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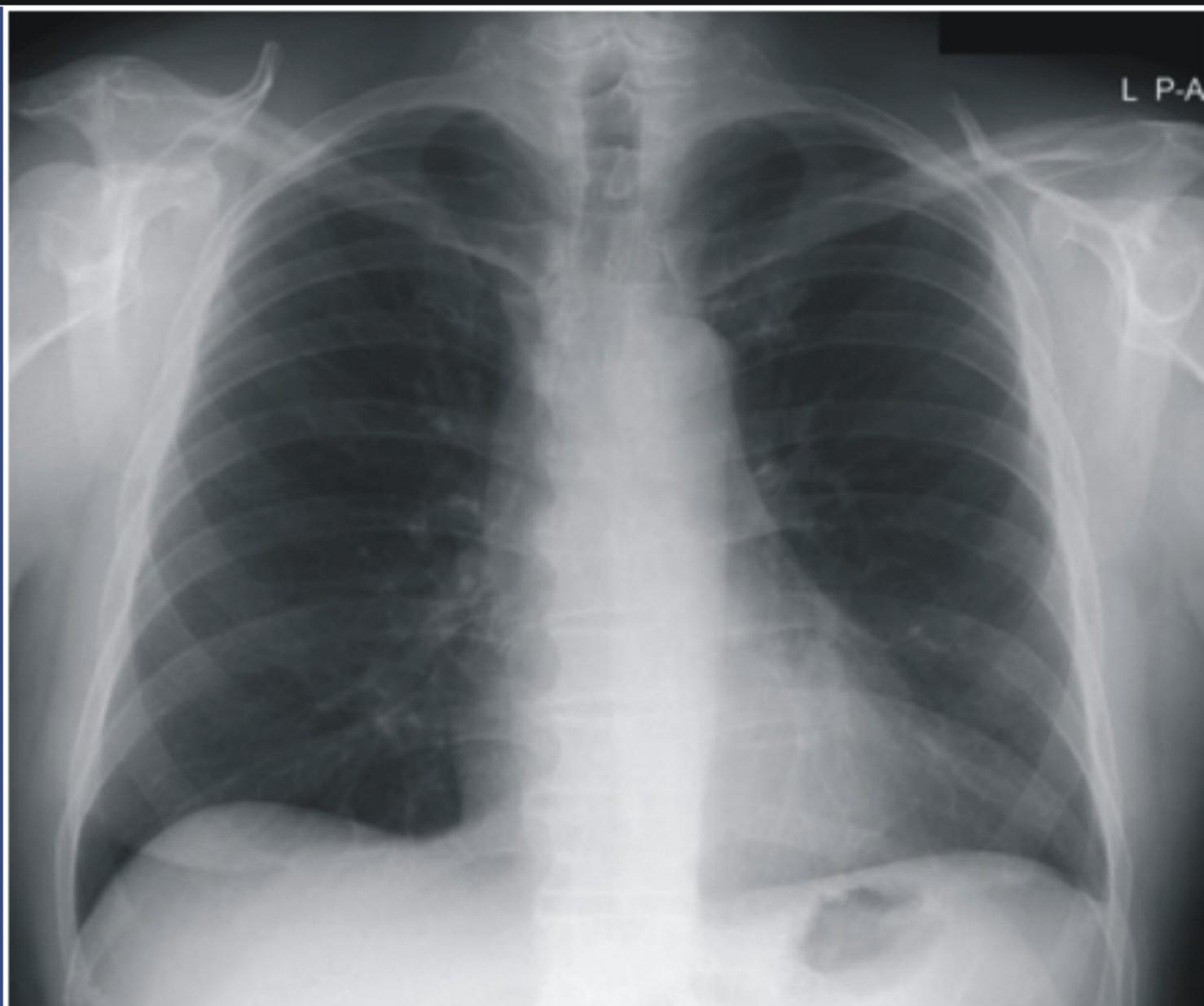
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Quality Control of Conventional X-ray Tube in Three Tertiary Hospitals in South-East, Nigeria

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ABSTRACT

Background

Quality control of conventional x-ray tube ensures that the patient integral radiation dose is minimized and image quality is improved, by controlling the x-ray beam to reduce scatter radiation.

