed
3	Passed	0.15	Passed	3.48	Passed
4	Passed	0.28	Passed	3.57	Passed
5	Passed	0.42	Passed	3.91	Passed
6	Passed	0.30	Passed	3.15	Passed

The results show that all the facilities have passed the kVp accuracy since the percentage difference between the measured and set kVp was within 5%. The machines in all facilities passed the kVp reproducibility test since as the coefficient of variance (CoV) was within 2% as shown in the above Table 1. The machines in all facilities passed the radiation output linearity and mAs linearity since as the graph of radiation dose (mGy) versus the set mAs shows that there was a linear relationship between the radiation output and mAs.The six facilities passed the half value layer test (HVL) [mmAl] as the results in the Table 1 above show that the HVL was above the recommended minimum HVL which is 2.3mmAl at 80kV and 20mAs.The machine also passed the beam alignment test as it was represented by the outcome results after the test that was done.

3.2 Entrance Surface Dose (ESD)

Analysis was performed on 120 entrance surface dose (ESD) measurements. The distribution of mean entrance surface air kerma (mGy) across the six radiological facilities is displaced on the Table 2 below.

Table 2: The distribution of mean entrance surface air kerma (mGy) across the six radiological facilities

Facilities	Obtained DRL (mGy)	IAEA DRL (mGy)
1	0.18	0.2
2	0.76	
3	0.14	
4	0.26	
5	0.15	
6	1.3	
Average	0.47	0.2

The IAEA (1996) recommends an (ESD), of 0.2 mGy, Windhoek's x-ray facilities show a variation in results.

Figure 2: Entrance surface dose (ESD) [mGy] for all 6 facilities

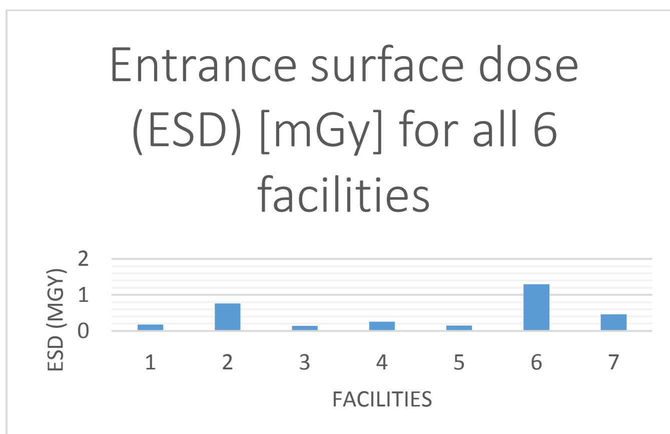

Table 3: Showing the DRLs for Windhoek which is 0.46mGy

Projection	Minimum (mGy)	Maximum (mGy)	DRLs (mGy)
Chest (PA)	0.14	1.3	0.46

At three facilities (1, 3 ,5) DRLs were below the IAEA recommended limit while facilities 2, 4, 6 the DRLs were above the recommended limit. The averaged DRLs for chest examination for Windhoek was 0.46mGy. This is above the recommended IAEA DRLs of 0.2mGy. The DRL for facility (2), (4) and (6) was high due to the usage of high milliampere second (mAs) and facility (6) used a focus to bucky distance of 115 cm. (Bontrager & Lampignano, 2013) recommended a minimum focus to bucky distance of 150cm to be used for chest PA examinations.

4. Discussion

Diagnostic reference levels are used to help manage radiation dose to the patient. Medical radiation dose must be controlled, avoiding unnecessary radiation that does not contribute to the clinical objective of the procedure. A dose significantly lower than the reference level may also be cause for concern, since it may indicate that adequate image quality is not being achieved. The specific purpose of diagnostic reference level is to provide a benchmark for comparison, not to define a maximum or minimum dose limit (Malone et al., 2014). The data obtained together with the data to be collect by the NRPA will provide a useful baseline against which the mean values of patient doses at individual X-ray department may be compared.

5. Conclusion

The diagnostic reference levels (DRLs) for chest examination for Windhoek was obtained to be 0.47mGy which was the first experiment. As it was compared to the IAEA DRLs, 0.2 mGy, it is observed to be above the recommended DRLs. However, some Windhoek facilities show a variation in results. The variation in the results was not because of poor equipment performance since all machines in all facilities passed the quality test, which means all the facilities are provided with an optimal image produced through good equipment performance. However, some facilities have high ESD which is 0.26mGy, 0.76mGy and 1.3mGy which is caused by usage of high exposure parameters and also the focus to bucky distance that is low.

Based on the results and conclusion drawn, the following recommendations are given:

The facility (2) and (4) that has high dose due to high mAs must reduce it by reducing the exposure parameter mAs. Facility (6) has high dose due to the fact that it has low maximum distance from the tube to bucky which is 115cm, since this distance cannot be changed, the reduction must be done on the exposure parameters (mAs), and this will reduce the dose to patients.

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