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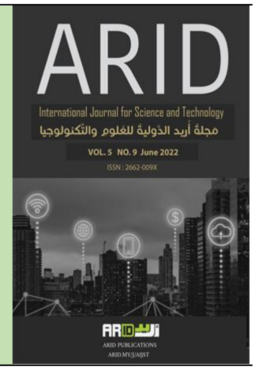

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The Effects of Different Exposure Factors on Leakage Radiation in an X-ray Room

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تأثير عوامل التعرض الإشعاعي المختلفة على تسرب الإشعاع في غرفة الأشعة السينية

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ABSTRACT

This study evaluated leakage radiation doses inside an x-ray room at patient's positioning levels. The effects of different exposure settings (X-ray tube voltage, radiation exposure intensity, dosimeter position, and distance from X-ray tube) on leakage radiation dose are estimated. Various x-ray tubes and models were used in this evaluation. The findings of this study revealed that, the increase of tube voltage (kVp), and tube current (mAs) led to a concomitant increase in the quantity of leakage radiation, whereas the increase in distance from X-ray tube and dosimeter position reduces the intensity of recorded leakage radiation according to inverse square low. In addition, the evaluation of leakage X-ray for investigated X-ray units illustrated that, leakage radiation doses at patient level around X-ray tubes were within the permissible occupational dose. Finally, the reduction of leakage radiation dose can be acquired by reducing the intensity of radiation (mAs) and increasing the distance between imaged object and x-ray source

Keywords: Assessment, leakage, radiation, exposure factors, X-ray room

الملخص

هدف هذا البحث حساب قيم الجرعات الإشعاعية المتسربة من أنابيب الأشعة السينية، وذلك داخل غرف الأشعة السينية عند مستوى وموضع المريض أثناء عملية التصوير الإشعاعي حيث تمت القياسات لأنابيب أشعة سينية مختلفة. كما تمّ تقدير تأثيرات معاملات التعرض الإشعاعي المتمثلة بإعدادات أنبوبة الأشعة السينية (فرق الجهد بين طرفي انبوبة الأشعة السينية، شدة التيار المار في أنبوبة الاشعة السينية، وبعد المسافة من مركز أنبوبة الأشعة السينية) على كمية جرعات التسرب الإشعاعي أثناء عملية التصوير الإشعاعي. وقد أظهرت نتائج البحث تأثير معاملات التعرض الإشعاعي على كمية التسرب الإشعاعي خصوصا شدة التيار المار في أنبوبة الأشعة السينية حيث إن زيادة شدة تيار الأنبوبة ينتج عنه زيادة كبيرة في كمية الإشعاع المتسرب منها أثناء عملية التصوير الإشعاعي، كما يوجد تأثير أقل درجة لمتغير فرق الجهد بين طرفي الأنبوبة على كمية الإشعاع المتسرب منها حيث إن زيادة فرق جهد أدت إلى زيادة مصاحبة في كمية الإشعاع المتسرب أثناء التصوير الإشعاعي. وفي المقابل تقل قيمة جرعة الأشعة السينية المتسربة كلما زادت المسافة عن مركز الإشعاع في الأنبوبة، ويخضع ذلك لقانون التربيع العكسي. إضافة إلى ذلك أظهرت نتائج القياس لكمية الإشعاع المتسرب من أنابيب الأشعة السينية أن قيم جرعات الإشعة المتسربة داخل غرف الأشعة السينية، كانت ضمن حدود الجرعة المهنية المسموح بها. وتوصي الدراسة من أجل تقليل كمية الأشعة المتسربة أن يتم تخفيض قيم شدة التيار المار في الأنبوبة وتعويض ذلك بزيادة فرق الجهد بين طرفي الأنبوبة، إضافة إلى ذلك زيادة المسافة بين أنبوبة الأشعة السينية والمريض أو الجسم المراد تصويره بالأشعة السينية.

كلمات مفتاحية: تقييم، التسرب الإشعاعي، غرفة الأشعة، عوامل، التعرض الإشعاعي.

1. Introduction

Medical X-ray tube is considered a major source of industrial radiation exposure to workers, patients, and the general populace, hence there is a problem of safely using of ionizing radiation during medical imaging [1, 2, 3]. For example, general radiography accounts for 88 % of X-ray–based imaging in Yemen and make up the most of ionizing radiation dose in radiology departments [4].

Leakage radiation arises from x-ray tube, especially those with defects in housing or shielding, this leakage spreads out of x-ray tube in different directions [5]. Hence, leakage radiation is an important source of radiation dose exposure that patient's receive during x-ray imaging [3].

