# DOSE DETERMINATION IN RADIODIAGNOSIS USING EXPOSURE FACTORS

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## Abstract

*The dose of X-rays to patients undergoing Radiological examination in the Radiology Department of the University of Ilorin Teaching Hospital, Ilorin, Nigeria, was determined using exposure factors. Optical density of the X-rays films was also measured using a locally developed densitometer. The mean values of dose to the leg, chest and skull determined are 2817 ± 0.61μG, 2195 ± 0.41μG, and 2649 ± 0.38μG respectively. The results of our measurements were found to be in agreement with the standard value existing in literature. The use of this method is suggested to Hospitals where dosimeters are not available.*

*Keywords: Dose, exposure factors, optical density*

## 1. Introduction

The determination of patient doses in various radiographic examinations (of pelvics, spine, skull and leg) has long been an issue of general interest to medical Physicists as it forms a step towards a quantitative relation between the radiation and the effect they produce (Greening, 1985). It is known that X-rays, which is the most encountered radiation in diagnostic radiology, have injurious somatic and genetic effects on human beings.

Beside cell sterility and death, which are somatic effects due directly to high radiation doses, the most probably serious risk from X-rays involves developmental effects on the new-born child from irradiation in the uterus. (UN-SCEAR, 2000). Here, relatively low doses can have most damaging effects. Genetic damages due to radiation is manifested in the uniting of sperm and ovum, one or both of which have suffered radiation damage, and the subsequent production of abnormality in an offspring called mutation (Turner, 1995)

One of the means of preventing the danger of over exposure is the direct dose determination using badge dosimetry. Film badge dosimetry is based on the principle that ionizing radiation exposes the silver halide in the photographic emulsion, which results in the darkening of the film. The degree of darkening which is the optical density of the film worn can be measured with a densitometer. Hence, by comparing the optical density of the film worn by an exposed individual to that of the film exposed to known amount of radiation, the exposure to the individual may be determined (Cember, 1996).

Regular monitoring of radiation doses received by personnel is not only important from individual point of view; but could as well yield relevant information on procedures adopted by that individual in everyday diagnostic practice (Griffith, 1990). Apart from

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professionals working with radiation, there is a concern for the safety of young trainees in the radiation field and for those workers or any other persons not involved with radiation. Thus, means for the protection of patients undergoing various medical exposures, (ECCD, 1997) has recently been introduced for each standard radiological investigations.

In addition, measurement of radiation dose to patient also provides essential information about radiographic facilities and techniques, clearly demonstrating where improvements are necessary. This is important in the implementation of ALALRA principle (Kathren, 1985).

In keeping the radiation dose to the barest minimum, it is important to determine the dose to the patient as a function of radiographic parameters. Dose of ionizing radiation have been measured by direct means through the use of calorimeters, and by direct means on the basis of the secondary effects produced by the energy loss of the particles such as ionization, photographic and chemical effects. Some authors have employed several other methods recently for this purpose (Theocharopoulos, 2002). However, our problems are the non-availability of these equipments in Nigeria Hospitals, and also the need to keep the radiation dose to the barest minimum (IOPEM, 1998; NRPB, 1992). This article is therefore based on the determination of dose of X-rays using radiographic parameters, (i.e. kilovolts peak(kVp), miliampere second(mAs), sourcse skin distance(SSD) and filtration). The advantage of this method is that one can obtain an estimate of the radiation dose to the patient prior to examination.

## 2. Materials and Methods

### 2.1 Calibration of densitometer

The densitometer used in measuring the optical density is the same described by Bassey and Fletcher (1991). It uses 12V, 21W automobile bulb as the light source and Cadmium Sulphide (CdS) photoconductor as the light detector. The maximum optical density is 2, noise level is approximately 0.9mA and the signal to noise ratio ranges between 18 and 500. The densitometer was calibrated against a calibrated density strip obtained from measurements using standard densitometer in the Department of Medical Physics, University of Wisconsin, Madison, U.S.A. The strip that has been exposed to X-rays at fixed exposure factors and films, with different amount of darkening were obtained.

Firstly, the aperture of the photocell was completely labeled with a black paper so that no light was incident on the linear scale that corresponds to infinity on the scale. Light from the source was then passed through the unexposed part of the film and the reference intensity $I_0$ obtained. This was done as a correction to any error the thickness of the film would introduce. The maximum intensity on the linear scale, which is 500*mA*, was taken as the reference intensity $I_0$. This corresponds to zero optical density in which case, the light is transmitted through the unexposed part of the film. The intensity of the light transmitted through steps of the strip on the film was obtained.

