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Image Quality and Dose Dependence on X-ray Exposure Factors

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Abstract

In this study, the investigation of image quality and dose dependence on diagnostic X-ray exposure factors was conducted using kVp multi-meter, Edmond's formula and densitometer. A total of 100 patients were exposed to diagnostic X-ray during their routine chest X-ray examinations. The exposure factors of kilovolt (kVp) and tube current time (mAs) that produced optimal doses and optical density associated with X-ray films obtained from three Hospitals labelled HSP1, HSP2 and HSP3 showed the mean exposure factors of 55 kVp and 5.4 mAs with 0.72 optical density; 67 kVp and 34 mAs with 0.94 optical density; 62 kVp and 16 mAs with 0.75 optical density respectively. The fourth hospital labelled HSP4 showed the mean exposure factors of 73 kVp and 3.5 mAs with 0.88 optical density.The kVp and mAs investigated show optical density in the range of 0.72 to 0.94 OD that produced good image quality. The measured and calculated patients dose in the Hospitals was compared with reference dose levels. This study provides guidance on where efforts on dose reduction will need to be directed to fulfil the requirements of optimization process.

Keywords: X-ray, Film, Image, Quality, Exposure, Factors.

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Introduction

Radiography is one of the oldest diagnostic imaging methods in which X-rays are used to obtain images about the internal anatomy of patients. Imaging techniques are those techniques that enable us obtain visual information about the structure, function, status and state of biological tissues and organs [1]. The images are usually recorded on photographic films or other suitable X-ray detectors, the energy and intensity of the produced X-ray beams depend directly on the applied kilo voltage (kV), tube current (mA) and the time of the X-ray exposure (s) or mAs. These factors influence the exposure and the quality of the image produced on the film[2]. A report by the United Nations Scientific Committee on the Effects of Atomic Radiation [3] estimates that the annual number of all types of medical X-ray examination undertaken in the world was about 2100 million in 2000, corresponding to an annual frequency of 360 examinations per 1000 individuals worldwide. This frequency is about 10% higher than the previous estimate of 330 per 1000 for the period 1991–1995 [4]indicating an increase in practice. However, further growth in medical radiology can be expected in developing countries where facilities and services are often lacking.

Radiation dose to patients from diagnostic X-ray machine depends on radiographic exposure parameters of kVp, mAs, SSD, filtration and patient thickness [5]. Patient's dose has often been described by the entrance skin dose (ESD) as measured in the centre of the X-ray beam [6]. Because of the simplicity of its measurement, ESD is considered widely as the index to be assessed and monitored. Because of the limitation associated with both TLD and TIC several mathematical equations have been suggested to relate skin dose to the used exposure factor such as the applied mAs, surface to skin distance (SSD), filtration, field size, output and the applied kVp [6]. This equation provides an easy and more practical means of estimating skin dose even before exposure. Despite the attractive nature of the calculation methods of patient dose, one should make sure that the used X-ray equipment has an adequate quality control (QC) protocol that ensures the accuracy of the measured factors [7]. Assessment of radiation exposure during X-ray examinations are of great importance in radiation protection field. Patient's radiology should be governed with high professional techniques to minimize radiation hazard while they are examined by X-ray. Also, there is an increasing interest in investigating the methods to reduce the dose received by the patient due to medical exposure, in line with the directives of Health Protection laws. For diagnostic radiological examinations the basic concept is optimization, in order to use the minimum necessary dose to achieve a good image quality [8]. Optimization of X-ray imaging parameters must be guided by the ALARA principle (as low as reasonably achievable) [9].

The utility of radiographic image and the accuracy of image interpretation depend on the quality of image and the ability of the interpreter. The importance of image quality to radiation exposure is its provision for required information in a radiograph in order to make an accurate diagnosis. In light of the significance of medical radiation exposure to diagnosis and the chance of patient to develop radiation effects which is relative to the dose absorbed by the patient. It is necessary to protect patients, radiation workers and the public from radiation effects arising from high doses in order to compliment clinical interest. To achieve this, there is a need to optimise radiological techniques, patient dose measurement is an integral part of this optimisation procedure [10].

