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Ionizing Radiation Leakage in Radio-Diagnostic Centers at Gaza Strip Hospitals, Palestine

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Abstract

The fact of using radiation in medicine has led to major improvements in the diagnostic and treatment of human diseases. However, it carries some risks of health problems. In Gaza governorates hospitals, there is tremendous development has taken place in the radio-diagnostic field and there is no clear radiation protection program, lack of clear information about radiation protection measures and guidelines. The objective of this study was an assessment whether yearly equivalent radiation dose received by the radio-diagnostic workers and public in governmental Gaza governorates hospitals are within the dose limits recommended by ICRP or not. The study was carried out in nine governmental hospitals. The hospitals were selected because of their large and diverse of their radio-diagnostic services. The radiation survey meter (OD-01) was used to measure radiation leakage. Data sheet was also used to elicit information about the radio-diagnostic rooms and machines specifications. The results indicate that the fluoroscopy and CT scan rooms were not efficiently lead lined and the radiation protection is not well organized. The measured values of radiation dose rate at different locations in basic X-ray and mammography rooms are found within a permissible limits for occupational stuff and public. However, the recommended distance between the X-ray machine and control panel have not been achieved in some rooms. Therefore, there is a desperate need for rules, regulations and radiation protection act in the field of radiation in medical field.

Keywords: Radiation protection, Radio-diagnostic, Equivalent radiation dose rate, Workload.

Contents

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1. Introduction

Recently, tremendous development has taken place in the radio-diagnostic field at governmental Gaza governorates hospitals. Newer modalities are being applied in hospitals and latest radiological machines are recently obtained. Besides, there is a noticeable increase year after year in the frequency of radiological procedures. This quantitative increase may have a positive impact on the health service system of the country, but the lack of control can cause serious problem especially radiation hazard to the radiation workers as well as public.

Ionizing radiation is radiation with enough energy so that during an interaction with an atom, it can remove tightly bound electrons from the orbit of an atom, causing the atom to become charged or ionized. Ionizing radiation has been putting to use in diagnosis of various diseases and treatment since its discovery in 1895 by Wilhelm Conrad Rontgen [1].

The radiological protection principles in practical field, the optimization of protection and the individual dose limitation should be continuously performed. Dose limitation for occupationally exposed individuals is necessary to reduce the level of risk and ensures safety for workers. Knowledge and education have strong direct effects in technical protection against health hazards associated with radiation exposures [2]. It is advisable that assessing radiation doses received by radiology workers at periodic intervals will ensure their occupational safety [3]. personal radiation monitoring is essential to ensure that dose limits for staff are not exceeded. The accepted effective annual dose limits for occupational staff as reported by the International Commission on Radiological Protection (ICRP) in 1977 was 50 mSv. Public should not be exposed to more than an average of 1 mSv per year. A downward review was done in 1991 and an effective annual dose limit of 20 mSv was adopted as an average for a period of five years, with the further provision that the effective dose should not exceed 50 mSv in any single year. The downward review of annual dose limit was adopted in order to put a stricter control over the use of ionizing radiation in medicine and minimize possible hazards, especially the stochastic effects [4].

2. Objectives

The main objective of the study is to measure of ionizing radiation level inside and outside of radio-diagnostic rooms to assess whether yearly equivalent radiation dose received by the radio-diagnostic workers and public are within the dose limits recommended by ICRP or not and to evaluate of radiation protection measures in radio-diagnostic centers at governmental Gaza governorates hospitals. The other specific objectives are:

- To assess whether annual equivalent dose received by the radiation workers are within the dose limits recommended by ICRP or not.
- To identify the dangerous locations in radio-diagnostic centers.
- To evaluate of radiation protection status in radio-diagnostic rooms.
- To make an inventory of availability of radio-diagnostic machines of the surveyed hospitals.
- To help the planners and decision makers to modify the future plans regarding radiation protection to be more and to develop radiation safety culture.

3. Materials and Methods

The study was carried out in radio-diagnostic centers at nine selected governmental Gaza governorates hospitals including: Al Shifa Medical Complex, Nasser Medical Complex, European Gaza hospital, Abu Yousef Al Najjar Martyr hospital, Kamal Adwan Martyr hospital, Al Aqsa Martyrs hospital, Abdel Aziz Rantessi Martyr hospital, Al Naser pediatric hospital and Beit Hanoun hospital.

The hospitals were selected because of their large and diverse of their radio-diagnostic services.

Two ways were applied to assess the status of ionizing radiation dose rate and radiation protection measures in radio-diagnostic centers at governmental Gaza governorates hospitals, namely:

- Radiation survey
- Radio-diagnostic machines and rooms specifications data sheets

The radiation survey has been carried out to measure the radiation dose rate indifferent locations in the radio-diagnostic rooms at nine governmental Gaza governorates hospitals which include: 19 basic X-ray, 8 fluoroscopy, 1 mammography and 3 CT scan rooms.

The radiation dose rate in this study was carried out using radiation survey meter (OD-01) that designed by Step – Sensotechnik and ElektronikPockau GmbH, Germany. Figure (1) displays the radiation survey meter that used throughout the measurements. The calibration of the survey meter (OD-01) is performed according to ISO 9001 TUV Quality Management System Certification, headquartered in Munich, Germany by using Co-60 (photon energy 1.2 MeV).

