STUDIES ON THE STATUS OF LIGHT BEAM DIAPHRAGMS *IN CALABAR*: *EFFECTS AND IMPLICATIONS ON RADIATION PROTECTION*

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ABSTRACT
The status of Light Beam diaphragms (LDBs) in Calabar, Cross River State were studied using a quality assurance test method to check the beam alignment and collimator accuracy of x-ray equipment in diagnostic centers in Calabar. Results showed an increase in misalignment of the x-ray field and light field with an increase in the light field. The greatest misalignments were 7.9% and 5.6% along the cassette and across the cassette respectively. On the other hand, the least misalignments across and along the cassettes were 0.3% and 1.1% respectively. This indicates an unacceptable status of LBDs in Calabar, and the implication of this in image quality and radiation protection is noted as an undesirable development as it evidently contributes an unwelcome quantity to the radiation dose to the patient population.

ABSTRAIT
Le statut des diaphragmes de faisceau lumineux (LDBs) dans Calabar, L'état en travers de fleuve ont été étudiés en utilisant une méthode d'essai de garantie de la qualité pour verifier l'alignement de faisceau et l'exactitude de collimateur de l'équipement de rayon X aux centres de diagnostic dans Calabar. Les résultats ont montré une augmentation de la deviation d'alignement du champ de rayon X et du champ de lumière avec une augmentation dans le domaine léger. Les plus grandes déviations d'alignement étaient 7.9% et 5.6% le long de la cassette et à travers la cassette respectivement. D'autre part, les moindres déviations d'alignement à travers et le long des cassettes étaient 0.3% et 1.1% respectivement. Ceci indique un statut inacceptable de LBDs dans Calabar, et l'implication de ceci en qualité d'image et radioprotection est notée pendant qu'un développement indésirable pendant qu'elle contribue évidemment une quantité fâcheuse à la dose de rayonnement à la population patiente.

INTRODUCTION

The field of medical imaging provides opportunities for a physical foundation in the understanding of the proper utilization of instruments and equipment applied in the imaging, diagnosis and treatment of human diseases, and how imaging scientists can be active participants in enhancing the opportunities offered by their use. It is incumbent upon the practitioners of medical imaging to understand the basic principles employed in instruments that image human anatomy and to be aware of any undesirable conditions that may arise from their use. Practical use and function of diagnostic x-ray equipment is affected inevitably in its construction by the need to employ an x-ray beam which is optimally useful in production of images, with minimum input from deleterious influences of secondary radiation which often contributes to high patient doses.[5]

Therefore, 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. The effectiveness of collimation by these beam collimators is strongly dependent on the accuracy with which the x-ray beam is centered to the anatomical area of interest. An infinite variety of field shapes and sizes give the opportunity of optimum protection and image contrast in all situations enhancing quality assurance.[3]

This however, fails to be the case when changes in the features of these collimators occur, providing observable difference in its function. It is therefore useful to consider the consequences of an undetected error which occurs as a result of misaligned radiolucent light reflecting mirrors or other sources of error in a light beam diaphragm, which forms part of modern x-ray equipment and functions in providing a visible demonstration of beam centering and the field shape and size.[5,3] Knowledge of these possible errors enhances the applicability in the patient radiation dose control.

The limitations of a light beam diaphragm become obvious when the lamp fails or the mirror is dislodged from its precise position. Even after wise precautions are carried out to lessen these failures, they could still occur hence regular checks are recommended after repairs, or maintenance work on the x-ray equipment for quality assurance.[9,3] This is however not a common practice in the area under study, where little or no quality assurance has been practiced or reported.

Occasionally, the mirror of a light beam diaphragm goes out of alignment so that the light and x-ray fields no longer coincide[4,3]. This usually leads to problems of geometry in the emerging beam of radiation with the attendant effects on image quality and even radiation dose to the patient.

This research work is aimed at obtaining information as to the status of light beam diaphragms in radiographic equipment at used in Calabar. It will also showcase, though inadvertently, the position of diagnostic centers with regards to quality assurance, as well as highlight and give insight into the effects of such status on image quality and patient dose obtainable in the area under study. Adequate justification for this study is found in the need for the practice of quality control.[1] and assurance in this area. A yield of consistent quality radiographs will translate into considerable positive cost containments.