In this optimisation procedure, X-ray facilities with high doses will be made known after which possible dose reduction measures may perhaps be taken. Dose measurement is necessary so as to ascertain dose constraints, determine risk to patient and to justify the examination [11]. In view of that, repeated monitoring of radiation doses delivered to patients is important with the view of reducing its effects during and after medical examination while keeping them as low as reasonably achievable and at the same time trying to optimise image quality for accurate diagnosis of which one of the methods is determination of Entrance Skin Dose as proposed by the National protocol for patient dose measurement in diagnostic radiology [12]. To this end, this study investigates the image quality and dosedependence on exposure factors in some selected hospitals in Makurdi, Benue State, Nigeria.

Materials and Methods

The materials used for this study include; Philips Technix (S.P.A), YangzhouKangtai, SF50AX-Ray machines and SKANRAY (OX – 100L) X-ray machine. LIANGJIN® Measuringtape, HAMASON Weighing scales, X-ray films (fujifilm), kVp multi-meter (Gammex 330), Gammex X- Rite (331C)Transmission Densitometer, patients who came for routine chest x-ray examination and a self-designed assessment sheet.

Using convenience sampling technique (available and willing to participate) which is a type of non-probability sampling method where the sample is taken from a population easy to reach [13], The study was carried out in four hospitals selected based on the availability of functional x-ray units and acceptance of the ethical committees of the respective hospitals to execute the study. Ethical clearances were obtained from the ethical committees of the hospitals. A total of one hundred (100) patients with twenty-five (25) from each of the centres were drawn for the investigation. Patients from both sexes attending X-ray examination in the Radiological Centres were selected and the approval of their consent was sought.

The source to image distance (SID) and source to skin distance (SSD) was measured using measuring tape. The kVp and mAs for each examination was read directly from the control panel of the X-ray machine. The patient dose was read by the kVp meter and was recorded

accordingly for each examination. The SID and SSD were measured in accordance with the exposure factors. The kV multi-meter was positioned at the image receptor stand, at a distance equal to SSD and exposed after exposing the patient. The film was processed and the optical density (OD) was measured using Densitometer

The mean difference between measured and calculated patient dose and percentage (%) mean difference between measured dose and calculated dose in the hospitals weredetermined. The ratio of the mean measured dose and the mean calculated for the hospitals were also determined.\

Results and Discussion

Results of the study are summarized in the following tables.

Table 1: Average (range) of age, weight, chest thickness, heights, BMI and number of patients

Hospital	HSP1	HSP2	HSP3	HSP4
Age(year)	47.6(22 – 88)	43.2(25 – 75)	43(18 – 78)	41(18 – 66)
Weight(kg	71.6(30 – 98)	65.4(36 – 98)	58.0(30 –89)	66.0(40 – 95)
Chest thickness(cm)	23(10 – 30)	18(10 – 30)	20(14 – 29)	22(14 – 30)
Height(m)	1.70(1.53-1.89)	1.60(1.40-1.85)	1.60(1.40 - 1.90)	1.70(1.40 – 1.85)
BMI(kg/m^2)	24.7(12.8-33.9)	24.8(15.6-44.1)	22.3(13.3-30.8)	24.6(13.2 – 43.4)
No of	25	25	25	25

Table 2: Average (range) of exposure factors and optical density associated with the factors

Examination/ Projection	Hospital	Potential (kVp)	Exposure setting (mAs)	Source to skin distance(SSD)	Optical Density (OD)
Chest PA/AP	HSP1	55 (53-58)	5.4 (4-6.3)	125 (100-140)	0.72 (0.42 – 1.20)
	HSP2	67 (55-80)	34.0 (32-40)	131(120-140)	0.94 (0.54 – 1.21)
	HSP3	62 (55-70)	16	130 (120-140)	0.75 (0.39 – 1.20)
	HSP4	73 (60-85)	3.5 (3.2-4.0)	89 (75-99)	0.88 (0.54 – 1.32)