Figure-1. Radiation survey meter (OD-01)

To measure the equivalent radiation dose rate, Specific locations were selected according to radio-diagnostic rooms design and machines types. These locations are: Directional dose rate, at one meter distance from the X-ray tube by closing the tube collimators, at control panel, at corridor outside the X-ray room (door closed), at dark room and behind the chest stand wall. For CT scan the measurements also conducted at door near the control panel (door closed), in additional to patient waiting rooms.

The measurements were performed during the daytime between 8 AM to 2 PM. The electrical zero balancing was recorded before the radio-diagnostic machines were switched on in respective rooms to verify the electrical zero of the measuring device. The reference phantom was used as a scattering medium to simulate physiological characteristics of patient body. The Measurements behind the chest stand wall was done without a patient or a phantom and the distance between X-ray tube and chest stand equal 180 cm. The measurements were conducted by using Source Image Distance (SID) is equal 100 cm.

In this study the radiation level at each location was calculated using the workload. The National Council on Radiation Protection and Measurements (NCRP report no. 49) workloads could be used throughout this work. However, the NCRP workloads might be more or less than the workloads at some of those rooms. For this reason, can be calculated the workloads in each radio-diagnostic room to simulate the real workloads in radio-diagnostic rooms at governmental Gaza governorates hospitals.

The radiation level at each location in one week was calculated using the workload mA.min/week (= mAs/60), the current workload in each room could be calculated as:

$$\text{Workload} = \sum_i (\text{mA.min})_i . N_i$$

Where N_i is examination number of type i and mA·min used for type I [5]. In order to calculate the radiation level in different locations, we have considered the different characteristic parameters of radiation like kilo-Volt (kV), milli-Ampere (mA) and time (s).

In basic X-ray, the radiation parameters taken to evaluate radiation level were about 100 kV_p in voltage, 1 s in time (t), and tube current (I) was 100 mA, to give high energy of radiation.

In CT scan, the radiation parameters taken to evaluate radiation level were about 100 kV_p in voltage, 1 s in time (t), and tube current (I) was 210 mA.

In fluoroscopy, the radiation parameters taken to evaluate radiation level were about 100 kV_p in voltage, tube current (I) was 3 mA.

In mammography, the radiation parameters taken to evaluate radiation level were about 30 kV_p in voltage, 1 s in time (t), and tube current (I) was 50 mA.

The equivalent radiation dose rate to whole body at each location (H_W) in unit of $\left(\frac{\text{mSv}}{\text{week}}\right)$ was calculated using:

$$H_W\left(\frac{\text{mSv}}{\text{week}}\right) = R\left(\frac{\text{mSv}}{\text{min}}\right) . \frac{1}{I_m(\text{mA}_m)} . \text{Workload}\left(\frac{\text{mA.min}}{\text{week}}\right)$$

Where is the equivalent dose rate level readings in air at each point in units of (mSv/min); intensity (I_m) in mA units and Workload in units of $\left(\frac{\text{mA.min}}{\text{week}}\right)$ [6].

Data sheets are also used to obtain information about radio-diagnostic machines and rooms. The information was taken from medical equipment engineering department in ministry of health and from the head of radio-diagnostic center. The data sheet includes information about: name of hospital, radio-diagnostic room number, manufacturer of machine, model of machine, status of machine, date of machine installation, type of machine working (constant or portable), (electronic or manual), (film processing digital or analogue), dimensions of radio-diagnostic room in cm, width of the room walls in cm, material of the room walls, material of the control panel wall, thickness and high of lead lining the room walls, the distance between the radiation source and control panel, thickness of lead lining the room doors and number of radiological procedures in the radio-diagnostic room per day.

4. Results and Discussion

4.1. The Equivalent Radiation Dose Rate

4.1.1. The Equivalent Radiation Dose Rate at Control Panels

The measured values of equivalent radiation dose rate at control panels are carried out in radio-diagnostic rooms at nine selected hospitals shown in Figure (2). The results could be accepted and remain within permissible limit for occupational stuff.

We have also noticed that the CT scan room at Al Shifa Medical Complex ranked the first in term of the highest radiation dose rate, and gives (14.2 mSv/yr). Then followed by fluoroscopy room at Nasser Medical Complex, and gives (10.9 mSv/yr).

In addition , the higher values at control panels for basic X-ray rooms found in emergency room at Kamal Adwan hospital and at emergency room at Al Shifa hospital, and gives (4.03 mSv/yr and 3.8 mSv/yr) respectively. The lowest radiation dose rate at control panel found in mammography room at Nasser Medical complex.