This study will encourage proper handling of the x-ray tube and the light beam diaphragm, so as to keep the device operating accurately thereby enhancing its durability. The study is expected to stimulate quality assurance studies and programmes which will go a long way in improving radiographic services, equipment handling and patient radiation protection since quality assurance serves as the yardstick for evaluation of general standard of practice.[8]

It has been reported[5] and as is common in daily radiographic practice, that radiographers and other users of the final product of x-ray images often encounter radiographs, which are off-centered even when proper radiographic techniques are applied. The presence of this condition, which may be due to misalignment of the light field and the x-ray field, can be proved by means of quality control tests[5,9]. Perfect alignment exists when the light field coincides with the x-ray field.[9] Loss of alignment could be attributed to degree of utility, susceptibility to knocks and other mechanical problems, with the loss of accuracy increasing with increase in field size.[2,9] This makes quality assurance programmes more useful in our imaging departments, either following fresh installations[2] or repair and maintenance operations[3]. This will ensure the area covered by the light field corresponds to the field of irradiation by x-rays.

The relevance of this light and x-ray field identity to radiation protection is supported by data from the 1970 x-ray exposure study of the United States (US) public health service, which showed that genetically significant dose could be reduced by 21% if the beam size were reduced to the film size[6] with such reduction also reducing the amount of scatter radiation[2], thereby improving image detail and contrast. All radiation outside the area of interest contributes nothing to diagnostic detail and results in unnecessary irradiation, hence the need to ensure light beam diaphragm accuracy to the radiation field.

Materials and Method

X-ray imaging and diagnostic centers (within Calabar) with equipment having light beam diaphragms and possessing variable collimators, radiographic cassettes (35 x 35 cm, 24 x 30 cm, 18 x 24 cm); radiographic films of corresponding sizes, 9 coins, a meter rule; film processing equipment (manual) and a stop watch were employed for this work.

An 18 x 24 cm cassette pre-loaded with corresponding film size in the darkroom was placed on the x-ray couch under the light beam diaphragm, which was opened so as to visually observe the light field. The focus to film distance was maintained at 90 cm. The film was placed such that the light beam was focused at the center of the cassette.

Nine (9) coins were positioned as shown in Figure 2 below, to correspond with the cross lines (shown as dotted or broken lines) of the light beam diaphragm placing a legend at the corner of the cassette for identification of the exposure number and the diagnostic center.

This arrangement was then exposed to x-radiation using exposure factors of 60kV, 6mAs (50mA, 012 seconds) and processed for images of the alignment of the light field to the x-ray field.

The light beam was gradually increased thereafter until a field size of 15.2 x 15.2 cm was attained. The measurements were made with the meter rule. That is, exposures were made for light field sizes of 20.3 x 20.3 cm; 25.3 x 25.3 cm; and 30.3 x 30.3 cm.

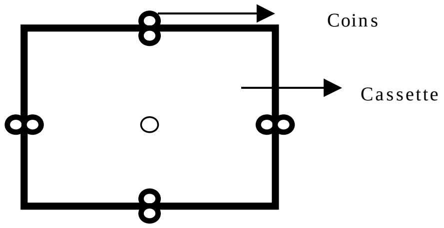

Figure 1: Arrangement of experimental set up for exposure

This was carried out in all the centers under study and all the films collected and manually processed, and dried. From the distances between the light field (the point at which the coins made contact with each other) and the x-ray fields for all coin locations for each film were measured and recorded as AC1, AC2, AL1 and AL2 respectively, as shown in the figure (Fig. 2) below.

AC1 and AC2 = Misalignment across the cassette for two positions in cm

AL1 and AL2 = Misalignment along the cassette for two positions in cm.

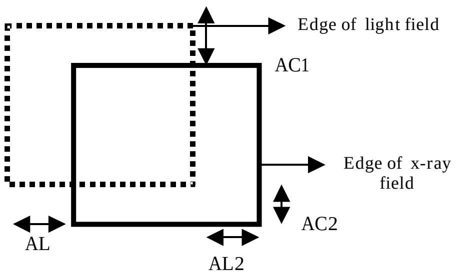

Figure 2: Method of Measurement of Misalignment

Misalignments across the cassette (AC1 and AC2) and that along the cassette (AL1 and AL2) were added and recorded as total misalignment TOT AC and TOT AL, as follows:

AC1 + AC2 = TOT AC (total misalignment across the cassette)

AL1 + AL2 = TOT AL (total misalignment along the cassette)

To determine the % misalignment of light versus x-ray field along and across the cassette, the total misalignment was divided by the focus to film distance (90 cm) and multiplied by 100 as shown.

$$\frac{\text{TOT AC}}{90} \times 100 = \text{\% misalignment of light vs x-ray field across cassette}$$

$$\frac{\text{TOT AL}}{90} \times 100 = \text{\% misalignment of light vs x-ray field along cassette}$$

Results

The results of the study of the status of light beam diaphragms to determine the total misalignment of the light and x-ray field, are presented in Tables 1 6, for each of the centers covered coded as XR 1 to XR 5, respectively.