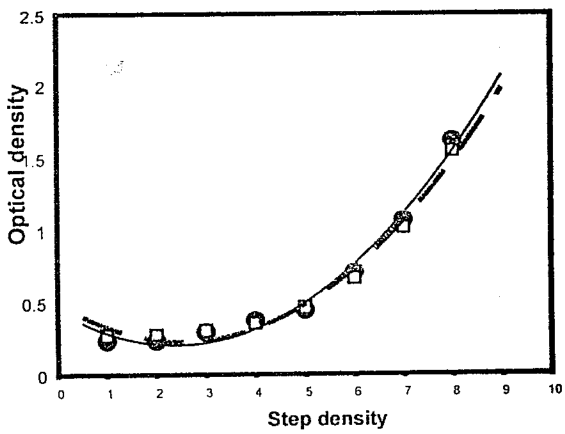


**Figure 1: Calibration curve for local densitometer against standard densitometer**

Measurements of optical densities of the different steps of the wedge were made and the results compared with those obtained using standard densitometer from the University of Wisconsin. The calibration curve shown in Fig. 1 indicates that there is no remarkable difference between measurements made with the two densitometers. However, the percentage difference ranges between 3% and 14%. The highest difference occurred at the lighter part of the film.

### 2.2. Measurement of patient dose, exposure and optical densities

Patient doses and exposure in various radiographic examinations (of chest, skull and leg) were measured using the X-ray facilities in the Radiology Department of the University Of Ilorin Teaching Hospital, Ilorin, Nigeria. An *R* -501 three - phase X-ray generator was used for exposing patients over a wide range of radiographic conditions. As mentioned earlier, the radiographic parameters of interest are kVp, mAs, SSD and filteration.

The skin dose (SD) to patient was determined using the examination technique of Edmond (1984), giv- by

$$SD(\mu Gy) = \frac{836*(kVp)^{1.74}*(mAs)}{(SSD)}\left(\frac{1}{T}+0.14\right) \quad (1)$$

where *T* is the total filtration (inherit plus added) in *mm* of Aluminium and SSD is measured in *cm*. The inclusion of inverse square law dependence on distance neglects the effect of air absorption.

Patients exposure (PE) was estimated using an approach proposed by Cameron (1990). That is,

$$\text{PE} = (\text{Exposure number from table})*$$

$$\left(\frac{kVp}{80}\right)^2 * \left(\frac{30in}{SSD}\right)^2 * mAs \quad (2)$$

Using eq. 2, the exposure to the chest, skull and leg were estimated.

The optical density (OD) of each of the films used for patients' examination was also measured with the aid of the Bassey and Fletcher (1991) densitometer. Values of *OD* of the exposed and unexposed part of the film were obtained; and the difference gives a measure of the dose to the patient.

### 3. Results and Discussion

Skin doses, exposures and optical densities for the patients examined under various radiographic conditions were obtained as described previously. The results for leg, chest (P/A) and skull examinations are shown in Table 1. The mean value of the skin dose for chest X-ray examination was found to be 2195 ± 0.41μGy. This figure compares well with the direct measurement of 2320μGy reported by Weatherburn (1983), within an accuracy of 5%. For leg examination, the mean skin dose was found to be 2817 ± 0.61μGy. For the skull examination, only one film was available for analysis and the skin dose was measure as 2649.72uGy.

The difference (OD) between the optical densities of the exposed ($OD_e$) and unexposed ($OD_u$) films gives a measure of the dose to the patients. The relationship between the skin dose and optical density for chest (P/A) examination is shown in Fig. 2. The result reveals that optical density of X-rays film increases linearly with skin dose, and this is in good agreement with previous studies (Kathren, 1985).