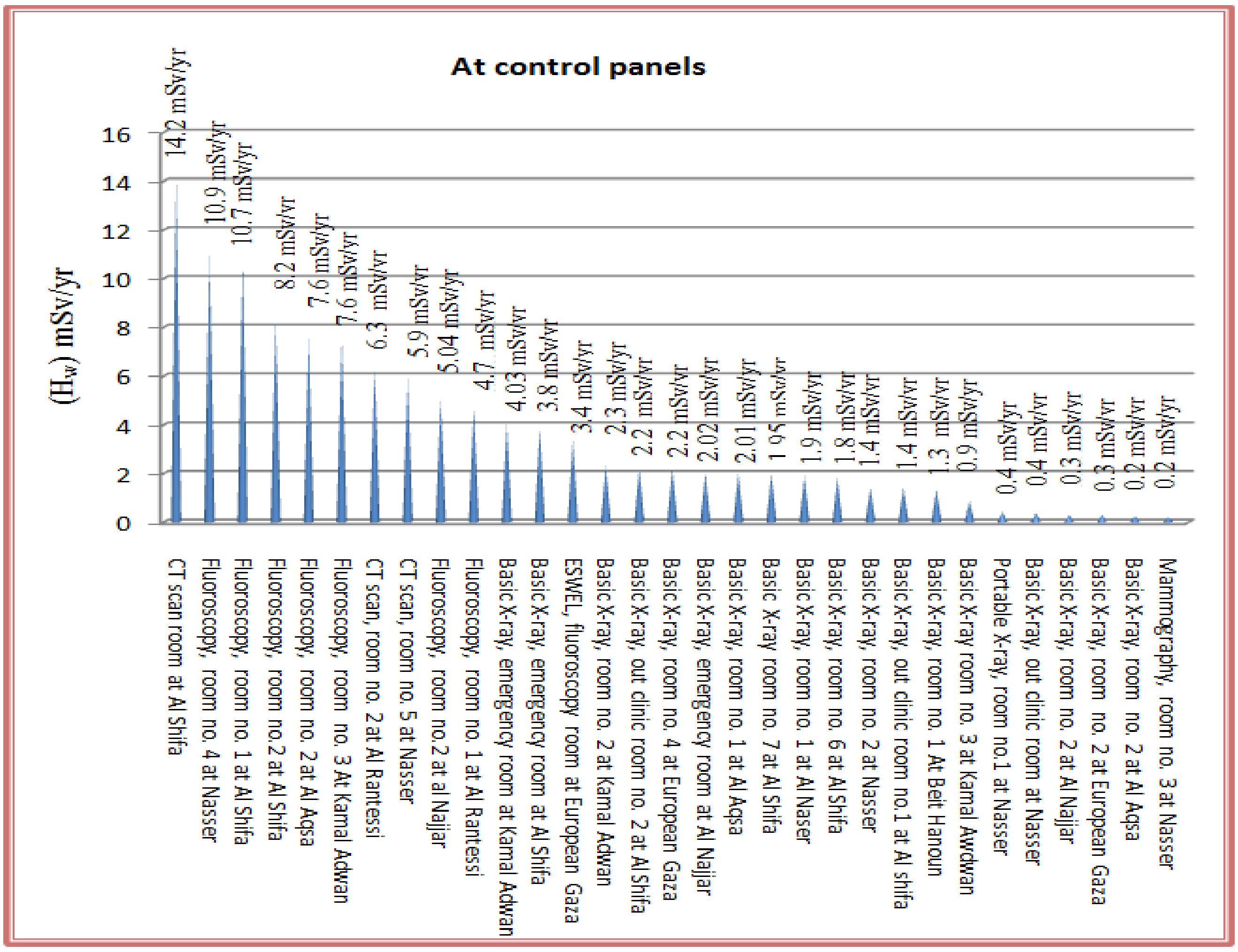

Figure-2. The equivalent radiation dose rate at control panels

4.1.2. The Equivalent Radiation Dose Rate at Corridors

Figure (3) illustrates the measured values at corridors during closing the doors in thirty radio-diagnostic rooms at nine selected hospitals. The results showed that the values at CT scan , fluoroscopy, and some of basic X- ray rooms are higher than the reference limit for public exposure and indicate that the doors that leads to these rooms should be efficiently lead lined. Clearly, there is a health risk of radiation exposure for people who visiting this rooms. Certainly, this would give notice to the stakeholders for an adequate protection. However, the measured values for the rest rooms were found within the permissible limits and the lowest radiation dose rate was found in mammography room at Nasser Medical complex.

