Technical Note

A Survey on Exposure Parameters Variation due to Aging in Radiology Devices

Fataneh Nemati[1], Mahdi Mohammadi[2], Mehrdad Gholami[3]*

[1]MSc, Science & Research Branch, Islamic Azad University, Tehran, Iran
[2]PhD Candidate, Department of Medical Physics and Biomedical Engineering, School of Medicine, Tehran University of Medical Sciences, Tehran, Iran
[3]PhD, Department of Medical Physics, Lorestan University of Medical Sciences, Khorramabad, Iran

ABSTRACT

The inevitable use of medical imaging examinations and lack of a suitable alternative lead to the need to control and minimize the amount of radiation from such artificial medical sources. To assess the relation between exposure parameters and lifetime of radiology devices, quality control tests were carried out on 13 radiology devices in 11 general hospitals. In this study, a barracuda dosimeter, SE-43137 Sweden, was calibrated to measure and record the quantities of kVp, mAs and exposure parameters. In all the devices using applying the minimum and maximum values of kVp, the minimum and maximum values of the internal resistances were calculated. The lowest mR/mA for the device C was observed at a flow rate of 200 mA (equal to 2,425), while the highest value was for the device A (2) at a current intensity of 200 mA (equal to 14.625). By increasing the age of the device, the output of the device is reduced. Therefore, to compensate for this decrease in the output, higher exposure conditions are usually applied to the device, which can greatly increase the damage to the device.

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Keywords

Quality Control; Radiology Devices; Aging; Internal Resistance; Hospitals

Introduction

Despite many benefits of medical exposure, especially medical imaging, it causes people to receive dose. Radiography is a major contributor to imaging examinations due to easy access throughout the world, as well as lower doses compared to other X-ray imaging modalities.

The inevitable use of radiation, especially in medical diagnosis, has led to the need to control and minimize the amount of radiation from artificial medical sources. On the other hand, there is always a compromise between the diagnostic quality of radiographic images and dose received by patients. In the case of the patient's dose, ALARA (As Low As Reasonably Achievable) is the most prominent principle limiting radiation exposure. The World Health Organization (WHO) has emphasized quality assurance (QA) in diagnostic radiology and defined criteria for QA program so that image quality is acceptable and the patient's radiation is minimized based on used and proper modality for the patient [1]. The QA program includes both quality control (QC) tests and executive procedures. The QA program and QC test aim to maintain image quality, reduce the cost of the procedure and minimize the patient's dose [2]. Many studies have been carried out based on the quality control

*Corresponding author: Mehrdad Gholami
Department of Medical Physics, Lorestan University of Medical Sciences, Khorramabad, Iran
E-mail: gholami.mehrdad@lums.ac.ir

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of diagnostic radiology devices. These studies are often based on the accuracy of the output parameters of the device (kVp, mAs and Exposure).

Changes in the output exposure of the device lead to changes in the patient's dose; some of these changes also provide local reference dose levels for various diagnostic tests [3-5]. Some researchers have also studied both the patient's dose and image quality at the same time [6, 7]. One of the issues that has always emphasized on diagnostic devices is considering the useful life of the device and accuracy of its long-term performance [8]. So far, no studies have been conducted on output variations with respect to age parameters of the device. Therefore, the aim of this study was to examine changes in the output parameters of radiology devices with respect to the useful efficiency of such devices using appropriate quality control tests.