The hazard of leakage radiation exposure to patients and radiology staff during radiological procedures is imperative because of patient's position during radiographic imaging and long term of X-ray exposure for medical personal [6]. Hence, leakage radiation is considered the main source of over exposure dose for patients and radiology staff [7, 8]. Therefore, there is a need to decrease leakage radiation to protect patients and medical personal from unnecessary x-ray dose [9].

To elucidate matter interactions with leakage radiation from X-ray tube, the mechanism of X-ray propagation should be understood. When a leakage beam of X-ray strikes any object or inner cladding of X-ray room, it is either scattered, absorbed, transmitted or reflected to backward [10]. Leakage photons can change its direction due to interaction with some medium inside x-ray room.

The leakage photons from x-ray tube negatively affect radiographic image quality thereby hindering accurate representations of human anatomy, and increase radiation dose that patients and medical personnel are exposed to [11]. Leakage X-ray scatter is one of the foremost factors that negatively affects image quality by causing the underestimation of attenuation difference in image reconstructions. The leakage radiation decreases image sharpness and contrast, which makes the image hazy and indistinct [12, 13]. The generated secondary photons continue to dissipate energy in different directions due to the scattering interactions [14].

Also, leakage radiation can have a significant effect on the quality of a radiograph, due to the increasing the level of random background noise on the image receptor which degrades radiograph details visibility [15, 16].

Leakage radiation doesn't absorbed by the X-ray tube housing shield. Hence, leakage radiation had particular concern to limit radiation leakage from the X-ray tube to less than 0.88 mGy/hr at 1 metre from the x-ray tube focus [17, 18]. Because of the exposed patient will typically be closer than 1 m to x-ray tube in various radiographic investigations, the exposure dose measurements at closer distances than those is important and required for both safety and regulatory purposes [8]. So that, this study aims to assess leakage radiation from some of x-ray tubes inside radiography room with different radiation exposure factors.

2. Experimental:

2.1 Materials

The measurements of this study were carried out in the radiology departments at University of Science and Technology Hospital and Medical Complex in Sana'a city, Yemen. The measurements of this study involved utilizing some of x-ray tubes types and models, the measurements of leakage radiation dose curried out using two dosimeters: the first one is PTW-UNIDOS radiation dosimeter (the chamber voltage from 0 to 400 V with selectable polarity, while the linearity is ≤ ± 0.5 % , and 115V/230 V power supply) which is available to read both dose and dose rate, while the another dosimeter is an accurate survey meter (Gamma-scout) which is equipped with a Geiger-Muller counter tube, able to detect electromagnetic radiation as well as alpha and beta radiation, with calibrated scale from 0.01μSv/h to 5000.00 μSv/h. The assessment of leakage radiation done by monitoring area around X-ray units.

2.2 Methods

This study estimated leakage radiation from x-ray tube at different distances from x-ray source including patient table and standing bucky levels at X-ray room wall. The X-ray machine tube is a leading source of medical radiation, which was directed towards an exposed object. The leakage radiation doses were estimated using ionization chambers dosimeters. The measurements were carried out with different exposure factors (Tube voltage (kVp), radiation intensities (mAs), and distance from x-ray tube) to assess the effect of these factors on resultant leakage radiation (the data was listed and presented in Tables 1- 4, in Appendix), and. For all measurements the normalized exposure rate are determined after correction factors' calculation to estimate leakage radiation values.

3. Results and discussion:

3.1 Evaluation leakage radiation for different types of x-ray tubes

In this part, the leakage radiation from investigated X-ray tubes is estimated using radiation survey meter, the exposure factors were set at 100 kVp, 10 mA, and exposure time of 1 sec. The survey meter set at 100 cm from focal spot at four locations (directions); anode side, cathode side, right and left of the tube, the exposures are made and the leakage radiation from the x-ray tubes are recorded and presented in Figure 1.