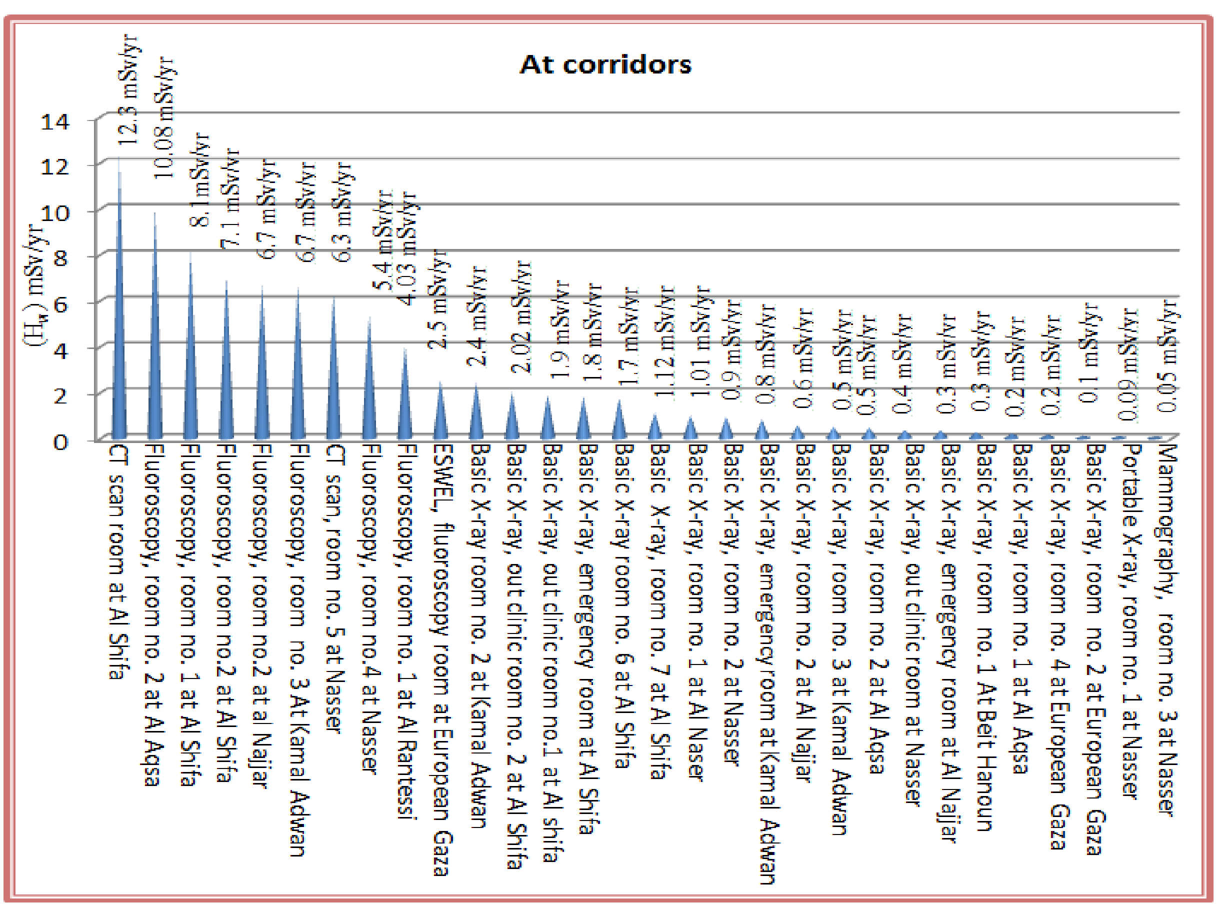

Figure-3. The equivalent radiation dose rate at corridors

4.1.3. The Equivalent Radiation Dose Rate at Patient Waiting Rooms

Figure (4) exhibits the measured values at patient waiting rooms in nine radio-diagnostic rooms at nine selected hospitals. The results could be described the most of equivalent radiation dose rate are higher than the reference limits for public exposure. The results showed that the values in patient waiting room at CT scan room at Al Shifa Medical complex are the higher compared the reference limit for public exposure and indicate that the doors that leads to these rooms should be efficiently lead lined. However, the lowest radiation dose rate was found in patient waiting room at CT scan room at Nasser Medical Complex.