Table 3: Exposure factors, measured dose and optical density of film

Hospital	kVp	mAs	Measured Skin Dose (mGy) (Mean±SE)	Optical Density (OD)	Image Quality(Accepted or Not)
HSP1	55	5.4	0.06±0.00	0.72	Accepted
HSP2	67	34	0.47±0.01	0.94	Accepted
HSP3	62	16	0.25±0.01	0.75	Accepted
HSP4	73	3.5	0.14±0.00	0.88	Accepted

Table 4: Exposure factors, calculated dose and optical density of film

Hospital	kVp	mAs	Calculated Skin Dose (mGy) (Mean±SE)	Optical Density (OD)	Image Quality(Accepted or Not)
HSP1	55	5.4	0.07±0.00	0.72	Accepted
HSP2	67	34	0.46±0.01	0.94	Accepted
HSP3	62	16	0.24±0.01	0.75	Accepted
HSP4	73	3.5	0.13±0.01	0.88	Accepted

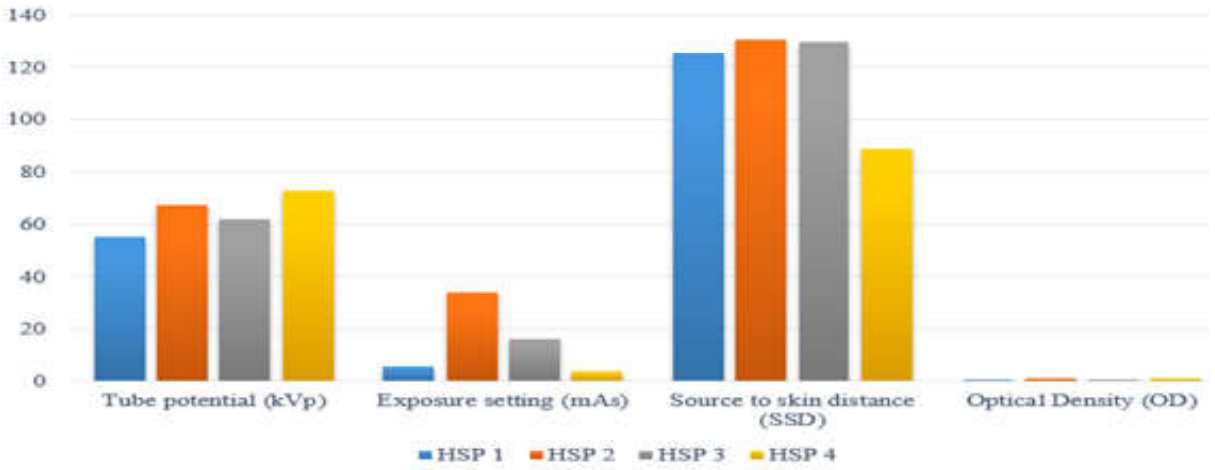

Figure 1. Illustration of tube potential (kVp), exposure setting (mAs), source to skin distance (SSD) andthe associated optical density