(1) The light and x-ray field % misalignment does not exceed 2% of the focus to film distance (FFD) in either the length or the width of the film[9,3].

(2) The percentage differences greater than 2% in either direction were considered abnormal requiring remedy.

Discussion

The light beam diaphragm basically provides a means of offering a variety of field sizes and shapes, giving an opportunity of optimum radiation protection and image contrast[3]. This specific function of the light beam diaphragm makes it a vital accessory in the x-ray equipment as it promotes radiation protection.

The limitations of a light beam diaphragm become obvious when the lamp fails or the mirror is dislodged from its precise position. The recommendation of regular checks after repairs or maintenance work on the x-ray equipment for quality assurance is not a common practice in these parts of the world as little or no quality has been reported.

A possible explanation of the cause of the misalignment could be a deviation from the 45°C angle, at which the radiolucent mirror is positioned so as to obtain full and proper alignment between the light field and the x-ray field.[3] Any misalignment due to deviation from this angle readily produces a change in the direction of the two fields. When there is misalignment in a light beam diaphragm, light, which is reflected towards the diaphragm leaves cannot pass through to the film as a result of the closing edges of the diaphragm leaves, which overlap as the aperture is closed. As the field size is increased, some areas of the object which are not exposed by the light field could be exposed to the x-radiation field, resulting in the production of scatter radiation and as a result, poor image contrast, which could necessitate repeated exposures with higher doses to the patients. Such misalignment of the x-ray and light fields must not exceed 2% of the FFD in either length or width of the film[9]. A % difference greater than 2% in either direction is considered abnormal, requiring remedy.

Results of the experiments which focused on beam alignment and collimator accuracy, has shown evidently that there is need for prompt quality assurance programmes in the area of study, since most of the light beam diaphragms were unable to maintain the relationship between the light field and the x-ray field.

The values of percentage misalignment obtained were compared with the confirming criteria based on the EPA (1975) criteria that the percentage misalignment of the x-ray and light fields must not exceed 2%. This is without prejudice to the school of thought that allows only a variation of 1%.[9]

The results of this work reveal that values exceeding the allowed 2% were obtained in some centers, while others were closely approaching the mark. There is also increase in total misalignment with increase in field size, though it is obviously only the light field that is altered. This shift in the light field leaves the x-ray field unaffected and in its normal path. This manifests on radiographs as geometric cut-off, sometimes with sufficient loss of information to warrant repeats and therefore increase the incidence of radiation effects.[10]

The implication of these results is that the status of light beam diaphragms in the study area could be classified as poor. It follows therefore that misalignment of the light beam diaphragm produces geometric cut-off, which leads in many cases to repeated exposures with the attendant increase in the patient radiation dose.

Conclusion

Light beam diaphragms in the area under study are in a state that portents danger with respect to increased radiation dose to the patient as a result of repeats emanating from losses due to geometric cut-off. There is therefore need for urgent corrective measures to be adopted, and subsequently, frequent and regular quality assurance checks must be carried out as a routine or after servicing or maintenance of the units (e.g. changing of the light bulb). Besides, some form of legislation that would ensure the phasing out of x-ray equipment older than ten (10) years should be enacted, since these showed very marked deviation from acceptable values. Such legislation should also cover monitoring of, and dose regulation in all radiodiagnostic centers. There is need for an improved maintenance culture among radiography equipment users.

Table 1: Total misalignments measurements for XR 1

Field Sizes (cm x cm)	Measurements of misalignment		
	Direction	Measurement (cm)	Total (cm)
15.2 x 15.2	AC1 AC2	0.80 0.80	1.60
	Al1 Al2	1.80 1.70	3.50
20.3 x 20.3	AC1 AC2	0.70 1.00	1.70
	Al1 Al2	2.40 1.80	4.20
25.3 x 25.3	AC1 AC2	0.90 1.00	1.90
	Al1 AL2	2.90 1.40	4.30

Table 2: Measurements of misalignment for XR 2

Field Sizes (cm x cm)	Measurements of misalignment		
	Direction	Measurement (cm)	Total (cm)
15.2 x 15.2	AC1 AC2	0.40 0.80	1.20
	AL1 Al2	0.40 0.80	1.20
20.3 x 20.3	AC1 AC2	0.60 0.90	1.50
	AL1 Al2	0.60 0.70	1.30
25.3 x 25.3	AC1 AC2	0.10 0.50	0.30
	AL1 Al2	0.80 0.50	1.30
30.3 x 30.3	AC1 AC2	0.10 0.20	0.30
	Al1 Al2	0.80 0.50	1.30