Objective

To assess x-ray tubes for half value layer (HVL), x-ray field and light field congruence using known standard.

Methodology

The HVLs were measured using calibrated, non-invasive, digital multifunctional detector meter that incorporate computer output. The detector was positioned at the center of the collimated beam axis with focus-to-image distance (FID) of 100 cm. Tube potentials of 80 and 100 kVp were selected, and used to make exposures. The corresponding HVLs were then recorded. Also, x-ray field and light field congruence were measured by placing 18 cm x 24 cm cassette loaded with film at FID of 100 cm. The collimator light was in ON position and metal markers were used to delineate the periphery of the light field. Misalignment was calculated from the developed radiographs using standard formula.

Results

The HVL ranged from 3.40 to 4.4mmAl. Also, the sum of the misalignment in both orthogonal directions ranged from 7.21 to 9.70 % of FID in all three centers.

Conclusion

The HVL were within standard limit at 80 and 100 kVp in all the centers studied. However, x-ray field and light field were grossly misaligned.

Key words: X-ray, Quality Control, Compliance, Collimator, Light field congruence

Introduction

Quality control (QC) of x-ray equipment is the technical aspect of quality assurance, and is related to equipment process monitoring [1]. A

periodic quality control assessment enhances the optimization of the radiation protection of the patients [2].

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X-rays are produced in the x-ray tube and are used to obtain medically useful information about a patient. These x-rays are generated in a controlled way with the help of collimator assembly which helps to control the beam of x-rays to smallest possible area. The collimator assembly has variable lead shutters that define the size of the x-ray field. Also, it has a bulb and a mirror that are used to project a light field identical in size and location to the x-ray field [2]. This collimator assembly comprises of metallic filters usually aluminum or in some cases copper, that helps remove low x-ray energy that do not have sufficient energy to penetrate through the patient body and as a result contribute significantly to the patient radiation dose [3].

The collimator bulb or the mirror or both may be displaced from its original position causing misalignment of x-ray field and light field. This misalignment normally increases the number of reject films, leads to additional patient exposure and increased cost for the management [4].

Although, some previous studies have been done on QC of conventional x-ray equipment in South-West, South-South, and North-East parts of Nigeria [5 - 7], none was seen from South-East which paid attention to compliance of x-ray and light field congruence and HVL. Furthermore, it was revealed that the values obtained from the various equipment settings showed significant variations between the preset values and the measured values [8]. The present study was conceptualized to replicate a similar study in South-East zone of Nigeria, using standards recommended by American Association of Physicists in Medicine (AAPM) [9].

Material and methods

This research was a cross-sectional survey undertaken in three tertiary hospitals in South-East, Nigeria between May and June, 2017. Ethical approval was obtained from Nnamdi Azikiwe University Teaching Hospital Ethical Committee (NAUTH/CS/66/Vol.9/21).

Written permissions were also obtained from all the centers involved in the study. The three centres which were located far apart, were selected on the premise that they were centres of excellence. Two of those centres were in Anambra State while one was in Enugu State. In order to guarantee their rights to privacy, they are coded as A, B and C. The machines in the centres were all static, manufactured in Europe between 2005 – 2008, and installed between 2006 – 2012. Tube potential and tube current were a maximum of 150 kVp and 630 mA, respectively. These specifications were obtained from the body of the x-ray tube and control panel due to inaccessible manuals.

The cooperation of Radiographers in the centre was sought, and the work was taken with their collaboration as they were responsible for exposures of the films and machine manipulations. In one centre the work was undertaken at night when throughput was lower, while in two other centres, it was done during working hours due to low throughput. One of the centres utilized digital processing while the other two used manual processing methods.

