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Assessment of X-Ray Beam Collimation Practice and Light Beam Diaphragm Alignment in Gombe State, Nigeria

***Mohammed Anas[1], Nzotta C.C[2], Bappah S. Yahaya[1].**
[1]Radiology Department,
State Specialist Hospital Gombe,
Gombe State.

[2]Department of Radiography and Radiological sciences,
College of Health Science and Technology,
Nnamdi Azikiwe University, Nnewi Campus,
Anambara State.

Email: anas.mohammed202020@gmail.com

Abstract
The radiological medical practitioner is responsible for ensuring that the radiological procedure provides images adequate for diagnosis and treatment while keeping the radiation dose as low as reasonably achievable. The objective of this study is to assess x-ray beam collimation by carrying some quality control test on the x-ray machines. A retrospective cross-sectional study involving a total of 100 radiographs retrieved from the film achieve of six hospitals were selected and evaluated based on x-ray beam collimation observed on the radiographs and presence of silver lines was used as evidence of collimation. Skull, chest, abdominal and lumbo-sacral spines radiographs were chosen because of their proximity to radio- sensitive organs in the body. Collimation was considered adequate if 3 or 4 side clear edges were noted on an appropriate film size for the study. The LBD misalignment test was carried out by placing a 35 x 43 cm cassette loaded with unexposed film on the x-ray table under the light beam diaphragm and the x-ray tube head adjusted to maintain an FFD of 90 cm. Eight rounded shaped coins were placed at the edges of the light and a lead marker placed at the center of the field to indicate the centering point. Another marker was placed at one end to indicate the orientation of the misalignment. Two separate exposures were made with the field size of the light beam selected to fit a 20x20 cm size and 15x10 cm. The film was processed and evaluated. Result showed 10%, 23%, 51%, 14%, 21% and 7% for A, B, C, D, E and F respectively has 3 and 4 sided evidence of x-ray beam collimation while 75%, 71%, 43%, 76%, 68% and 84% of the radiographs evaluated in the same facilities showed evidence of 1 and 2 sided x-ray beam collimation. This study revealed that facility F has the highest number of x-ray films with inadequate collimation 93 (93%), while facility C has the highest number of x-ray films with adequate (3 & 4 sided) collimation 51% while lumbosacral x-rays showed the highest percentage of poor beam collimation 88.7%with respect to different parts of the body.

Keywords: Radiation protection, Optimization, X-Ray collimation

**Author for Correspondence*

INTRODUCTION

Optimization of protection can be achieved by optimizing the procedure to administer a radiation dose which is as low as reasonably achievable (ALARA), so as to derive maximum diagnostic information with minimum discomfort to the patient (Nkubli *et al.,* 2017; Do, 2016). The radiological medical practitioner is responsible for ensuring that the radiological procedure provides images adequate for diagnosis and treatment while keeping the radiation dose as low as reasonably achievable, a concept designated as optimization by the ICRP (ICRP, 2007).The reduction of radiation dose to the patient and effect of secondary radiation on the image contrast is achieved by use of x-ray beam collimators. Collimators are devices that restrict the primary x-ray beam to the area of interest. The larger the area covered by primary x-ray beam, the greater the scattered radiation produced. Scattered radiation must be minimized because they increase radiation dose and add to film darkening thus reducing visualization of details. ALARA and ORP (Optimization of Radiation Protection) are concepts of the ICRP and the NCRP. The history of the ALARA concept is traced back to the Manhattan project of World War-II that radiation exposures are kept at lowest possible level (Eze *et al.,* 2013; Eze & Okaro 2004). This means that all radiation exposures to patients and personnel are to be kept as low as possible while still obtaining the accurate diagnostic information needed from the procedure. ALARA recognizes that there will always be some radiation exposure to patients involved in radiological procedures using ionizing radiation, but it also recognizes that these exposures can be minimized (Grover *et al.,* 2002). Dose optimization recognizes the potential risk of any radiation and emphasizes the need for appropriate dose management for all imaging procedures (Balter & Moses, 2007).