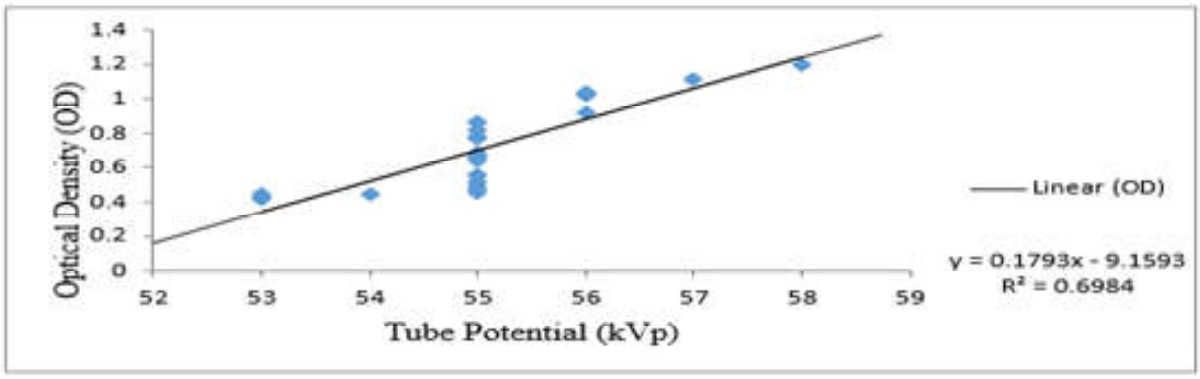

Figure 2. Graph of optical density (OD) versus tube potential (kVp) for HSP_1

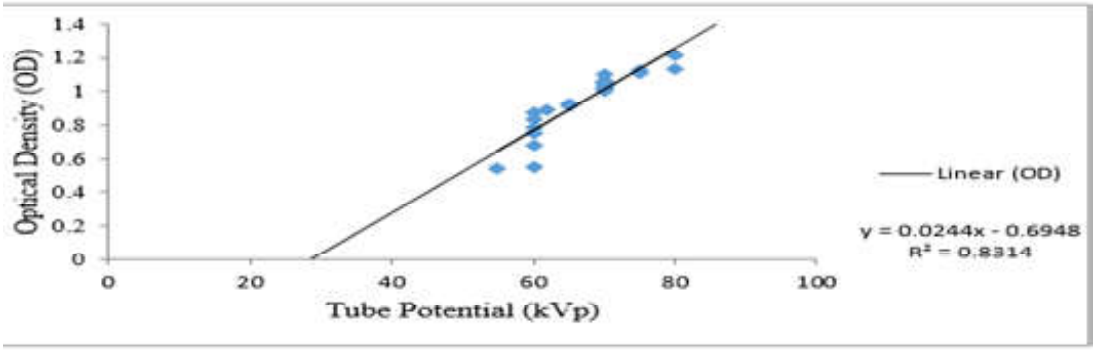

Figure 3. Graph of optical density (OD) versus tube potential (kVp) for HSP_2

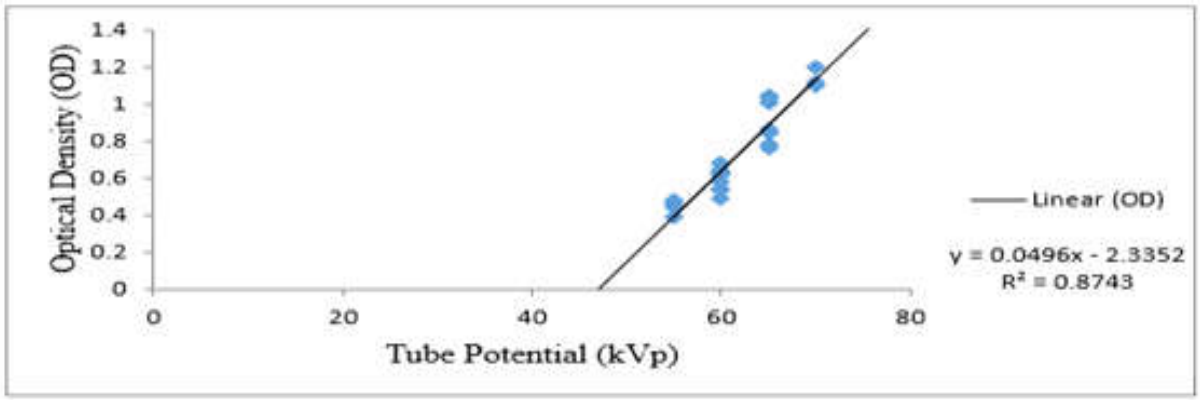

Figure 4. Graph of optical density (OD) versus tube potential (kVp) for HSP_3

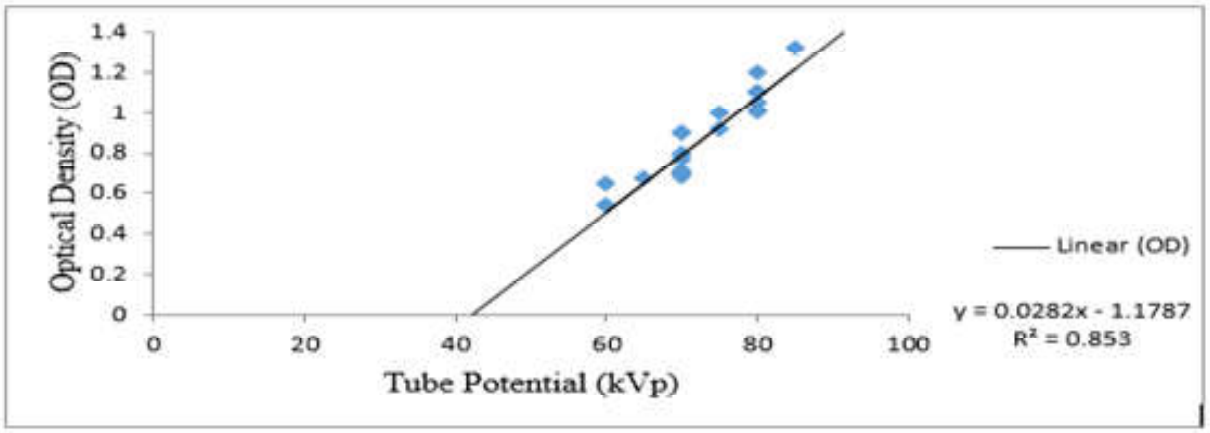

Figure 5. Graph of optical density (OD) versus tube potential (kVp) for HSP_4

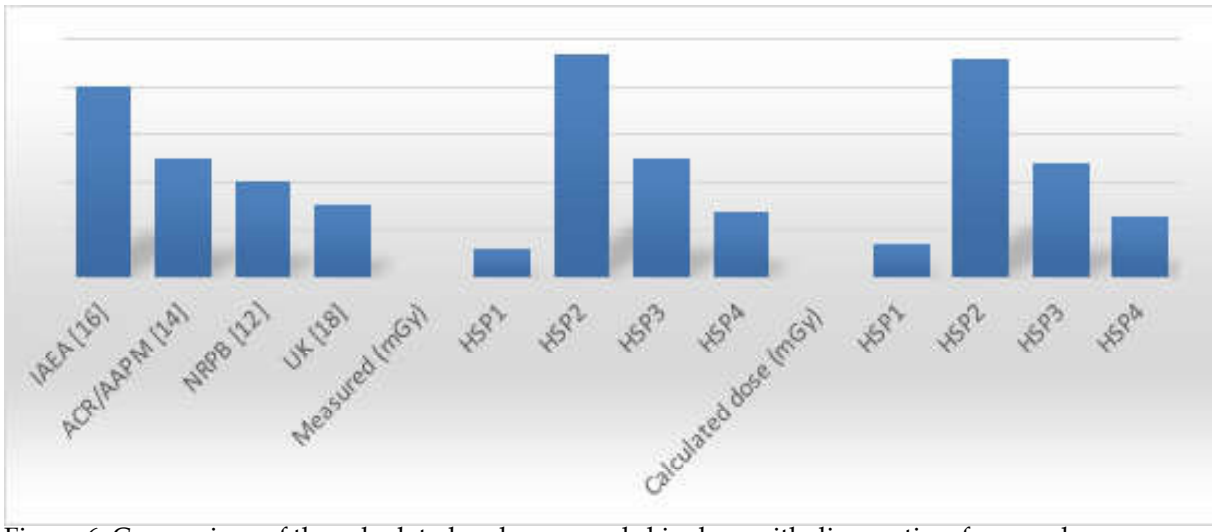

Figure 6. Comparison of the calculated and measured skin dose with diagnostic reference dose

Figure 1 shows the exposure factors and optical densities associated with the factors. This reveals that in HSP1, 55 kVp and 5.4 mAs produced image of optical density of 0.72 OD, in HSP2, 67 kVp and 34 mAs produced image of 0.94 OD, in HSP3, 62 kVp and 16 mAs produced 0.72 OD and in HSP4, 73 kVp and 3.5 mAs produced image of 0.88 OD. High optical density is recorded in HSP2 which is due to high mAs and within the useful OD range of approximately 0.5 to 1.25 OD [18]. The image quality in these hospitals was accepted since they are within the useful range of OD. Image or

radiographic quality is the fidelity with which the anatomic structure being examined is imaged on radiograph. In this study, the optimal optical density (OOD) includes 0.72 OD, 0.94 OD, 0.75 OD and 0.88 OD for HSP1, HSP2, HSP3 and HSP4 respectively.

