World Applied Sciences Journal 34 (7): 975-978, 2016
ISSN 1818-4952

DOI: 10.5829/idosi.wasj.2016.34.7.145

Status of Light Beam Diaphragm and its Implication in Radiation Protection

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Abstract: Medical exposure accounts for 98 % of contributions from all artificial sources and contributes 20 % to the total population dose worldwide. The light beam diaphragms (LBDs) function to control the field size of x-ray beam passing through the patient onto the film thereby reducing the radiation dose to the patient and improving the image quality. The LBDs in some Government and private radiology departments/centres in Enugu State, Nigeria were assessed in order to determine their working status and possible contribution to population radiation dose. A total of 19 functional x-ray machines in 19 radio-diagnostic departments/centres were enlisted into the study. Light beam misalignment test was conducted on all the x-ray equipments in the centres using simple test kit sourced locally. A researcher-developed questionnaire was administered to the radiographers-in-charge in all the centres to elicit information among others on age of the x-ray machine, availability of test kit, conduct of light beam misalignment test and how often it was conducted. Of the 19 x-ray equipments 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 to 5.8cm across and along the cassette respectively. Most of the x-ray equipments (95%) were refurbished and older than 10 years from the date of manufacture. Also majority of the respondents reported application of collimation. Majority (74%) of the departments reported that quality assurance (QA) was being conducted periodically. However there was no evidence of QA kits in 95 % of the centres. Increase in patients' radiation dose is expected due to the LBDs misalignment in most of the hospitals studied. Concerted efforts should be made by regulatory agencies to monitor compliance with QA tests in all radio-diagnostics centres.

Key words: Light beam misalignment · Radiation protection · X-ray collimation · Film quality

INTRODUCTION

Medical exposure remains the largest artificial source of exposure of humans to ionizing radiation [1]. Medical exposure accounts for 98 % of contributions from all artificial sources and contributes 20 % to the total population dose worldwide [1]. Radiation exposure, even for low dose medical imaging procedures, has been reported to possess the potential of induction of cancer based on the linear non-threshold model [2]. Also some epidemiological studies reported that exposure to ionizing radiation increases the risks of some cancers at organ dose ranges of approximately 50–100 mSv [3]. Modern x-ray tubes are fitted with beam restrictors, which are lead shields placed near the anode of the x-ray tube and function to control the field size of x-ray beam passing through the patient onto the film. It therefore reduces the radiation dose to the patient and improves the image quality. The light beam diaphragm (LBD) is the best form of restrictor and consists of a lamp and a suitable optical mechanism to allow projection on the patient's area of interest being irradiated [4]. There should be congruence of the light field and the x-ray field, else the function and basic goals of LBD is defeated.

Effective x-ray beam collimation dependents on the status of the beam restrictor and the accuracy with which the radiographer centers to the anatomical area of interest. Situations arise where the LBD is misaligned with the x-ray beam resulting in off-centering. Off-centering is when the central ray does not pass through the anatomical area

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of interest thereby cutting off structures of interest or including unwanted anatomical areas. When this occurs the radiographer often makes such statement as "but I collimated properly" [5].

The empirical means of establishing collimator's misalignment is the LBD accuracy test. The LBD accuracy test is one of the quality assurance (QA) tests expected to be conducted every six months [6]. It is important that the light field is congruent at all times in order not to irradiate non areas of interest, larger areas of interest than desired or cutoff anatomical areas of interest. Misalignment also results in poor radiographic image due to scatter radiation. Misalignment may be caused by a shift in the light bulb inside the LBD, mirror position, collimator position on the tube or anode focal spot [7].

There is paucity of literature on light beam diaphragm accuracy test in public and private radiology centres in Enugu State. This study therefore was aimed at evaluating the status of light beam diaphragm of functional x-ray machines in Enugu State to establish possible sources of unnecessary radiation exposure to the members of the public.