The half value layer (HVL) was measured using non-invasive, factory-calibrated, multifunctional digital radiation detector meter (Piraham 500), manufactured in Sweden. This multi-functional detector meter has the capability to measure the selected kVp with corresponding HVL and also displays results with the help of a computer connected to it at the same time. The computer had installed software to make this reading possible.

The procedure was carried out by placing the detector meter in the x-ray beam at an FID of 100 cm along the central rays. Caution was taken in aligning the digital detector device to the beam, and careful collimation of the light beam to the marked area of the detector was done to avoid systematic error. Tube potentials of 80 and 100 kVp were selected and exposures made. The corresponding HVLs were then recorded.

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Three different measurements were carried out on each KVp and the average values, and percentage deviations were calculated. It is recommended that the HVL at 80 and 100 kVp should not be less than 2.3 and 2.7mmAl, respectively [2, 10].

X-ray field and light field congruence were also measured by placing an 18 x 24cm size cassette loaded with film at FID of 100 cm. The light localizer was in ON position and pointed perpendicular to the cassette. Metal markers were used to delineate the periphery of the light field (Fig. 1). A radiographic exposure of the film was taken using 60 kVp, 200 mA and 3mAs and processed. The misalignment of the metal markers with the edge of the x-ray field was determined from the developed radiograph. The national and international regulatory body specifies that the misalignment in any one orthogonal direction should not exceed 2.0 % of focus to image distance [2].

As shown in Fig 2, the magnitude of deviation (E) in percentage was calculated as follows:

$$E \text{ in horizontal direction} = \left(\frac{a}{|AB|} \right) \times 100\% \quad \dots (1)$$

$$E \text{ in vertical direction} = \left(\frac{b}{|AC|} \right) \times 100\% \quad \dots (2)$$

Sum of E in both orthogonal directions = (1) + (2)

Where $|AC|$ is the magnitude of AC, $|AB|$ is magnitude of AB, while 'a' is misalignment in horizontal direction, and 'b' is misalignment in vertical direction.

Results

Specification of the x-ray machines in the centres are shown in Table 1. The results presented in Table 2 shows that the measured HVLs (2.40 – 4.71) were within the recommended values (>2.3 mmAl) at 80 and (> 2.3 mmAl) at 100kVp, respectively. The result of x-ray field and light field congruence is presented in Table 3.

The sum of misalignment in both orthogonal directions ranged from 7.21% to 9.70%. Figure 1 gives the pictorial arrangement for the measurement of HVL, while Figure 2a - d shows the arrangement for testing x-ray field and light field congruence.

Table 1: Specifications of x-ray machines at the centres

| Parameters | Centres | | |
|------------------------|-----------------------|---------------------------------|---------------|
| | A (Rooms 1 & 2) | B | C |
| Machine type | Static | Static | Static |
| Where mounted | Floor | Floor | Floor |
| Mode | Digital | Digital | Digital |
| Manufacturer | General Electric (GE) | Stephania Radiological Solution | Siemens |
| Year of manufacture | 2008 | 2005 | 2005 |
| Country of manufacture | Germany | France | Germany |
| Year of installation | 2012 | 2006 | 2010 |
| Inherent filtration | 1.5mmAl | 2.0mmAl | Not available |
| Total filtration | | Unknown | |
| kVp maximum | 150 | 150 | 133 |
| mA maximum | 630 | 500 | 500 |

Table 2: Measurements of HVLs

| Centres | Input | Output | Input | Output |
|----------|-------|--------|-------|--------|
| | kVp | HVL | kVp | HVL |
| A room 1 | 80 | 4.40 | 100 | 4.50 |
| A room 2 | 80 | 3.78 | 100 | 4.71 |
| B | 80 | 2.40 | 100 | 3.00 |
| C | 80 | 3.40 | 100 | 3.40 |