Figure 2-5 shows the relationship between optical density and tube potential (kVp) which is obtained from linear path of the graph of optical density against tube potential (kVp). These results show that as the tube potential (kVp) increases, optical density also increases, which is an indication that tube potential (kVp) is a contributing factor to optical density.

The average measured dose 0.23 mGy and average calculated dose 0.225 mGy are determined using equations (1) and (2). The 0.5% difference of the measured dose and calculated dose is evaluated using equation (3).

The comparison of the calculated dose and measured dose with the diagnostic reference levels is presented in Figure7.The measured dose in HSP1 is 19% lower than the reference dose by ACR/AAPM 2014 [14], 34% lower than reference dose by IAEA,2001 [20], 14% lower than reference dose by NRPB 2002[19]and 9% lower than the reference dose by UK, 2010 [18]. This means that, the measured dose is below the reference dose which by implication, the radiation dose to patients in this hospital is optimised and the risk to workers is minimal. The measured dose in HSP2 is 22% higher than the reference dose by ACR/AAPM 2014 [14], 7% higher than the reference dose by IAEA,2001 [20], 27% higher than the reference dose by NRPB 2002[19] and 32% higher than the reference dose by UK 2010[18]. The disparity here is due to higher mAs, higher body mass index and lower kV which is an indication that patients in this hospital received higher dose which poses health hazards on the patients and the workers. In HSP3, the measured dose agrees with the reference dose by ACR/AAPM 2014 [14], 16% above the reference dose by IAEA, 2001 [20], 4% above the reference dose by NRPB 2002 and 10% above the reference dose by UK 2010. This is as a result of inconsistent factors and in HSP4, the measured dose is 11% lower than the reference dose by ACR/AAPM 2014 [14], 26% lower than reference dose by IAEA, 2001[20], 6% lower than reference dose by NRPB,2002 [19]and 1% lower than reference dose by UK 2010 [18]. The reasons for these differences are as due to lower mAs and higher kV. Similarly, the calculated dose in HSP1 is 18% lower than the reference dose by ACR/AAPM 2014, 33% lower than reference dose by IAEA, 2001, 13% lower than reference dose by NRPB 2002 and 8% lower than the reference dose by UK, 2010. This means that, the calculated doses are below the reference doses and as such the radiation dose to patients in this hospital is optimised and the risk to workers is minimal. In HSP2, the calculated dose is 21% higher than the reference dose by ACR/AAPM 2014, 6% higher than the reference dose by IAEA, 2001, 26% higher than the reference dose by NRPB 2002 and 31% higher than the reference dose by UK 2010. The disparity here is due to higher mAs, higher body mass index and lower kV which is an indication that patients in this hospital received higher dose which poses health hazards on the patients and the workers. In HSP3, the calculated dose is below ACR/AAPM 2014 by 1%, below IAEA, 2001by 16%, above NRPB 2002 by 4% and above UK 2010 by 9%. This could be as a result of inconsistent factors. the calculated dose of HSP4 is 12% lower than the reference dose by ACR/ AAPM 2014, 37% lower than the reference dose by IAEA, 2001, 7% lower than the reference dose by NRPB 2002 and 2% lower than the reference dose by UK 2010. The reasons for these differences are as a result of lower mAs and higher kV.

Conclusion

The investigation of image quality dependence on exposure factors is presented. From the result, the optical density in this study ranges from 0.72 ODto 0.94OD. The optical density is within the useful range of 0.5 to 1.25. However, HSP2 recorded high optical density when compared with HSP1, HSP3 and HSP4. Nonetheless, the results of this study conforms with useful optical

density and with appropriate exposure factors, this produces optimal dose to patients and good image quality. Based on these findings,calculated and measured skin doses are very close to each other, calculated skin dose can therefore be used to monitor patient dose in our hospitals.

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