Methodology: A total of 19 functional x-ray machines in 19 radio-diagnostic departments/centres were enlisted into the study. Light beam misalignment test was conducted on all the x-ray equipments in the centres by the researchers using simple test kit sourced locally. A researcher-developed questionnaire was administered to the radiographers-in-charge in all the centres to elicit information among others on age of the x-ray machine, availability of test kit, conduct of light beam misalignment test and how often it was conducted. The questionnaire was validated by three experts in the Department of Radiography and Radiological Sciences, University of Nigeria. The reliability of the instrument was conducted using test re-test and computed using Cronbach's alpha which yielded a coefficient of 0.83.

The LBD misalignment test was carried out by placing a 24 x 30 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 100 cm. Four L-shaped markers were placed at the four edges of the light and a lead marker placed at the centre of the selected field to indicate the centering point. Another marker is placed at one end to indicate the orientation of the misalignment either to the right or left (Fig. 1). An exposure factor of 60 kV and 6 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 15x15 cm size and 20x20 cm, determined using a meter rule and centered on the cassette. The film was thereafter processed and measurements taken as in Figure 2. Measurement for misalignment was carried out according to the authors [4, 6, 8]. Misalignment across (AC_1 to AC_2) and along (AL_1 to AL_2) the film were 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 below:

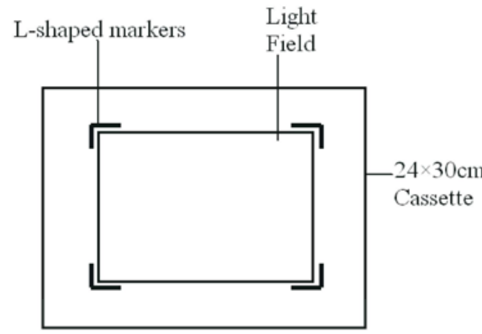

Fig. 1: Set up arrangement for misalignment test

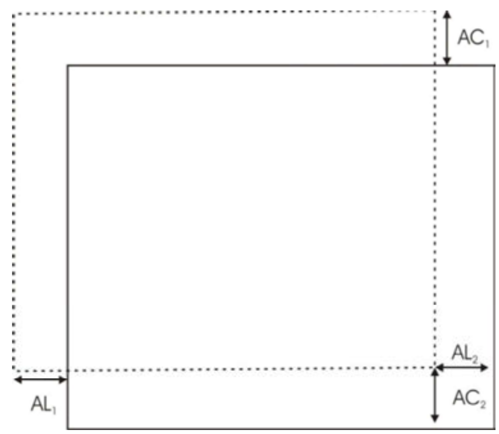

Fig 2: Measurement of misalignment

$$AC\% = \frac{\text{Total AC}}{\text{FFD}} \times 100$$

$$AL\% = \frac{\text{Total AL}}{\text{FFD}} \times 100$$

RESULTS

The result of quality assurance test to establish the status of light beam misalignment in the 19 radiology centres are presented in Table 1. The names of the hospitals were coded for anonymity.

Table 1: Results of light beam misalignment test in percentages conducted in the 19 radiology centres for AC and AL

Radiology Department	Field Size (cm× cm)	AC (in %)	AL (in %)
UNTH	15 × 15	1.5	4.1
	20 × 20	1.8	4.8
NOHE	15 × 15	3.4	1.3
	20 × 20	3.6	1.8
ESUTH	15 × 15	3.0	4.5
	20 × 20	3.2	4.8
HCE	15 × 15	2.8	1.9
	20 × 20	2.3	2.4
BRC	15 × 15	1.7	2.9
	20 × 20	3.4	4.8
LCDC	15 × 15	3.0	0.4
	20 × 20	3.5	0.6
HTOH	15 × 15	2.0	2.1
	20 × 20	2.3	2.4
NFH	15 × 15	0.8	0.7
	20 × 20	0.9	0.8
ST. MDC	15 × 15	5.0	5.5
	20 × 20	5.4	5.8
ARS	15 × 15	1.8	1.9
	20 × 20	2.0	2.2
Mc CHUKS MDC	15 × 15	2.1	0.9
	20 × 20	1.5	1.1
CMI	15 × 15	2.1	1.1
	20 × 20	3.1	1.2
BSH	15 × 15	10.0	2.4
	20 × 20	10.6	3.7
AH	15 × 15	0.8	1.7
	20 × 20	1.1	2.0
CXS	15 × 15	3.2	0.4
	20 × 20	3.2	0.7
MCH	15 × 15	1.2	1.3
	20 × 20	1.7	1.1
ENMC	15 × 15	2.7	1.8
	20 × 20	3.1	3.2
FFH	15 × 15	0.9	0.8
	20 × 20	1.1	1.2
NMDC	15 × 15	3.7	3.5
	20 × 20	4.1	4.0