Optimization involves keeping radiation exposure to the patient and radiation workers to minimum by using appropriate exposure factors and limiting number of repeat exposures (IAEA, 2014). The radiation control of radiation workers is more structured and controlled than in the case of patients where rules and regulations are difficult to standardize. Justifying x-ray requests results in effective management of patients ensuring optimization of the cost to the benefit ratio (Triantopoulou *et al.,* 2004).Field of view (FOV) which is the size of the irradiated area, directly affects the patient dose is controlled by beam collimators such that, only the diagnostically important area is irradiated (Joseph *et al.,* 2017; Bari *et al.,* 2015). Collimation or limiting the x-ray beam to the area of interest requires use of beam restricting devices. It is good practice to collimate such that the resulting image has collimated edges on all four sides of film. A good alignment between the field of the collimator and the radiation beam, reduces the possibility of beam cut off and beam overlap, thus reduces the chances of diagnostically inadequate exposures and prevents repeat exposures (Alameen *et al.,* 2017).

The study is aimed at providing information that can serve as a baseline data to radiation protection regulatory bodies, radiology staff and hospital management in determining the level of improving the principle of radiation protection in protecting the patient, personnel and the public from unnecessary exposure to ionizing radiation.

MATERIALS AND METHODS

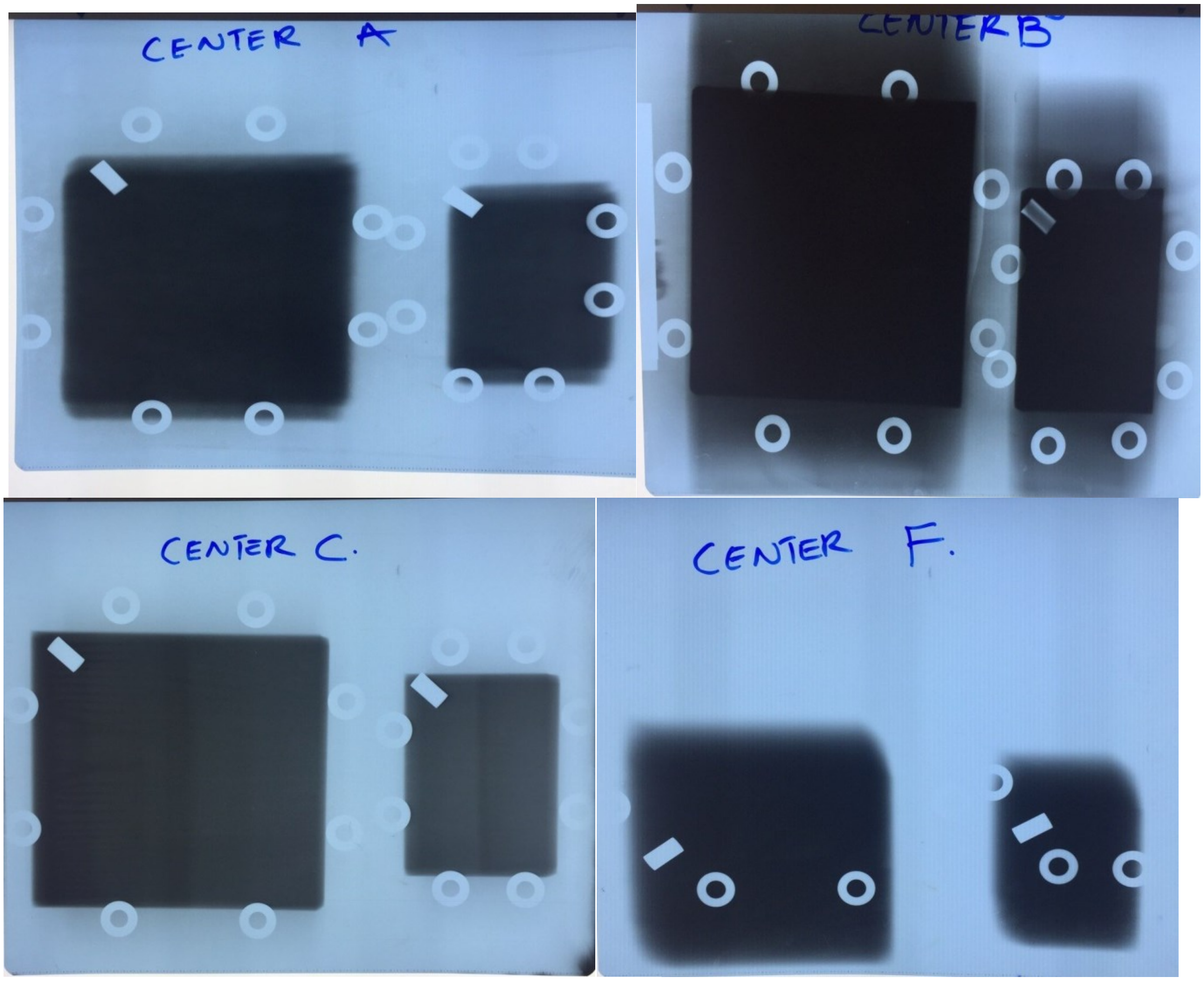
Materials
The materials used in this research study include the following;

