# A PROTOCOL FOR SETTING DOSE REFERENCE LEVEL FOR MEDICAL RADIOGRAPHY IN NIGERIA: A REVIEW

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**ABSTRACT**
*Patients' dose audit reports in some Nigerian hospitals had shown large inter- and intra-hospital variations for the same radiological examinations. They have thus presented the need, to have a national standard for radiological diagnostic procedures and set dose limits for individual x-ray examination centers in Nigeria. These will go a long way in reducing inter- and intra-hospital dose range factors, thus reducing doses to as low as reasonably achievable and consistent with clinical objectives of the examinations. In establishing a national dose limit for medical radiological examinations, there is a need to have a national dose survey. This paper suggests a reasonable and easy procedure for achieving a national radiological dose survey. Due to its simplicity of measurement, the use of entrance surface dose as the dose parameter to be used for setting the dose limit as recommended by the European Union and the International Atomic Energy Agency (IAEA) is also suggested. ESD can be measured directly through the use of solid state detectors, or indirectly by measuring free air exposure which can later be converted to ESD using standard formula. The methods of measuring the entrance surface dose and how to derive the dose limit from them are also highlighted.*

*Keywords: medical x-ray, patients' dose, dose limit, entrance surface dose*

## INTRODUCTION

The exposure of man to radiation from medical practices arises from diagnostic, therapeutic and general medical screening procedures. Consequently, individuals (patients), medical practitioners and the populace at large receive significant exposure to radiation. Medical exposures contribute the largest component of the radiation dose to the population from artificial sources (Hart, *et. al.* 1996). It was estimated that diagnostic radiology and nuclear medicine contributed 96% to the collective effective dose from man made source in the U.K (NRPB, 1993). Similar estimate showed that this contribution was 88% in the U.S.A (NCRP, 1987). Exposure to ionizing radiation carries with it an increased risk of malignant disease and a risk of hereditary disease in descendants of the exposed person. There is also the possibility of inducing deterministic effects. However, the overall benefits from the diagnostic use of ionizing radiation in medicine greatly exceed the small risks to the individual from the radiation exposure. The health of the population would decline if ionizing radiation techniques were not available to diagnose disease and detect trauma. Nevertheless, there is no excuse for complacency and it is a basic premise of radiation protection practice that any exposure should be justified by weighing the potential harm against the perceived benefit. Furthermore, it is requisite that procedures should be adopted to ensure that techniques are optimized so that doses to individual patients are as low as compatible with the medical requirements of each examination.

The international commission on radiological protection (ICRP) in 1990 recommended that all medical exposures should be subjected to the radiation safety principle of justification of practice and optimization of protection including the consideration of dose reference level. Justification is the first step in radiation protection. It is accepted that no diagnostic exposure is justifiable without valid clinical indication, and results in a net benefit for the patient. This only applies when it can be anticipated that the examination will influence the efficacy of the decision of the physician with respect to diagnosis, and patient management. Optimization requires that the magnitude of radiation doses be as low as reasonably achievable. The ICRP also affirms that optimization of doses in medical exposures has been given less attention compared to other applications of radiation.

Patient dose studies (Sharifat, and Olarinoye 2009;Oyeleke, 2009 ; Ogundare *et al,2008;* Ogundare *et al.* 2004a; Ogundare *et al.* 2004b; Ogunseyinde *et al.* 2002;Ajayi and Akinwumiju, 2000) completed had shown large intra- and inter- radiological centre entrance dose variation for the same diagnostic procedure in Nigeria. The National Radiological Protection Board (NRPB) in the U.K published the result of a nationwide survey (NRPB 1990) for a selection of x-ray examination in 20 U.K hospitals. The NRPB found that there was a ratio of almost 50 between the hospital with the highest dose and that with the lowest dose for an average size patient.

A similar national survey by the Food and Drug Administration of the U.S.A (Gray, 1999) revealed that the ratio of the maximum to minimum exposures ranged from 8.8 to 126.7.

Clearly these indicated that a good imaging technique was necessary to reduce patient doses to the lowest practicable levels consistent with the clinical purpose of the medical examination. Consequently, the NRPB in 1993 recommended reference dose values for a number of common diagnostic x-ray examinations, against which individual centers could compare their performance. Similarly, the Conference Of Radiation Control Program Directors (CRCPD) have published exposure guides for average size patients for use in the U.S.A.. (CRCPD, 1988).