Table1 showed that the highest percentage value of misalignment in AC (10.6 %) was seen at BSH while the highest percentage value of misalignment in AL (5.8 %) was seen at St. MDC.

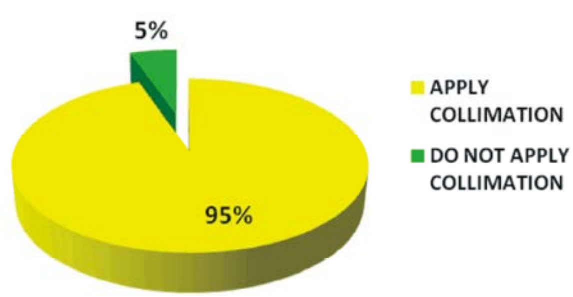

Fig. 1: Responses on collimation

DISCUSSION

The purpose of collimation is to protect the patient from unnecessary radiation by limiting the beam field to the anatomy of interest thereby reducing the volume of tissue irradiated [9]. X-ray equipment construction is guided by the need to employ x-ray beam which will produce optimally useful images, with minimum input from secondary radiation that contributes to high patients' doses [10]. The upper limit of normal for misalignment recommended is 2 cm (2 %) [11].

Of the 19 x-ray equipments 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 to 5.8cm across and along the cassette respectively. This finding is significant in view of the unnecessary radiation exposure of the population. The misalignment was attributed to shift in light bulb position, shift in mirror angle or shift of LBD position on the tube head. The faults have gone undetected due to absence of routine quality assurance tests in all the centres.

Our result differ from that of previous authors [8, 12, 13] where the light beam was incongruent with the x-ray beam in 60 %, 66.6% and 67 % of the x-ray equipments in some parts of Nigeria. The differences may be due to fewer numbers of centres surveyed by these previous authors who also conducted their study in Government owned radiology centers.

Our result showed that as the field size increases, the misalignment between the light beam and the x-ray beam increases. This is similar to the findings of some previous authors [8, 12, 14]. Also the centering point was noted to change with misalignment. There was no significant difference ($p > 0.05$) in the beam misalignment between Government and private radiology centres.

Most of the x-ray equipments (95%) were refurbished and older than 10 years from the date of manufacture.

Our result showed that majority (95%) of the departments reported practice of collimation with only one department (ENMC) that had burnt bulb for the light beam diaphragm not applying collimation (Fig 1).

Majority (74%) of the departments reported the practice of quality assurance (QA) periodically. However there was no evidence of QA kits in 95 % of the centres. The absence of QA kits may have accounted for the high number of undetected light beam misalignment in the studied centres with consequent unnecessary radiation exposure to the population.

CONCLUSION

Misalignments are acceptable at a certain level and above which the x-ray machine used should be suspended until the misalignment is corrected. When the misalignment of the x-ray beam or Bucky centre to x-ray beam is greater than 1cm (0.5cm for pediatric units), the LBD is to be adjusted but when it is greater than 3cm, the equipment should be removed from service until corrected [15]. The misalignment values acceptable vary with individual country's regulation but must be less than 2% [6, 16].

Beam alignment and collimation test ensures that there is congruency of the light to the radiation field and hence radiation will not fall outside the area of interest (optimization). It is therefore recommended that regular checks be conducted after repairs or maintenance work on the x-ray equipment for QA.

Government regulatory agencies should commence periodic monitoring to ensure compliance with QA tests in all radio-diagnostic centres in order to safeguard the population from unwarranted radiation hazards.

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