Table 3: Measurements of misalignments for XR 3

Field Sizes (cm x cm)	Measurements of misalignment		
	Direction	Measurement (cm)	Total (cm)
15.2 x 15.2	AC1 AC2	0.90 2.20	3.10
	AL1 Al2	1.50 3.10	4.60
20.3 x 20.3	AC1 AC2	1.10 2.20	3.30
	AL1 Al2	1.90 3.30	4.90
25.3 x 25.3	AC1 AC2	0.80 3.10	3.90
	AL1 Al2	2.10 3.10	5.20
30.3 x 30.3	AC1 AC2	1.40 3.60	5.00
	Al1 Al2	3.80 3.30	7.10

Table 4: Measurements of misalignment for XR 4

Field Sizes (cm x cm)	Measurements of misalignment		
	Direction	Measurement (cm)	Total (cm)
15.2 x 15.2	AC1 AC2	0.30 1.60	1.90
	Al1 Al2	0.90 0.90	1.80
20.3 x 20.3	AC1 AC2	0.30 0.60	0.90
	Al1 Al2	0.60 0.50	1.10
25.3 x 25.3	AC1 AC2	0.30 0.40	0.70
	Al1 AL2	0.60 0.50	1.10

Table 5: Measurements of misalignment for XR 5

Field Sizes (cm x cm)	Measurements of misalignment		
	Direction	Measurement (cm)	Total (cm)
15.2 x 15.2	AC1 AC2	0.20 0.20	0.40
	AL1 Al2	0.70 0.40	1.10
20.3 x 20.3	AC1 AC2	0.50 0.50	1.00
	AL1 Al2	0.70 0.30	1.00
25.3 x 25.3	AC1 AC2	0.90 0.80	1.70
	AL1 Al2	0.80 0.60	1.40
30.3 x 30.3	AC1 AC2	0.80 0.90	1.70
	Al1 Al2	0.80 0.90	1.70

Table 6: Summary of Results with % values for AC and AL

Diagnostic Centers	Field size (cm sq.)	AL %	AC %
XR 1	15.2 x 15.2	3.90	1.80
	20.3 x 20.3	4.70	1.90
	25.3 x 25.3	4.80	2.10
XR 2	15.2 x 15.2	1.30	1.30
	20.3 x 20.3	1.40	1.70
	25.3 x 25.3	1.40	1.70
	30.3 x 30.3	1.40	0.30
XR 3	15.2 x 15.2	5.10	3.40
	20.3 x 20.3	5.40	3.70
	25.3 x 25.3	5.80	4.30
	30.3 x 30.3	7.90	5.60
XR 4	15.2 x 15.2	2.00	2.10
	20.3 x 20.3	1.20	1.00
	25.3 x 25.3	1.20	0.80
XR 5	15.2 x 15.2	1.20	0.40
	20.3 x 20.3	1.10	1.10
	25.3 x 25.3	1.60	1.90
	30.3 x 30.3	1.90	1.90

References

1. Agwu KK. Radiation Practices in Radiodiagnosis in Nigeria. West African Journal of Radiology. 1992; 2 (1): 40 45.
2. Bryan GJ. Diagnostic Radiography. 3rd ed. London, Churchill Livingstone. 1979; 398p.
3. Carter P, Paterson A, Thornton M, Hyatt A, Milne A, Pirrie J. The X-ray Tube In: Chesney's equipment for Student Radiographers. 4th Ed. London. Blackwell Science. 2003; 315p.
4. Carrol QB. Field size Limitation In: Fusch's Principles of radiographic exposure, processing and quality control. 3rd Ed. Charles C. Thomas, 1985; pp. 124 129.
5. Chesney MO, Chesney DN. X-ray Equipment for Student Radiographers. 1st Ed. Blackwell Science. 1971; 522p.
6. Coulam CM, Erikson JJ, Rollo FD, James AE. The Physical Basis of Medical Imaging. 10th ed. New York, Appleton Century Crofts. 1985; 354p
7. Environmental Protection Agency EPA (1975): radiation, www.epa.gov/radiation.
8. Ikamaise VC, Osuagwu CN, Bassey DE, Egbe NO, Chiaghanam NO, Eduwem DU, Inah GB. Assessment of Chest radiographs for Quality assurance and radiation protection. West African Journal of Radiology. (2000); 7 (1): 18 25.
9. Lloyd PJ. Accessory Equipment In: Quality Assurance workbook for radiographers and radiological Technologists. 1st Ed. Geneva, World Health Organization. 2001; Pp. 29 44.
10. Yarmonenko SP. Direct and Indirect effects of Ionizing Radiation In: Radiobiology of Humans and Animals. 1st Ed. Moscow, Mir Publishers, 1988; pp. 45 50.