Technical Presentation

In this study, a barracuda dosimeter, SE-43137 Sweden, was calibrated to measure and record the quantities of kVp, mAs and exposure parameters [3]. The required values for the 13 radiological devices were collected from 11 hospitals in Lorestan Province (Table 1). To carry out the dosimetry, the radiology couch was covered with a layer of lead so that the backscatter beams did not reach the dosimeters and caused problems in the readings. Then, we placed the dosimeter on the couch and set the focal length to the dosimeter (FFD) at 100 cm. Moreover, based on the sensitive section of the dosimeter, we chose the dimensions of the radiation field to prevent any scattered rays reaching the dosimeter. To reduce the measurement error, each of the measurements was repeated three times and the mean readings was recorded as final readings. The output changes of the four devices (A (2), C, F, and G) were measured in terms of mA changes, recorded and monitored in constant kV. At different exposure conditions, the internal resistance of the device (R_{in}) was measured and recorded. The calculation of R_{in} was performed using Ohm's law (Equation 1). In this regard, V_r is the read voltage by the dosimeter;

Table 1: Specifications of the X-ray devices

City	Hospital	Machine Code	Company	kVpmax	mAmax	Machine Age (year)
1	A	A (1)	Ital ray	150	400	10
		A (2)	Varian	100	300	30
	B	B	Varian	120	400	22
	C	C	Genius	150	400	20
2	D	D (1)	Shimadzu	150	800	35
		D (2)	Ital ray	112	500	5
	E	E	Ital ray	150	400	4
3	F	F	Ital ray	160	500	12
4	G	G	Ital ray	150	400	15
5	H	H	Shimadzu	160	500	25
6	I	I	Shimadzu	150	800	18
7	J	J	Varian	120	400	10
8	K	K	Varian	100	320	12

V_{ex} is the regulated voltage on the device panel (exposure voltage), and I is the operating current intensity (mA).

$$R_{in} = \frac{\Delta V}{I} = \frac{V_r - V_{ex}}{I} \quad (1)$$

In fact, the R_{in} value is a part of the internal resistance embedded between the transformer and tube in the primary circuit of the radiology devices.

In all the devices applying the minimum and maximum values of kVp, the minimum and maximum values of the internal resistances were acquired (Figure 1). The highest and lowest values were recorded for the H and K devices, respectively. The process of changes in all the devices was incremental with the different rates for all the devices. Thus, the slope of the curve for each of the devices was calculated to examine and compare the trend of these incremental changes (Table 2). Based on the results, the maximum and minimum gradients were for the device C and the device D, respectively (2). According to the slope of this curve, the devices can be divided into three types as follows: slope devices up to 0.5, including the A (2), B, D (2), F, H, J and K devices; slope devices between 0.5-1,including the E and G devices; and slope devices up to 1, including A (1), C, D (1) and I.

Based on the assumption that the other parameters remained constant, the output of the device increased with mA; therefore, for the correction of this dependence, the output change diagram of the device was given as mR / mA (Figure 2). The lowest mR / mA for the device C was observed at a flow rate of 200 mA (equal to 2,425) while its highest value was for the device A (2) at a current intensity of 200 mA (equal to 14.625). The changes in the F and G devices were roughly flat while the changes in the A (2) and C devices were decreasing.

Discussion

In this study, we examined the internal resistance variations and output of the device under different exposure conditions. As mentioned above, these parameters were measured in different radiographic devices in Lorestan