Table 3: Measurement of x-ray field and light field congruence

| Centres | Misalignment on each orthogonal side (%) | Misalignment on both orthogonal sides (%) |
|----------|--|---|
| A room 1 | 2.20 and 6.08 | 8.28 |
| A room 2 | 9.00 and 0.70 | 9.70 |
| B | 5.26 and 1.95 | 7.21 |
| C | 3.70 and 4.91 | 8.61 |

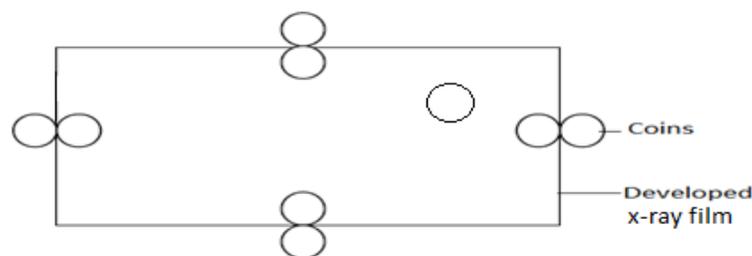


Figure 2b: Diagrammatic arrangement for testing x-ray field and light field congruence



Figure 1: Setup for Measurement of Half Value Layer

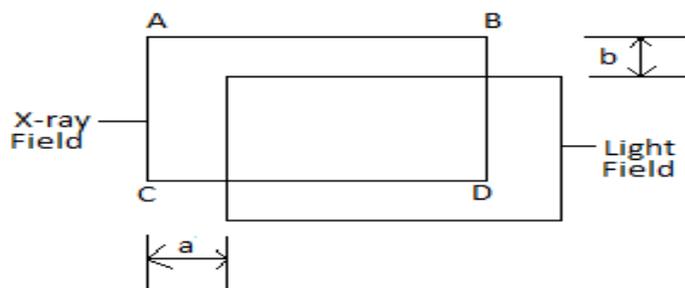


Figure 2c: Diagrammatic representation of misalignment from developed radiograph

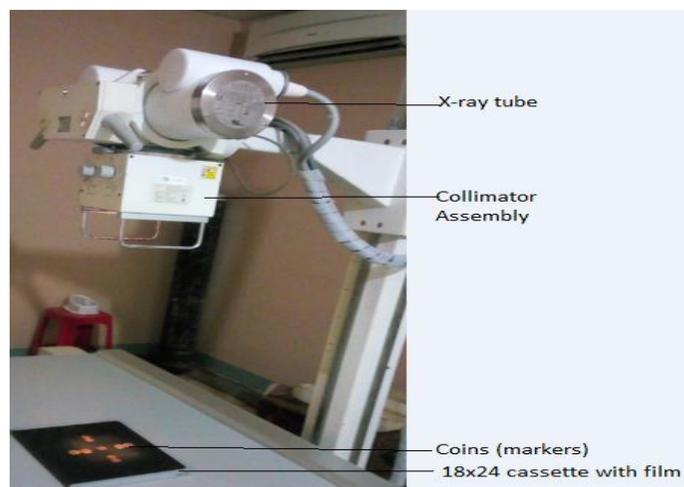


Figure 2a: Pictorial arrangement for measurement of x-ray and light field congruence

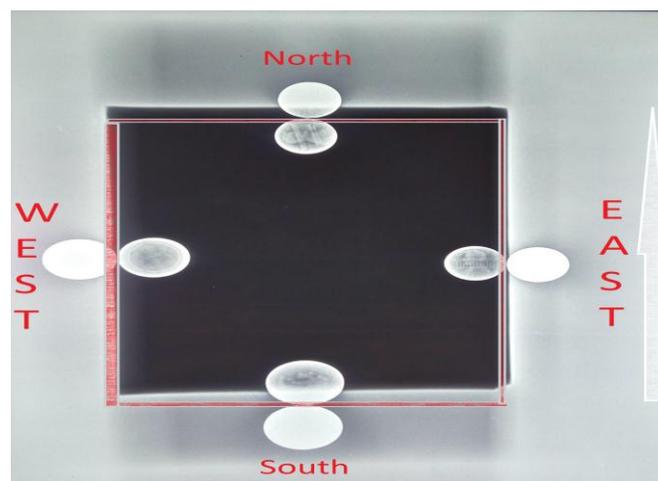


Figure 2d: Processed radiograph showing evidence of x-ray and light fields misalignment. The red perimeter which passes between coins represents collimation prior to irradiation. After processing, it was observed that the radiation field did not coincide with light beam but had a South – North movement as shown by the white arrow. Black portion represents radiation field while white portion within red perimeter represents light field.