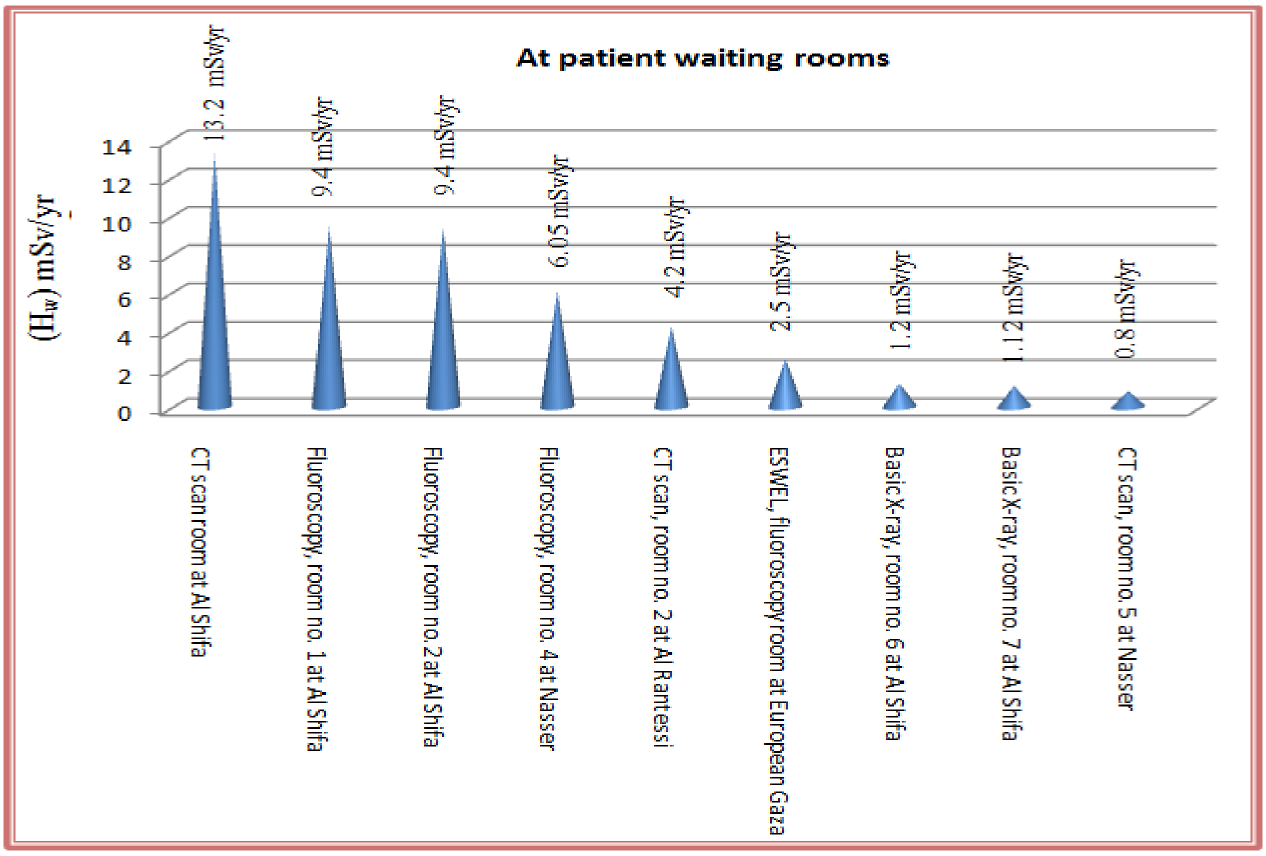

Figure-4. The equivalent radiation dose rate at patient waiting rooms

4.1.4. The Equivalent Radiation Dose Rate at Dark Rooms

Figure (5) describes the measured values in twenty first dark rooms at nine selected hospitals. It is noticed that the dark rooms near the fluoroscopy rooms ranked the first in terms of the highest radiation dose rate.

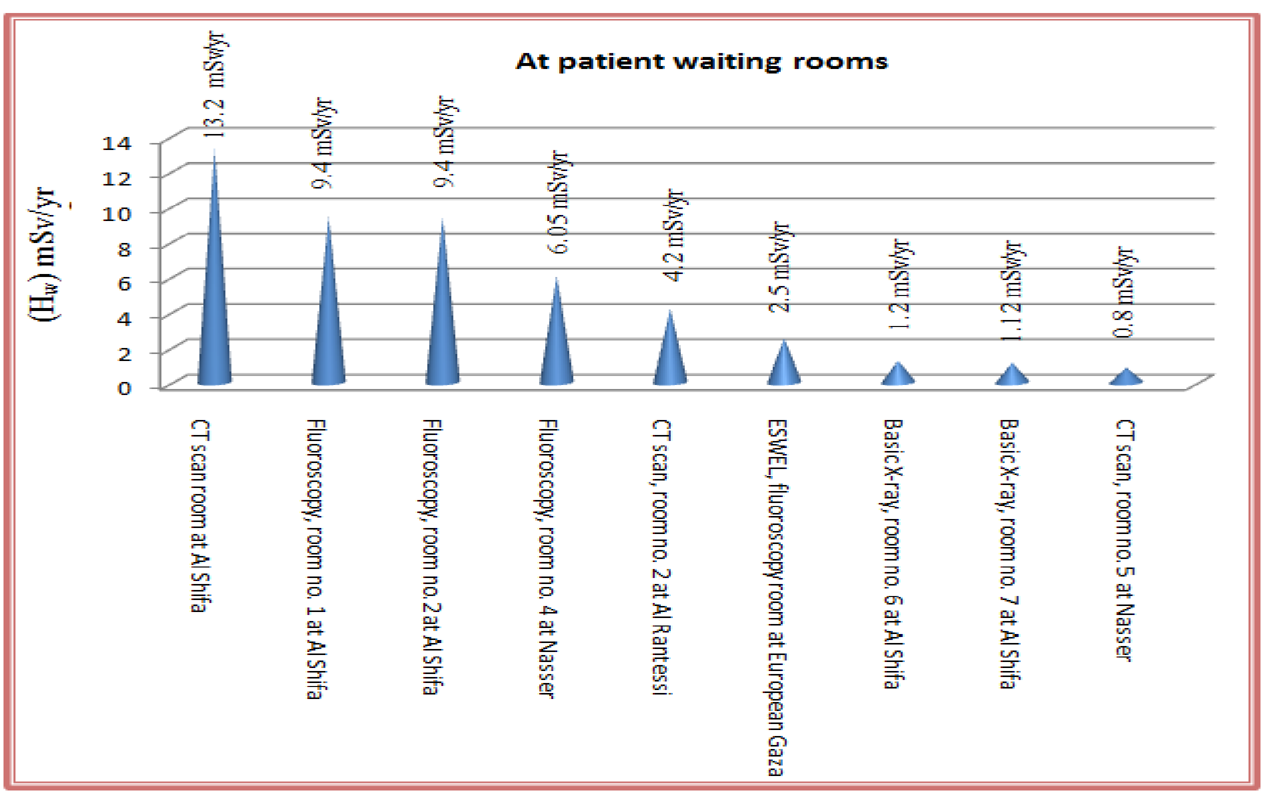

Figure-5. The equivalent radiation dose rate at dark rooms

4.1.5. Directional Equivalent Radiation Dose Rate and At One Meter from the X-Ray Tube in Basic X-Ray and Mammography Rooms

Figure (6) illustrates the difference between the directional radiation dose rate and the radiation dose rate at one meter distance from the X-ray tube by closing the collimators in basic X-ray and mammography machines. This indicates to the importance of using radiation protection techniques such as the distance from the X-ray source and X-ray beam collimators.