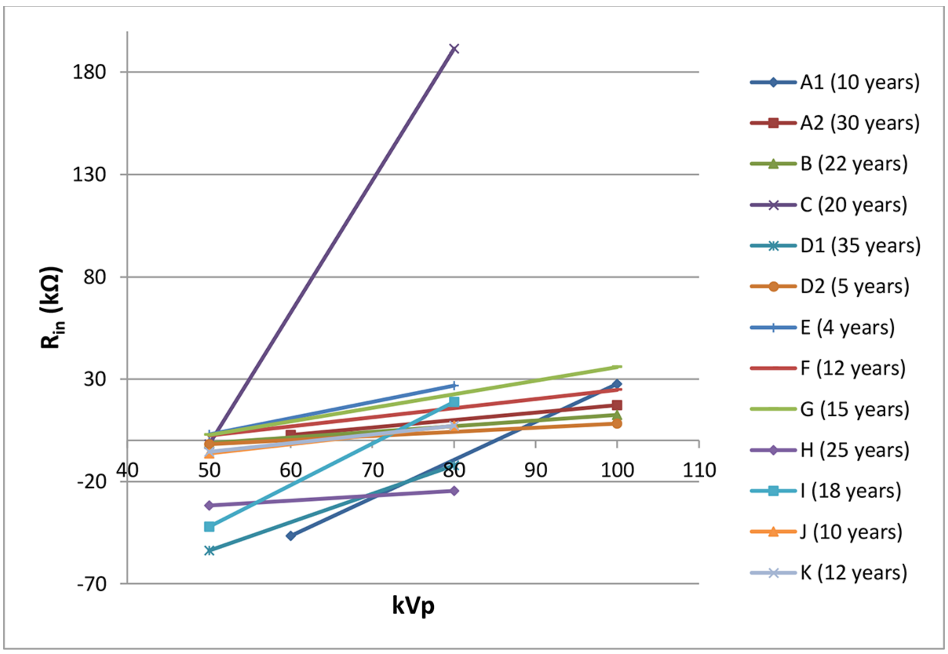

Figure 1: Variation of the internal resistance in terms of applied kVp variations

Table 2: Slope of the internal resistance variation curve according to the applied kVp variations

Machine Code	Slope
A (1)	1.8563
A (2)	0.3646
B	0.2763
C	6.4333
D (1)	1.3833
D (2)	0.2
E	0.7972
F	0.4454
G	0.6667
H	0.237
I	2.0333
J	0.4556
K	0.4222

province. Moreover, the internal resistance of all the devices also arises with increasing kVp, which is an incremental trend for more life-saving devices. Given the relation (1), we can conclude that the increase in R_{in} is due to an increase in ΔV. The total resistance is:

$$R_T = \Sigma R = R_{H.V} + R_{L.V} + R_{in} + R_{diod} \quad (2)$$

Where R_T (ΣR) is total resistance, R_{in} is internal resistance, R_{diod} is diodes resistor, $R_{H.V}$ and $R_{L.V}$ are the high and low voltage resistance, respectively.

There are the increases in internal resistance of older devices since the internal resistance increases by other factors (discussed below) and thus the differences are seen. It appears that as the age rises, the resistance of the diodes increases causing a greater difference in the applied voltage and measured voltage. Other factors can be attributed to the increased resistance of high-end devices such as the tanning or mirroring of the X-ray tube. In the process of mirroring, after the life of the device