In Nigeria, no national survey aimed at producing exposure guide for medical examination has been carried out. The large variation in patient doses observed in Nigeria in the local surveys mentioned earlier, has presented the need for the establishment of standards. Many factors influence patient radiation dose in x-ray examinations. These could be responsible for large intra- and inter-hospital dose variations for standard sized patients undergoing the same examination (Contento *et al.*, 1988). It is important to identify these factors, determine the level of contribution each makes to dose variation and remedial action taken in a cost effective way. This will lead to standardized and optimized radiological procedures. To facilitate standardization and optimization in Nigeria, there is a need for A National Dose Survey with a view to establishing a Diagnostic Reference Level (DRL). Establishing a national DRL should be for particular practices and equipments. The DRL established by relevant professional bodies in consultation with the relevant regulatory body such as the Nigerian Nuclear Regulatory Authority (NNRA) will serve as a reasonable indication of doses for average sized patients, and provide guidance on what is achievable with current good practice rather than on what should be considered optimum performance. DRL will also expose hospitals where doses are higher and identify the factors responsible. This will lead to an important reduction in patient doses in hospitals with high doses and where less than optimum procedures have been identified. The dose reduction potential of introducing a DRL is made obvious by the National Radiological Protection Board (NRPB). The NRPB publication of 1993showed reduction in patient doses up to 40% after the establishment of a DRL in 1992. In 2002 a further reduction of 20% was obvious (Hart *et al.*, 2002). This suggest that introduction of DRL could also reduce patient dose variation in Nigeria.

Although a strict limitation of doses to patients comparable to the practices in other field is unthinkable in diagnostic radiology, because it would adversely affect the care for the patient in special or critical situations. Dose constraints, however can be established such that for a certain examination of an average patient, recommended values may not be exceeded.

**Patient Dosimetry Parameters**
Three quantities play a central role in clinical radiation dosimetry; these are kerma, entrance surface dose (ESD) and the effective dose (E). Kerma is the Kinetic Energy Released per unit Mass (unit J/kg or Gray). For photon beams, kinetic energy released is the kinetic energy transferred to electrons in the material. The quantity is always defined with respect to the specific material in which the interactions are taking place (*e.g.* air kerma, water kerma *etc*) (James, 2006).

The effective dose is a radiation dose parameter which takes into account the absorbed dose received by each irradiated organ and the organ's radiosensitivity. It gives the amount of energy deposited in the irradiated organ. Since the effective dose may be taken as an approximate measure of the stochastic radiation risk, it may be used to quantify the amount of radiation received by patients undergoing diagnostic examination (Wall and Shrimpton, 1995). Patient dose in diagnostic radiology are reported in terms of effective dose by most national and international organizations. Consequently patient effective dose equivalent from a specific x-ray examination may be compared to that of any other radiological procedure as well as natural background exposures and regulatory dose limit. The E could also be used to determine and compare the dose received by patients, volunteers and radiological personnel who are exposed to additional radiation during research and radiological procedures. Unfortunately the computation of E for any type of radiological examination is generally complex and time consuming.

The quantity which is generally of greatest importance in routine measurement of patient dose in diagnostic radiology is the ESD. It is defined as the absorbed dose to air where the x-ray beam intersects with the skin surface. It is a quantity that can be measured directly and can easily be compared with previous measurements and with that obtained at other practices and countries. It can also be used as an indicator of effective dose for particular radiographic projections. Another reason for evaluating ESD is that the dose is greatest at the surface where radiation enters the body of the patient and the skin is therefore the main organ for which there is a possibility of deterministic effect (skin burn). The ESD has been recommended by the International Atomic Energy Agency (IAEA) in 1995 and the European Union in 1997 as the dose descriptor for guidance level in diagnostic radiography.

**Dose Reference Level (DRL) Protocol**
**[1] Survey of Hospitals and Equipments**
When attempting to establish national DRLs which are relevant to all hospitals in Nigeria, it is important to sample as many hospitals as possible. The hospitals to be included should be evenly distributed across all geopolitical zones and states in the country. These should comprise of all government owned x-ray centers and major private practitioners since they record the highest number of patients. Survey forms similar to that in table 1, should be distributed to the hospitals where technical parameters used by each center for various examination and measured dosimetry parameter will be recorded.

**Table1. sample of dose survey form**

| | |
|---|---|
| **Hospital/Centre Name:** | |
| **Address:** | |
| **Date**: | |
| | |
| **X-ray Machine** | |
| Make: | Model: |
| Year of manufacture: | Year of installation: |
| Generator waveform: | Inherent filtration (mmAl): |
| | |
| **Technical factors** | |
| kVp: | FFD (cm): |
| mAs: | focal spot size: |
| Added filtration: | Patient thickness: |
| | |
| **Exposure data** | |
| Focus chamber distance (cm): | Exposure (mR): |
| kVp: | mAs: |

**[2]    Measuring Free Air Exposure (FAE)**

Using the ESD as a criterion to set up DRL requires accurate measurement of the quantity. The ESD can be measured directly using thermoluminescent dosimeters TLD and indirectly by the use of a dose area product DAP meter and ion chamber to measure free air exposure (FAE).