All X-ray tubes have some radiation leakage, there is only 2-3 mm lead in the housing. Radiation leakage is limited in most countries to 1 mGy/hr at 1 meter, so this can be used as the actual leakage value for shielding calculations [5].

The directional radiation dose rate in basic X-ray machine in room no. 2 at Kamal Adwan martyr hospital was about (162.9mSv/yr), while the radiation leakage at one meter distance from the X-tube by closing the collimators about (4.4mSv/yr).This reflects the importance of using the distance from the X-ray source and X-ray tube collimators to protect the patients and their escorts.

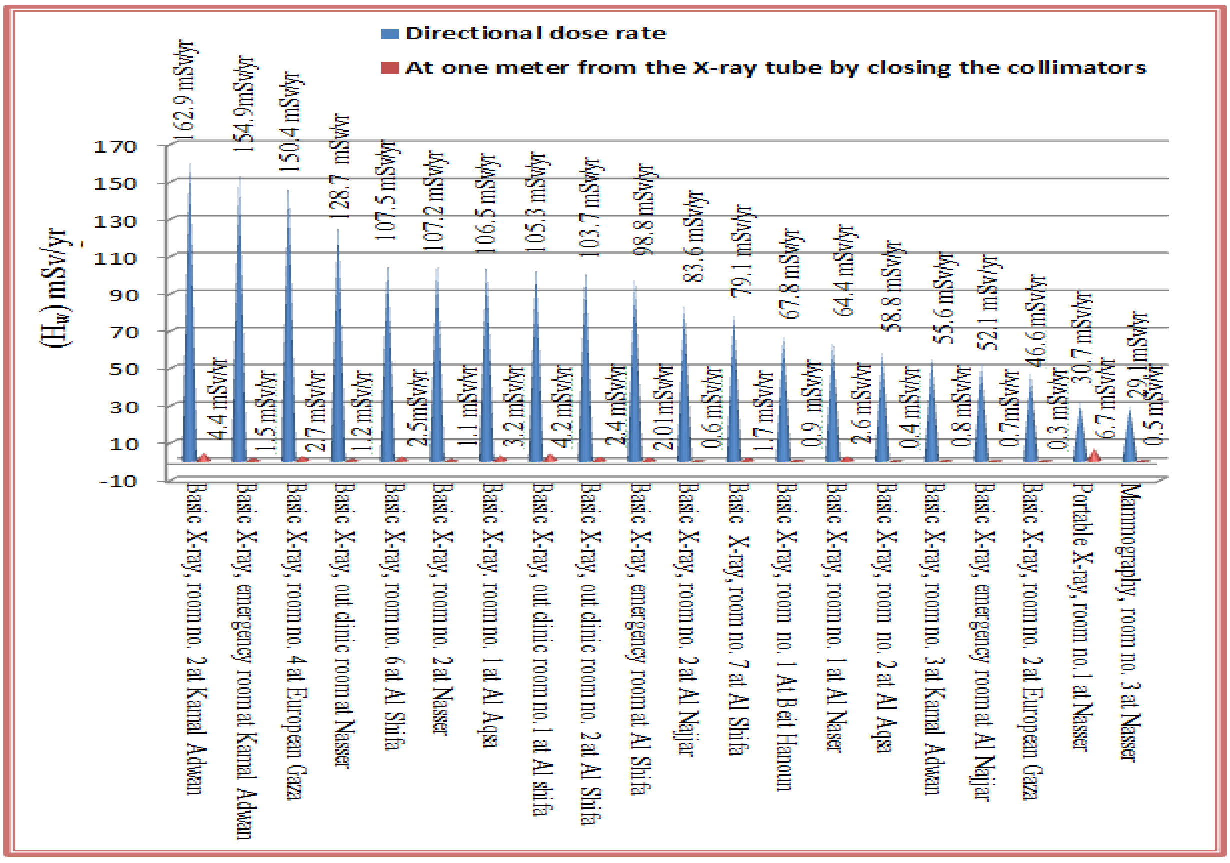

Figure-6. Directional equivalent radiation dose rate and at one meter from the X-ray tube in basic X-ray and mammography rooms