i. X-ray machine
ii. X-ray film
iii. Film cassette
iv. Meter rule
v. Measuring tape
vi. Metal coin

Methods
The study was conducted in six private and public hospitals in Gombe state, northeastern Nigeria this covers a period of six months (from April to September, 2019).The names of the hospitals were coded as A, B, C, D, E and F for anonymity. A total of 100 radiographs were retrospectively retrieved from the radiology archive of the hospitals were randomly selected from each of the hospitals and evaluated. The evaluation was based on x-ray beam collimation observed on radiographs.

The radiographs were studied in each of the hospitals for presence of clear edges (silver lines) as evidence of collimation. Skull radiograph, chest radiographs, abdominal and lumbo- sacral spines radiographs were chosen because of the proximity of these body parts to radio- sensitive organs in the body. Collimation was considered adequate if 3 or 4 side clear edges (silver lines) were noted on an appropriate film size. For cases done with large film sizes, the measurement included the appropriate film size area with 20% allowance (Okeji *et al.,* 2009)

The LBD misalignment test were carried out by placing a 35 x 43 cm cassette loaded with unexposed film on the x-ray table under the light beam diaphragm. The x-ray tube head was adjusted to maintain a focus-to-film distance (FFD) of 90 cm. Eight rounded shaped coins was placed at the eight edges of the light and a lead marker placed at the center of the selected field to indicate the centering point. Another marker was placed at one end to indicate the orientation of the misalignment either to the right or left. An exposure factor of 60 kV and 5 mAs was selected to ensure adequate darkening of the film. Two sets of exposures were made with the field size of the light beam selected to fit into a 20x20 cm size and 15x10 cm, was determined using a meter rule and centered on the cassette. The film was thereafter processed and measurements were taken as shown below and in figure 2.1.



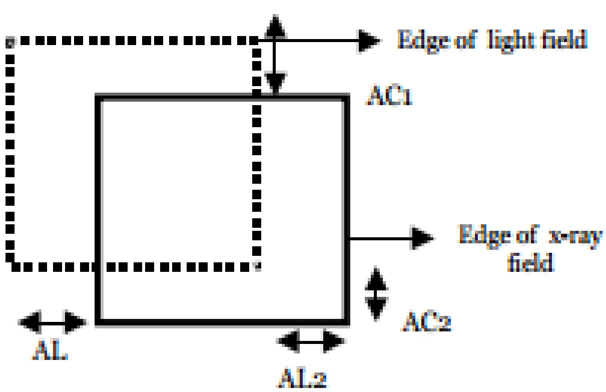


Figure 2.1: Measurement of misalignment
(Alfadoul *et al.*, 2016)

Measurement for misalignment was carried out as follows: Misalignment across the cassette (AC_1 to AC_2) and along the cassette (AL_1 to AL_2) of the film was added and recorded as total misalignment for AC and AL respectively. Percentage misalignment across (AC) and along (AL) the film was calculated by dividing the total misalignment by the focus to film distance and multiplied by 100 as shown in equation (1) and (2) (Okeji *et al.,* 2016).

$$AC\% = \frac{Total\ AC}{FFD} \times 100 \quad (1)$$

$$AL\% = \frac{Total\ AL}{FFD} \times 100 \quad (2)$$

RESULTS AND DISCUSSION

The data generated was analyzed and presented in tables based on the test performed.