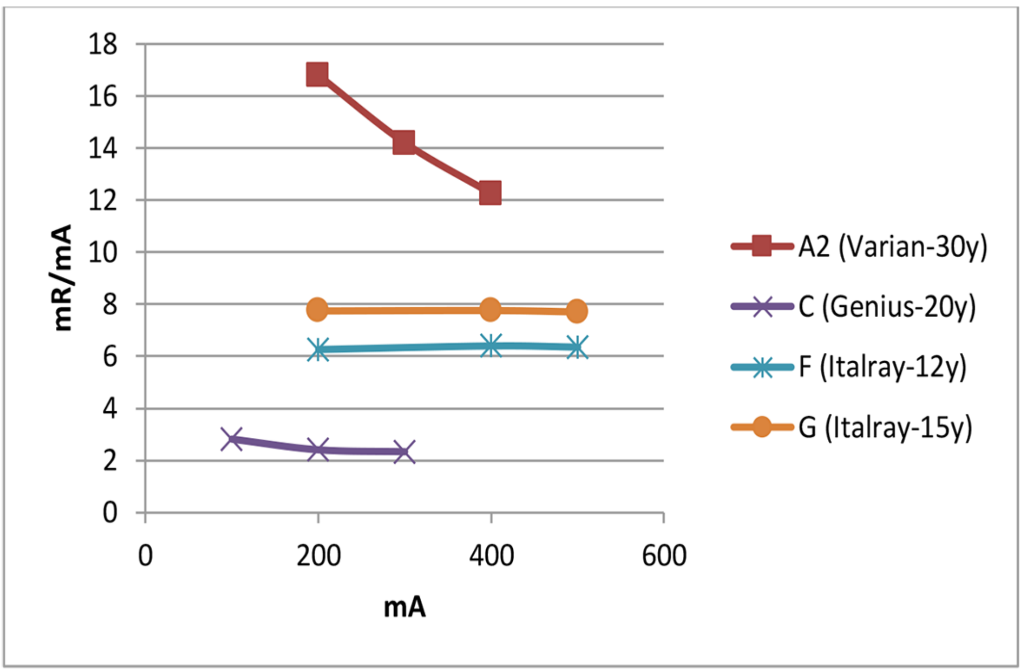

Figure 2: Output changes of devices in terms of mA variations

ends due to the activity of the tube filament, the vapor was released from the filaments steadily sits on the lamp glass, which is higher in amount for the devices with more work and longer life. This layer of filament molecules prevents X-rays from exhaust, and some of radiation rays are absorbed through this layer. Therefore, the output decreases and V_r varies with V_{ex}. There is an insignificant change in the device D (2) with a life span of 5 years due to the low effect of mirroring. The devices H and A (2), despite their high age (25 and 30 years, respectively), show variations of slight resistance attributed to the high quality of the tube and its filaments with little evaporation after many years (due to its high work load).

On the other hand, the device A (1) with a low life(10 years) shows numerous changes due to the annual workload of this device, located at the general hospital of the provincial capital and lower workload than older devices with lower annual workload. Another important factor in increasing the tensile strength of old machines is the reduction in the cooling effect of the oil surrounding the lamp resulting in an increase in the heat of the device, which is a type of resistance. In the study of Akpochafor et al. the kVp accuracy was associated with the age of the reported device and the longer lifespan had a greater chance of defect in the accuracy of kVp.

In this study, other factors such as insufficient knowledge and skills of some the radiographers in maintaining the devices don't warm the device before operating and not mention the calibration of the devices as repairs are the main factors reducing the accuracy of kVp [9]. However, in the studies of Akpochafor et al. and Khoshbin et al. there was no significant difference between the accuracy of kVp and age of the machine, but the trend of decreasing the accuracy with the age of the machine was observed [6, 9]. Asadinezhad et al. stated that changes in kVp led to changes in the supply voltage of the X-ray generator due to defects in the high voltage cables or the switching circuit of the transformer / kVp. They also described the main reason for the kVp deviation over time in a tube aging [10]; in addition, as the study did not specifically investigate the resistance of the device in different radiation conditions, the results of this study (the resistance variable) could not be compared with other results. In general, it is expected that the output of the device in terms of mR/mA in constant kV remains almost constant with the change in mA. This expectation only applies to devices with lower age (F and G, respectively, 12 and 15 years of age) and in older devices (C and A (2), respectively, with 20 and 30 years of age), a decreasing trend is correlated with the decreasing trend in A (2) because of significantly more severe than that in C.

According to the recommendation of the European Society of Radiology (ESR), the average life expectancy of a radiographic device is up to 10-14 years. For machines with a workload of less than 10,000, between 10,000 and 20,000, and more than 20,000 examinations per year, the average life expectancy is defined as 10, 12, and 14 years, respectively [8]. This instruction is, surely, for periodic tests of quality control on devices. Regarding the ESR benchmark without considering the regular conduct of quality control period tests, the output of the device is lower in devices with high age and high normal operating conditions.

Conclusion

By increasing the age of the device, the overall resistance of the device increases while the output of the device decreases, especially in high exposure conditions. To compensate for this decrease in the output, higher exposure conditions are usually applied to the device, which can greatly increase the damage to the device. Regularly, performing periodic quality of control tests, with special attention to the output changes of the device and evaluation of factors affecting its resistance, can lead to less error in selecting exposure conditions and protecting the patient, enhancing image quality and prolonging the useful life of the device.

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Conflict of Interest

None

References

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