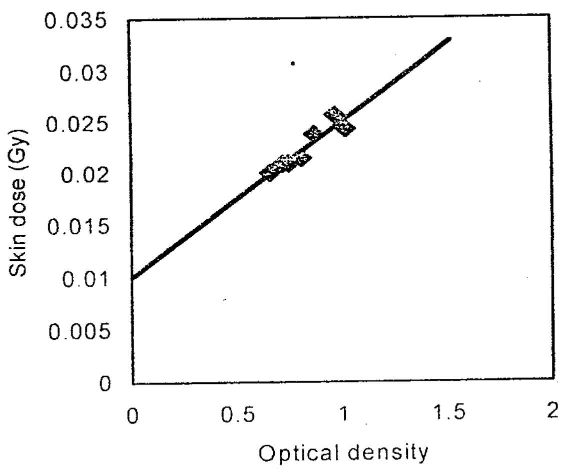


Figure 2: Graph of skin dose versus optical density

According to Kathren (1985), the absorbed dose (D) and the exposure (R) are related by the expression:

$$D = fR \quad (3)$$

where *f* is a constant depending on both the composition of the irradiated material and quality of the beam. Using our data, we plotted a graph of absorbed dose versus exposure (Fig. 3). The estimated value of *f is o.836 rad/R,* which is in good agreement with the literature value of 0.957 rad /R. A test for correlation between skin dose and the optical density gives a correlation coefficient between the two variables.

Table 1: Results of exposure, skin dose and optical density obtained from various radiological examinations

| Film no | Type of Examination | kVp | mAs | SSD (Cm) | Skin Dose (μGy) | $OD_u$ | $OD_e$ | $OD_e - OD_u$ | Exposure (mR) |
|---|---|---|---|---|---|---|---|---|---|
| 96241 | Leg | 75 | 20 | 78 | 2860.34 | 0.22 ± 0.03 | 1.15 ± 0.06 | 0.93 | 260.03 |
| 94367 | Leg | 80 | 22 | 78 | 3520.31 | 0.21 ± 0.02 | 1.12 ± 0.05 | 0.91 | 325.44 |
| 95173 | Leg | 70 | 16 | 78 | 2029.42 | 0.22 ± 0.01 | 1.22 ±0.07 | 1.00 | 181.21 |
| 96287 | Leg | 75 | 20 | 78 | 2860.34 | 0.20 ± 0.02 | 1.10 ±0.04 | 0.90 | 260.03 |
| 96243 | Chest | 75 | 20 | 90 | 2148.44 | 0.23 ± 0.02 | 1.04 ± 0.02 | 0.81 | 20.45 |
| 96275 | Chest | 65 | 22 | 85 | 2065.50 | 0.22 ± 0.02 | 1.09 ± 0.04 | 0.92 | 19.43 |
| 96282 | Chest | 65 | 25 | 90 | 2083.61 | 0.23 ± 0.03 | 0.95 ± 0.05 | 0.72 | 19.73 |
| 96283 | Chest | 63 | 18 | 80 | 1806.83 | 0.22 ± 0.02 | 0.98 ± 0.03 | 0.76 | 18.70 |
| 96292 | Chest | 80 | 25 | 100 | 2433.81 | 0.21 ± 0.01 | 1.23 ± 0.04 | 1.02 | 23.93 |
| 96291 | Chest | 70 | 25 | 90 | 2381.75 | 0.23 ± 0.03 | 1.10 ± 0.03 | 0.87 | 22.63 |
| 96284 | Chest | 70 | 22 | 90 | 2095.94 | 0.22 ± 0.02 | 0.92 ± 0.02 | 0.75 | 19.75 |
| 96289 | Chest | 65 | 28 | 90 | 2344.84 | 0.21 ± 0.01 | 0.94 ± 0.05 | 0.83 | 22.45 |
| 70783 | Chest | 70 | 28 | 90 | 2572.30 | 0.20 ± 0.02 | 1.17 ± 0.03 | 0.97 | 23.03 |
| 96299 | Chest | 63 | 20 | 80 | 2007.39 | 0.24 ± 0.02 | 0.90 ± 0.05 | 0.66 | 20.58 |
| 96060 | Skull | 80 | 25 | 80 | 2649.72 | 0.18 ± 0.01 | 1.38 ± 0.02 | 1.21 | 308.99 |

Finally, from Table 1, we find that the mean value of the estimated exposure for chest (P/A) examination is 21.27 ± 0.47mR. This figure also compares well with 23mR quoted by Cameron (1990) using the same technique. In Fig. 4, we show that our estimated exposure varies linearly with the optical density.