4.1.6. Directional Equivalent Radiation Dose Rate and At One Meter from the X-Ray Tube in Fluoroscopy and CT Scan Rooms

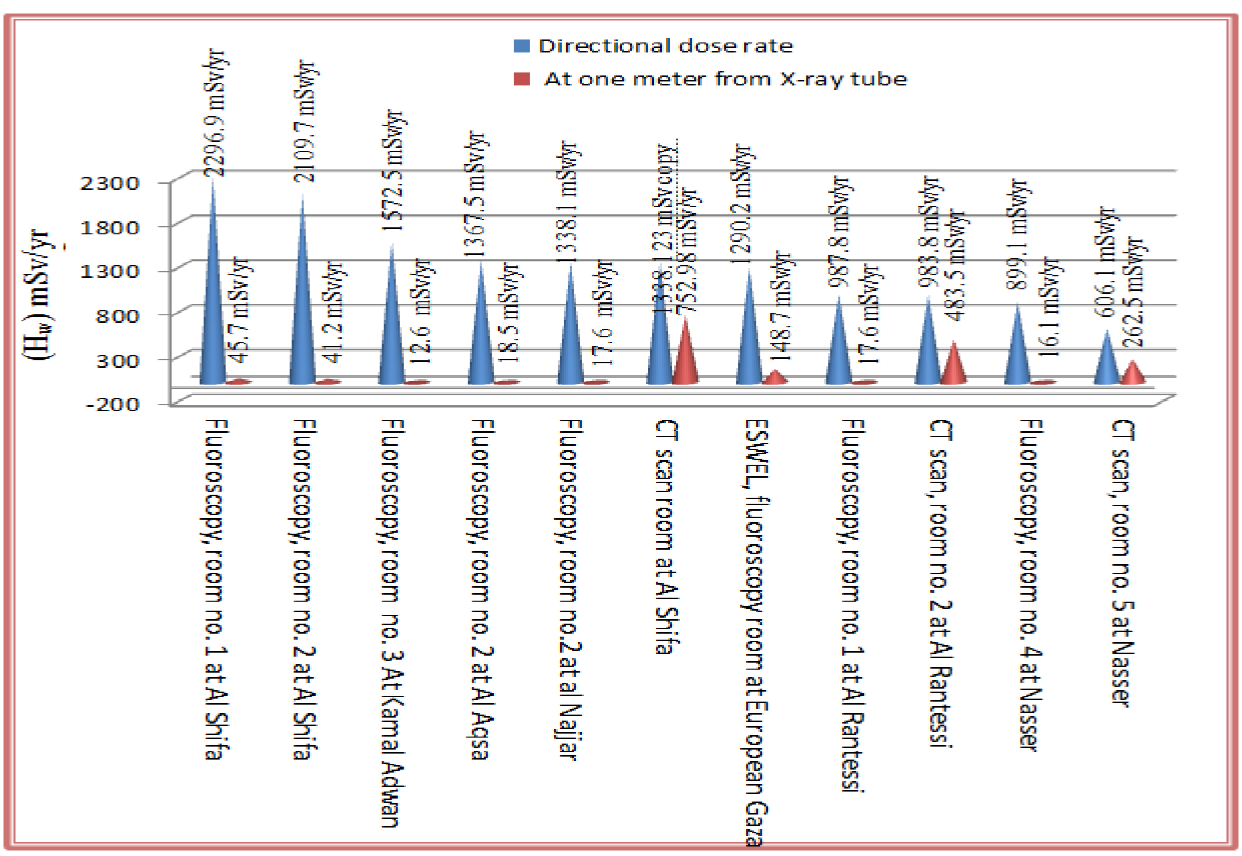

Figure-7. Directional equivalent radiation dose rate and at one meter from the X-ray tube in fluoroscopy and CT scan rooms

The measurements are also performed for both fluoroscopy and CT scan machines at the selected hospitals. Figure (7) describes the deference between the directional radiation dose rate and the radiation dose rate at one meter distance from the X-ray tube by closing the collimators in fluoroscopy rooms.

The difference between the directional radiation dose rate in CT scan machine at Al Shifa Medical complex (1338.12 mSv/yr), and the radiation dose rate at one meter distance from the X-ray tube (752.976 mSv/yr), refers to a huge radiation dose inside the CT scan rooms during imaging the patient. This high dose rate indicates a high health risk to the unsuspecting supportive persons such as nurses, hospital attendants and patient escorts. Such dose rate could pose more serious problem to a pregnant women. So, it is importance of evacuating the CT scan room from the patient escorts before giving the X-ray dose.

4.2. Specifications of Radio-Diagnostic Machines and Rooms at the Selected Hospitals

Data sheet information were collected and analyzed for all radio-diagnostic machines and rooms that available in the selected hospitals. The information was taken from medical equipment engineering department in ministry of health and from the head of radio-diagnostic center.

The analysis shows the Most of these machines are installed recently, working electronically.

The results of analysis show that all of radio-diagnostic rooms space less than the ideal X-ray rooms space, that should not be less than 36 m^2 according to *(NCRP, report no.* 147).The recommended distance between the X-ray machine and control panels have not been achieved in some rooms such as: emergency basic X-ray room at Al Shifa Medical Complex, fluoroscopy room at Nasser Medical Complex, basic X-ray room no. 4 at European Gaza hospital, emergency basic X-ray room at Abu Yousef Al Najjar Martyr hospital, basic X-ray in emergency room and fluoroscopy room at Kamal Adwan Martyr hospital, basic X-ray room at Al Naser Pediatric hospital and basic X-ray room at Beit Hanoun hospital.