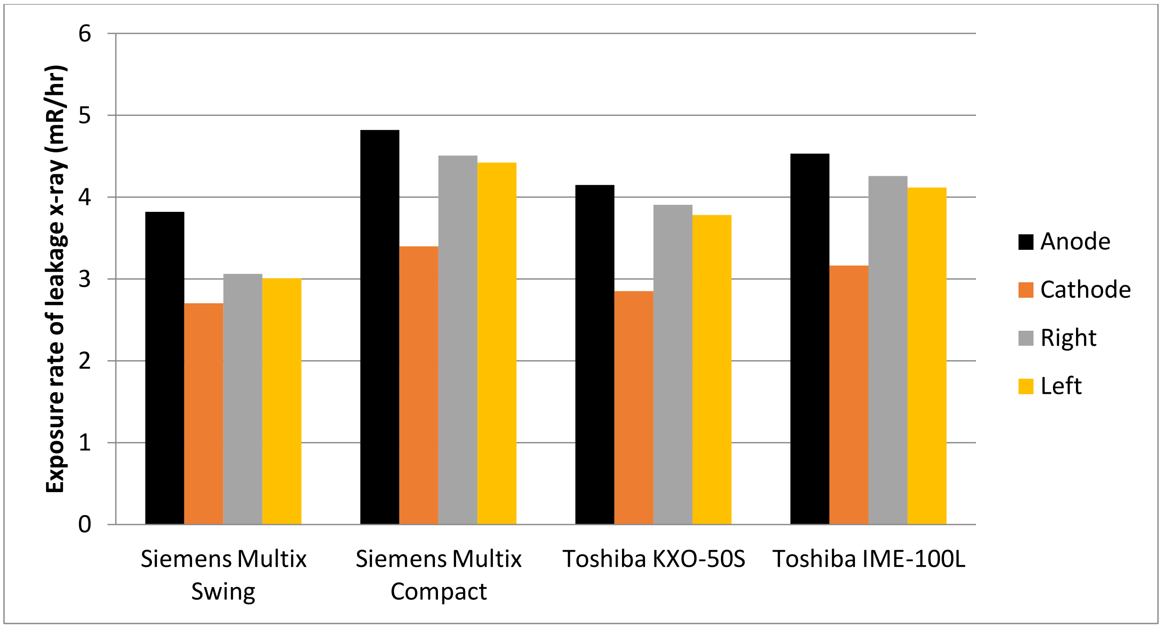


Figure (1): leakage radiation at different positions for investigated X-ray tubes

For all X-ray tubes the, largest radiation exposure dose rates is recorded at anode location, whereas the less exposure doses are recorded at cathode side. The highest radiation leaks dose rate 4.8 mR/hr was recorded for Siemens multi compact x-ray tube. The measurements of leakage radiation at fixed exposure settings present that the leakage radiation doses at different locations around X-ray tube fall below the maximum acceptable radiation leakage and within the permissible occupational dose (10 mR/hr) according to the United States food and drug administration regulations [19]. Moreover, Figure 2 illustrates the mean of absorbed radiation dose rate measured in (μGy/hr) and its equivalent exposure dose rate measured in (mR/hr).

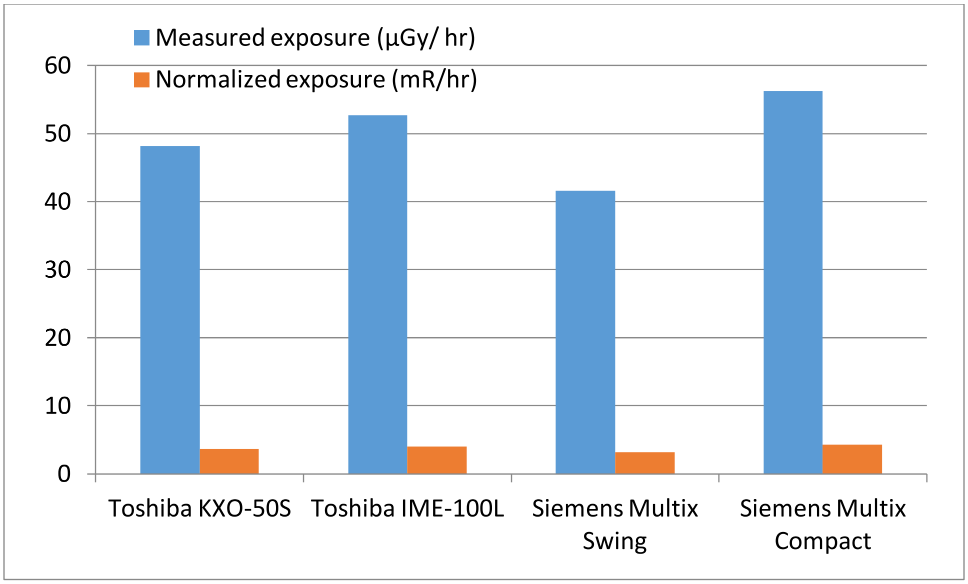


Figure (2): Radiation exposure dose rate for different types of X-ray tubes

Collectively, the results showed that all investigated X-ray units presented similar values for leakage radiation doses within the permissible occupational dose for the different locations around X-ray tubes according to some related standards such Malaysian standards (MS 838, 2007) which recommends that radiation leakage rate at 1 m from the tube housing should not exceed 10 mR/hr (100 µGy/hr) [20]. this finding agree with Joseph et al (2020) who found that, radiation tube leakage for assessed diagnostic rooms were within the reference level [21]. In addition, there is a slight effect for x-ray tube model and design on leakage radiation, the largest value of leakage radiation was observed with Siemens multi compact x-ray tube.