TLD is widely used to measure ESD due to their sensitivity and tissue equivalent. In Nigeria, there are few TLD readers; this might limit the use of TLD for a national survey. The use of DAP meters is limited by the fact that dose and area cannot be separated in DAP meters. For simplicity and convenience, we propose indirect measurement of ESD using the FAE. The FAE at the point where the x-ray central beam strike the body may be measured using the ion chamber. Standard methods for measuring the FAE for manual and automatic exposure control units have been described by the American Association of physicist in medicine (AAPM, 1991). In the AAPM protocol, the ion chamber is placed approximately 23cm above the table top to minimize back scattering. Alternatively the FAE can be measured indirectly using softwares such as the RADCOMP x-ray entrance skin exposure software. Information required by the softwares include machine specific data such as phase, total filtration, x-ray quality in halve value layer (HVL), tube voltage and current, exposure time, focus to film distance and patient thickness. All these could be obtained from the distributed survey forms when duly filled by respective hospitals or centers.

**[3]    Converting FAE to ESD**

To save time and equipment, FAE could be measured at a particular set of parameters say 80 KV, mAs, and at a distance of 100 cm. Correction for other parameters used for the real patient will then be made using the formular (Faulkner et al., 1999) :

$$FAE(mR) = tube\ output \times \left(\frac{kv^2}{80^2}\right)\left(100^2 / FSD^2\right) \times mAs$$

(1)

where tube output is the FAE at 80 KV at a distance of 100 cm normalized by mAs (mR/mAs), kV is the tube potential, mAs is the product of the tube current and exposure time FSD and is the focus to film distance. The FAE above is defined free in air without any back scatter. To obtain the ESD to air with back scatter, the following formula (Tung *et al.*,2001) could be used :

$$ESD\ (mGy) = FAE\ (mR)\ x\ 0.00877\ x\ BSF$$

(2)

Where the constant 0.88877 converts the FAE in mR to ESD in mGy, and the back scatter factor (BSF), accounts for contribution from back scatter radiation. The BSF depends on factors such as the kV, field size, FSD, etc.

**[4]    Setting DRL**

All data obtained from steps 1 to 3 above would then be recorded and analyzed. The analysis should be based on ESD, and technical parameters. The third quartile of the ESD (Wall and Shrimpton , 1995) would then be taken as the DRL for each examination included in the survey.

**CONCLUSION AND RECOMMENDATIONS**

The large variation in patient doses observed in Nigeria in some surveys earlier mentioned has presented the need for a thorough national survey aimed at producing dose constraints for at least common diagnostic procedures. International and national authorities have recommended the use of dose limits in order to reduce the risk of radiation injury to patients. It should be noted that different terms are used around the world. Exposure guide is used in the U.S.A; reference dose in the U.K. and New Zealand; baseline patient dose in Malaysia and guidance level by the International Atomic Energy Agency (IAEA, 1995).

The national DRLs would be widely used for control of medical radiation exposure to a level commensurate with the clinical objective of an imaging task.

In principle, the DRLs will be applicable in all areas of diagnostic radiology, but they will particularly be useful in those areas where a considerable reduction in collective dose is more essential i.e in frequent examinations and in examinations involving more radiosensitive organs and patients such as children. Furthermore DRLs in Nigeria will provide a framework with which dose levels from individual hospitals are compared and when exceeded, corrective actions could be taken where necessary. Although a strict limitation of doses to patients comparable to the practices in other field is unthinkable in diagnostic radiology, DRL could be applied with flexibility to allow higher exposures if these are indicated by sound clinical judgment.

The regulation of radiological practices in Nigeria is the responsibility of the NNRA, thus conducting a radiological survey and setting dose level could only be achieved through it. The NNRA will have to do more than it is presently doing as regard protection of life, health, property and the environment from the harmful effects of ionizing radiation. There is also the need for the NNRA to have offices with enough personnel in every state of the federation to monitor and regulate medical radiological standard before and after setting DRLs.

Quality and safety have become hallmarks for efficient and successful medical intervention. It should be noted that safety standards are only effective however if they are properly applied in practice. Thus it is not enough to set dose levels but it is also important to encourage compliance.

DRLs should be revised as technology improves. A culture of regular dose measurements, film rejection analysis and image quality assessment as recommended by the IAEA in 2004 need to become part of diagnostic radiology in Nigeria.

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