Assessment of collimation

From the radiographs evaluated in the six facilities A, B, C, D, E and F with 10%, 23%, 51%, 14%, 21% and 7% showing 3 and 4 sided evidence of x-ray beam collimation respectively while 75%, 71%, 43%, 76%, 68% and 84% of the radiographs evaluated in the same facilities showed evidence of 1 and 2 sided x-ray beam collimation respectively as shown in Table 3.1.

Table 3.2 reveals that facility F has the highest number of x-ray films with inadequate collimation 93 (93%), and facility C has the highest number of x-ray films with adequate (3 & 4 sided) collimation 51 (51%).

Table 3.3 shows the x-ray beam collimation for different parts of the body with chest x-rays showing the highest percentage of poor beam collimation 326 (78.6%).

Table 3.1: Optimization of practice using x-ray beam collimation

Facility	No. of films examined	No. of cases done with correct film size	No. of cases done with incorrect film size	No. of films with no evidence of collimation	No. of films showing evidence of 1& 2 sided collimation	No. of films showing evidence of 3 & 4 sided collimation
A	100	48 (48%)	52 (52%)	15 (15%)	75 (75%)	10 (10%)
B	100	36 (36%)	64 (64%)	6 (6%)	71 (71%)	23 (23%)
C	100	71 (71%)	29 (29%)	6 (6%)	43 (43%)	51 (51%)
D	100	62(62%)	38 (38%)	10 (10%)	76 (76%)	14 (14%)
E	100	74(74%)	26 (26%)	11 (11%)	68 (68%)	21 (21%)
F	100	55(55%)	45 (45%)	9 (9%)	84 (84%)	7 (7%)

Table 3.2: X-ray beam collimation practice

Facility	Number of films examined	Number of cases done with correct film size	Number of film showing evidence of 3 & 4 sided collimation	Number of films with inadequate collimation
A	100	48 (48%)	10 (10%)	90 (90%)
B	100	36 (36%)	23 (23%)	77 (77%)
C	100	71 (71%)	51 (51%)	49 (49%)
D	100	62 (62%)	14 (14%)	86 (86%)
E	100	74 (74%)	21 (21%)	79 (79%)
F	100	55 (55%)	7 (7%)	93 (93%)

Table 3.3: X-ray beam collimation for different body region across the facilities

Body Region	**Total**	**Number of films with adequate collimation**	**Number of films with inadequate collimation**
Abdomen	62	12 (19.4%)	50 (80.6%)
Chest	415	89 (21.4%)	326 (78.6%)
Lumbosacral	71	8 (11.3%)	83 (88.7%)
Skull	52	17 (32.7%)	35 (67.3%)

This study revealed that facility F has the highest number of x-ray films with inadequate collimation 93 (93%), while facility C has the highest number of x-ray films with adequate (3 & 4 sided) collimation 51 (51%). This is similar to a study conducted by Okeji *et al.*, 2009, on radiation exposure from diagnostic radiography: an assessment of x-ray beam collimation practice in some Nigerian Hospitals where 52% and 59% of the radiographs evaluated in the teaching hospitals and specialist hospitals respectively showed inadequate beam collimation.