Discussion

The measurement of HVL is used to assess the sufficiency of filtration in the x-ray beam. Insufficient filtration will result in increased patient dose. In this study, the HVL measured were higher than the values recommended. Though, these values were high enough to reduce radiation dose to patient; the equipment would be over-stressed as higher factors will be needed to acquire the useful image quality. Excessive filtration results in extra stress on the x-ray tube, a loss in radiographic contrast, and increased exposure time. Increased exposure times can result in image blurring due to the patient motion [2].

The results obtained in this study are similar to those of Akaagerger et al [11]. They attributed their variance in the HVL values to the aluminum alloy used. The alloy has some percentage of impurities from which the HVL values and attenuation coefficient are reflecting. Besides, the density of the aluminum filter used has the tendency to affect the values because it influences the attenuation of the x-ray beam. Furthermore, the beam quality will change as the x-ray tube ages due to result of deposition of anode material inside of the tube window and roughening of the anode surface.

In a study by Begun et al [12], they found out that none of the diagnostic x-ray equipment studied attained recommended standard. However, in Tanzania, Plainoi et al [13] revealed that about 92% of the equipment studied was within the standard recommendation. Furthermore, in the same country, Nkuba and Nyanda [14] reported that 97.0% of HVL values reported were within the standard recommendations. In that study, the authors stated that some of the measurements were up to 5.86 mmAl at 80kVp. Although, the last two reports from Tanzania revealed that a large number of the units were within recommended standard, nevertheless, measurement were on the high side.

X-ray field and light field congruence results presented in this study showed gross misalignment in all the centers surveyed, with sum of misalignment in both orthogonal directions ranging from 7.21% to 9.70% of FID. Similarly, Farzeneh [15] reported that all the nine units studied failed optical field and radiation field compliance test in Sistan and Baluchistan, Iran. In contrast, Nkuba and Nyanda [14] reported that out of sixty x-ray units in Tanzania, 97% of light field and x-ray field measurements were within recommended limits. Also, Kareem et al [16], reported from Malaysia in their measurement using collimation (beam) alignment test tool. In their study, their findings of radiation field and optical congruence tests were within standard limit (0.4%).

This misalignment occurs in the x-ray collimator when the reflecting mirror or the light bulb or both, shift from normal position. It can also occur when the secondary lead collimator blades shifts from its normal position. If the x-ray field and the light field are misaligned the image produced may be off-centered, too small or too large [2]. The effect of x-ray field and light field misalignment is that it would leads to increase in the waste films, waste of resources, time and increase in medical and occupational dose because, additional radiographs will be required to produce good quality image [4].

This study is not without limitations. The authors would like to note that (re)calibration could not be carried out in any of the selected facilities. This was because there was no medical physicist employed at these hospitals. Consequently, it was difficult to have a baseline data for comparison with the findings of the present study.

Conclusions

We have measured the HVL, x-ray field and light field congruence in conventional x-ray tube and collimator at three selected tertiary hospitals in South East, Nigeria.

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Details of how to evaluate the percentages of x-ray field and light field misalignment were shown. The results obtained showed that the x-ray field and light field are grossly misaligned, and the HVLs were within the recommended values at all the centers studied. While this study presents preliminary findings that deviate from internationally recognized indices, further studies are intended in the near future when necessary corrective measures may have been initiated.

Conflict of interest

There was no conflict of interest

Acknowledgment.

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