3.2 The effect of exposure factors on leakage radiation

To assess the effect of exposure factors on leakage radiation, various settings were carried out to estimate the resultant radiation leaks from x-ray tube during exposure. Figure 3 illustrates leakage radiation doses from two models of x-ray tubes using various exposure factors.

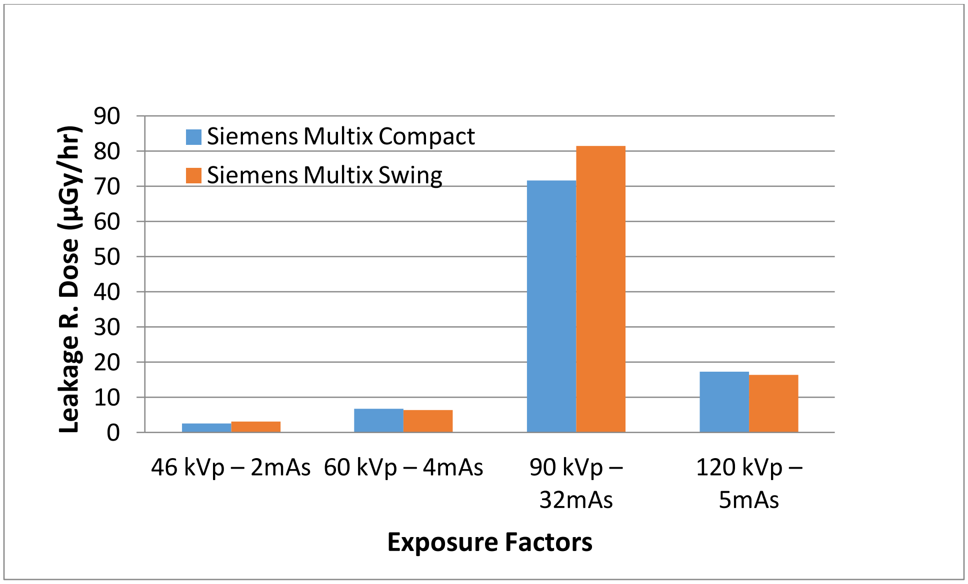
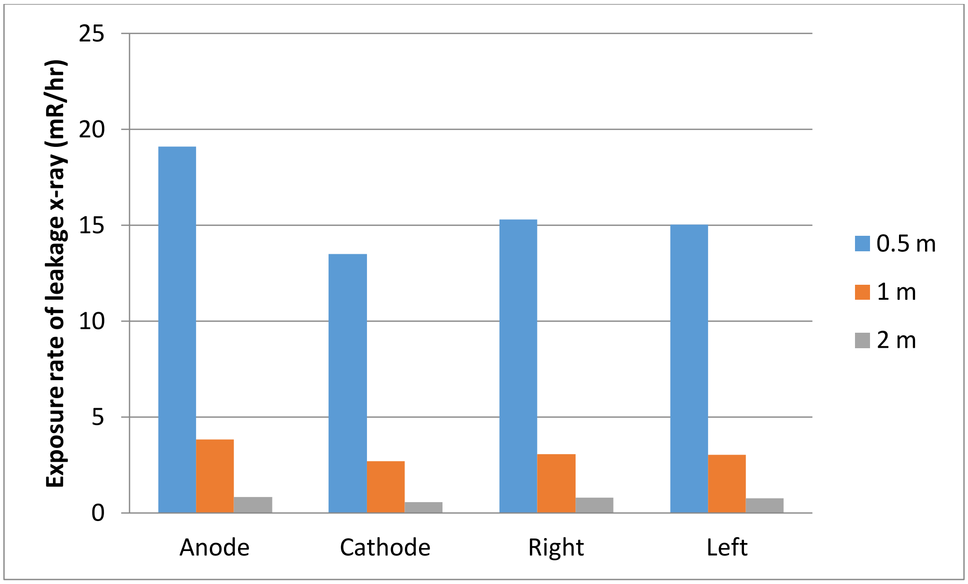


Figure (3): leakage radiation doses at different exposure factors

Figure 3 shows noticeable association between x-ray factors (parameters) and leakage radiation during x-ray exposure. The radiation exposure intensity (mAs) proved superior effect on radiation leaks , The largest value of leakage radiation was observed with the exposure factors (90 kVp, 32 mAs), so that its applicable approach to decrease radiation intensity (mAs) for x-ray settings and compensate that by increasing kVp to obtain adequate exposure for better x-ray image contrast.