From the result of the questionnaire administered regarding x-ray beam collimation practice, 73.1% (n= 19) of the participants consider their x-ray beam collimation practice as inadequate, while 26.9% (n=7) of the respondents consider it as adequate. The respondents that considered it inadequate, classify the cause of inadequacy into x-ray beam misalignment 42.3% (n=11) and faulty collimators 30.8% (n=8) which is in tandem with Abu-Draz, 2009 and Adejumo *et al.*, 2012. The misalignment may be attributed to shift in light bulb position, shift in mirror angle or shift of LBD position on the tube head. The faults may go undetected due to absence of routine quality assurance tests in all the centers.

Furthermore, concerning x-ray beam collimation for different parts of the body, lumbo-sacral x-rays showed the highest percentage of poor beam collimation 83 (88.7%) which is similar to the research conducted by Okeji *et al.,* 2009, on x-ray beam collimation for different parts of the body, lumbosacral x-rays showed the highest percentage of poor beam collimation (55.6%).However, this study presents a higher percentage of inadequacy in collimation. This can be due to differences in the study location which would contribute in variation of most frequently performed procedures.

Light Beam Misalignment test

Table 3.4 shows the result of quality assurance test to establish the status of light beam misalignment in the six radiology centers as part of a tool to assess optimization of practice. The table showed that the highest percentage value of misalignment in AC (15.8%) was at facility F while the highest percentage value of misalignment in AL (4.1%)is also seen at the same facility. The result also showed that 66.6% of the facilities showed negative misalignment across the cassette, while 33.3% showed positive misalignment across the cassette. Positive and negative misalignment along the cassette accounts for 66.6 and 33.3% respectively.

Table 3.4: Light beam misalignment test conducted in the facilities for AC and AL

Facility	Field size (cm x cm)	AC (In %)	AL (In %)
A	20 X 20	2.8	2.5
	15 X 10	2.6	3.5
B	20 X 20	2.0	0.8
	15 X 10	1.8	1.0
C	20 X 20	1.1	0.5
	15 X 10	1.0	0.6
D	20 X 20	2.2	1.2
	15 X 10	2.0	1.2
E	20 X 20	5.7	0.8
	15 X 10	5.8	0.8
F	20 X 20	15.6	4.1
	15 X 10	15.8	4.1

This study revealed the result of quality assurance test to establish the status of light beam misalignment in the six radiology centers as part of a tool to asses' optimization of practice', positive and negative misalignment along the cassette accounts for 66.6% and 33.3% respectively, in line with Ayoob *et al.,* 2015 and Brenner and Hricak 2010. Facility F has the highest percentage value of misalignment in AC and AL. This is contrary to a study conducted by Adhikari *et al.,* 2012 and Okeji *et al.,* 2016 on the status of light beam diaphragm and its implication in radiation protection; they later discovered that from the 19 x-ray equipment on which LBDs misalignment test was conducted, 79% showed positive misalignment beyond the normal limit of 2 % while 21 % showed beam alignment within the normal limits. The misalignment ranged from 0.8cm to 10.6cm and 0.4cm to5.8cm across and along the cassette respectively. The major effects of misalignment are poor quality diagnostic images and improper radiation exposure to unnecessary body organs during a given radiological procedure.

A study conducted by Alfadoul *et al.,* on Assessment of Collimator Accuracy for X-Ray Machines in Khartoum State to check the beam alignment and collimator accuracy of x-ray equipment in diagnostic centers in Khartoum, using a quality assurance test method, Results showed that the greatest misalignments were 4.3% and 1.5% along the cassette and across the cassette respectively. On the other hand, the least misalignments across and along the cassettes were 0.4% and 0.3% respectively.

CONCLUSION

There is significant evidence of inadequate x-ray beam collimation base on the study outcome with only one hospital having up to 50% (Hospital C), which indicate poor optimization and hence, subjecting the patient and personnel to unnecessary radiation exposures potential of causing radiation induced effects on the body. The facility with least evidence of collimation(Hospital F) has 7% of total examined radiographs. Generally, lumbo-sacral x-rays were the radiographs with the highest percentage of inadequate collimation. These alarming scenarios can be minimized through the implementation of constant quality control and quality assurance programs in all the hospitals and should be monitored by the regulatory authorities.

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