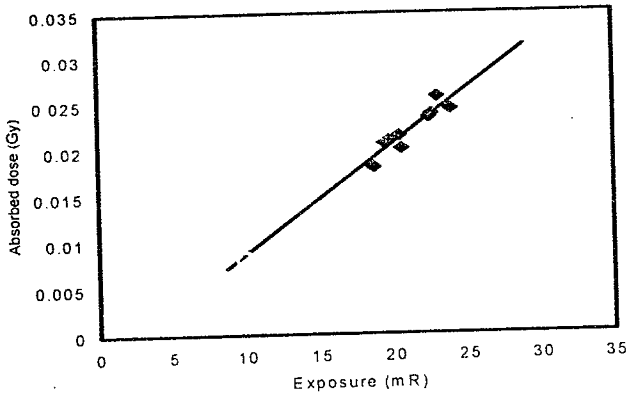


Figure 3: Graph of skin dose versus exposure

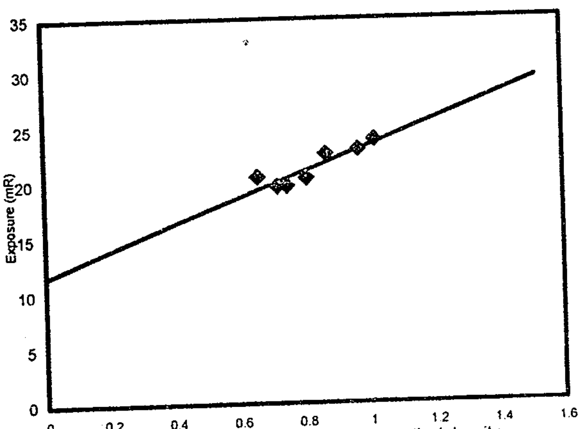


Figure 4: Graph of exposure versus optical density

## 4. Conclusion

Due to non-availability of equipment in the developing countries like Nigeria, there has not been a precise method for determining the dose of X-rays to the patients undergoing diagnostic X-rays procedure. Results from this study, using exposure factors to determine dose of X-rays to patients was found to be in good agreement with standard value. Thus, suggesting that dose to patients could be determined using this approach, where TLDs, film badges or dosemeters are not available.

To a reasonable extent, exposure to patients needs to be estimated prior to examination, and this should be done in order to keep radiation doses to the patient as low as possible in accordance with ALARA principle. The results of this study indicates that the exposure to the patients could be done using this technique; as it will give a reasonable idea of the exposure prior to examination.

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## References

Bassey, C.E. and Fletcher, J.J. (1991): Densitometry in Medical Radiation

Physics: A Nigerian Experience. Nig. J. Phys. 3:71-76.

Cameron, J.R. (1990): Radiation Safety in Diagnostic Radiology: In College on Medical Physics, International Center for Theoretical Physics (ICTP), Italy.

Cember, H. (1996): Introduction to Health Physics. Pergamon Press, New York. DH Department of Health (2000). The Ionizing Radiation (Medical Exposure) Regulations. London.

Edmonds, I. R., (1984): Calculation of patient skin dose from Diagnostic X-Ray Procedures. British J. Radiology 57:733-734.

EU European Union (1997): Community Council Directive 97/43/Eurotom of 30 June 1997 on health protection of individuals against the dangers of ionizing Radiation in relation to medical exposure. Official Journal of the European Communities L180: 22-27.

Greening, J.R. (1985): Fundamentals of Radiation Dosimetry. Page Bros (Norwich) Ltd. Britain.

Griffith, P. (1990): Principles of Radiation Protection: In College on Medical Physics, International Center for Theoretical Physics (ICTP), Italy.

IOPEM Institute of Physics and Engineering in Medicine (1998): Recommended Standards for the Routine Performance Testing of Diagnostic X-ray Imaging Systems. Report 77, New York.

Kathren, R.L. (1985): Radiation Protection. Adam Hilger Ltd., England.

NRPB, National Radiological Protection Board (1992): National Protocol for Patient Dose Measurements in Diagnostic Radiology. Oxford.

Theocharopoulos, N.(2002): Comparison of our four methods for assessing patients effective dose from radiological examinations. Med. Phys. 29: 2070-2078.

Turner, J.E. (1995): Atoms, Radiation and Radiation Protection. Wily-Interscience Publishers, New York.

UNSCEAR (2000): United Nations Scientific Committee on Effects of Ionizing Radiation, UNSCEAR 2000 report to the General Assembly with Scientific Annexes. Vol.1: Sources, Annex D, Medical radiation exposures, United Nations, New York.

Weatherburn, G. C., (1983): Reducing Radiation Doses in the breast, thyroid, and gonads during diagnostic Radiography. Radiography 49: 195-202.