3.3 Radiation exposure doses at different distances inside x-ray room

This part estimate leakage radiation dose at different distances from x-ray tube, the effect of increasing distance from x-ray source on recorded radiation leaks dose is shown in figure 4.



Figure(4): Radiation exposure doses at different distances from x-ray tube

The leakage radiation dose decreased as the distance from x-ray tube was increased. This relation obeys to inverse square low between radiation intensity and distance from x-ray source. The highest radiation leaks dose rate was 19.1 mR/hr recorded at 50 cm distance from x-ray source. Regarding to positioning and projection of patient during x-ray imaging, the posterior anterior (PA) projection at 2 m distance produced lower leakage radiation than anterior posterior (AP) projection at 1 m distance due to the shorter distance from x-ray source This result is consistent with Justin et al.' findings (2018) who reported higher scattered radiation with AP projection comparing with PA projection [2]. Leakage radiation can be reduced by providing external shielding or increasing distance between the patients and the X-ray tube.

4. Conclusion:

The leakage radiation is an undesirable radiation exposure should be kept at lowest level within the permissible dose limits. Through the assessment of radiation leakage, it was proven that, leakage X-ray depends on various factors, such as x-ray intensity (mAs), distance from X-ray source, and X-ray tube voltage. The reduction of leakage radiation dose can be acquired by adequate changes of radiation exposure factors particularly radiation intensity (mAs) and distance from X-ray source.

List of Abbreviations:

kVp	Kilo volte peak
mAs	Milli ampere second
mGy/hr	Milli gray per hour
m	Meter
mA	Milli Ampere
sec.	Second
cm	Centimeter
µGy/hr	Micro gray per hour
mR/hr	Milli Roentgen per hour
MS	Malaysian standards
PA	Posterior -anterior
AP	Anterior-posterior

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Appendix

Study's Data

Table(1): Means of leakage radiation doses (mR/hr) at different locations for various x-ray tubes

Dosimetry location	leakage radiation doses in mR/hr for different types of X-ray tubes			
	Siemens Multix Swing	Siemens Multix Compact	Toshiba KXO-50S	Toshiba IME-100L
Anode	3.82	4.82	4.15	4.53
Cathode	2.7	3.4	2.85	3.16
Right	3.06	4.51	3.91	4.26
Left	3.01	4.42	3.78	4.12

Table(2): The means of leakage radiation dose rate measured in (µGy/hr) and its equivalent exposure dose rate measured in (mR/hr).

Type of X-ray tube	Measured dose (µGy/ hr)	Normalized dose (mR/hr)
Toshiba KXO-50S	48.19	3.67
Toshiba IME-100L	52.72	4.02
Siemens Multix Swing	41.63	3.15
Siemens Multix Compact	56.28	4.29

Table(3): Leakage radiation doses (µGy/ hr) at different exposure factors

Exposure setting	X-ray tube (Siemens Multix Compact)				X-ray tube (Siemens Multix Swing)			
	Reading 1	Reading 2	Reading 3	Mean dose	Reading 1	Reading 2	Reading 3	Mean dose
46 kVp/ 2mAs	2.64	2.68	2.63	2.65	3.24	3.19	3.17	3.2
60 kVp / 4mAs	6.89	6.81	6.88	6.86	6.46	6.45	6.53	6.48
90 kVp / 32mAs	71.63	71.54	71.72	71.63	81.51	81.52	81.47	81.50
120 kVp/ 5mAs	17.31	17.25	17.34	17.30	16.51	16.58	16.41	16.50

Table(4): Means of leakage radiation doses at different distances from x-ray tube

leakage radiation dosimetry location	Leakage radiation doses (mR/hr) at different distances from x-ray tube		
	0.5 m	1 m	2 m
Anode	19.1	3.82	0.83
Cathode	13.5	2.7	0.57
Right	15.3	3.06	0.782
Left	15.05	3.01	0.756