The thickness and materials of the X-ray rooms walls (20 cm and cement) respectively. The thickness and height of lead lining of room walls (2 mm and 200-210 cm) respectively. The thickness of lead lining the room doors (2 mm), this is in conformity with safety standards. However, we found that the wall of the control panel in some rooms made of wood lined with lead thickness 2 mm, this is not compatible with ALARA principle.

Table-1. Radio-diagnostic machines and rooms specifications data sheet

Name of hospital	Name of machine and room number	Thickness and height of lead lining of room walls	Width of room walls/cm	Type of machine working (electronic or manual)
		Distance between the X-ray tube and control panel	**Material of room walls**	**Date of installation**
		No. of radiological procedures per day	**Material of control panel wall**	**Room dimensions /cm**
Nasser Medical Complex	Fluoroscopy and basic X-ray room no. 2	Electronic	20 cm	2 mm 200-210 cm
		2007	Cement	200 cm
		490 X 380	wood	2 mm
	Basic X-ray Emergency room	Electronic	20 cm	2 mm 200-210 cm
		2005	Cement	150 cm
		410 X 410	Wood	2 mm
	Basic X-ray room no. 2	Electronic	2 cm	2 mm 200-210 cm
		2002	Cement	330 cm
		570 X 420	Cement	2 mm
	Basic X-ray room no. 4	Electronic	20 cm	2 mm 200-210 cm
		2007	Cement	140 cm
		480 X 415	Cement	2 mm
	ESWEL (lithotripsy) Fluoroscopy room	Electronic	20 cm	2 mm 200-210 cm
		2011	Cement	300 cm
		600 X 500	Cement	2 mm
	Portable basic X-ray room no. 1	Electronic	20 cm	2 mm 200-210 cm
		2008	Cement	220 cm
		580 X 450	Wood	2 mm
	Basic X-ray room no. 2	Electronic	20 cm	2 mm 200-210 cm
		2006	Cement	230 cm
		520 X 450	Wood	2 mm
	Mammogra-phy room no. 3	Electronic	20 cm	2 mm 200-210 cm
		2011	Cement	30 cm
		360 X 300	Leaded glass	2 mm
				Continue

	Fluoroscopy room no. 4	Electronic	20 cm	2 mm 200-210 cm
		2011	Cement	160 cm
		580 X 430	Cement	2 mm
	C.T Scan room no. 5	Electronic	20 cm	2 mm 200-210 cm
		2006	Cement	290 cm
		480 X 430	Cement	2 mm
	Basic X-ray out clinic room	Electronic	20 cm	2 mm 200-210 cm
		2012	Cement	240 cm
		500 X 370	Wood	2 mm

Shifa Medical Complex	Fluoroscopy room no. 1	Electronic	20 cm	2 mm 200-210 cm
		2009	Cement	280 cm
		600 X 580	Cement	2 mm
	Fluoroscopy room no. 2	Electronic	20 cm	2 mm 200-210 cm
		2013	Cement	300 cm
		460 X 450	Cement	2 mm
	Basic X-ray room no. 6	Electronic	20 cm	2 mm 200-210 cm
		2012	Cement	240 cm
		450 X 350	Cement	2 mm
	Basic X-ray room no. 7	Electronic	20 cm	2 mm 200-210 cm
		1997	Cement	250 cm
		580 X 340	Wood	2 mm
	C.T scan room	Electronic	20 cm	2 mm 200-210 cm
		2011	Cement	330 cm
		500 X 450	Cement	2 mm
	Basic X-ray Emergency room	Electronic	20 cm	2 mm 200-210 cm
		2011	Cement	180 cm
		600 X 400	Cement	2 mm
	Basic X-ray out clinic room no.1	Electronic	20 cm	2 mm 200-210 cm
		2009	Cement	260 cm
		400 X 380	Cement	2 mm
	Basic X-ray out clinic room no. 2	Electronic	20 cm	2 mm 2 m
		2005	Cement	250 cm
		400 X 360	Cement	2 mm
Al Aqsa Martyrs hospital	Basic X-ray room no. 1	Electronic	20 cm	2 mm 200-210 cm
		2002	Cement	310 cm
		500 X 450	Wood	2 mm
	Fluoroscopy and basic X-ray room no.2	Electronic	20 cm	2 mm 200-210 cm
		2007	Cement	330 cm
		450 X 360	Wood	2 mm
Al Naser Pediatric hospital	Basic X-ray room no.1	Electronic	20 cm	2 mm 200-210 cm
		2011	Cement	100 cm
		500 X 400	Wood	2 mm
Abdel Aziz Rantessi Martyr Pediatric hospital	Fluoroscopy room no. 1	Constant	20 cm	2 mm 200-210 cm
		2011	Cement	230 cm
		480 X 440	Cement	2 mm
	C.T scan room no. 2	Constant	20 cm	2 mm 200-210 cm
		2008	Cement	280 cm
		550 X 450	Cement	2 mm
Kamal Adwan Martyr hospital	Basic X-ray Emergency room	Electronic	20 cm	2 mm 200-210 cm
		2011	Cement	150 cm
		550 X 390	Wood	2 mm
	Basic X-ray room no. 2	Electronic	20 cm	2 mm 200-210 cm
		2010	Cement	200 cm
		500 X 390	Wood	2 mm
				Continue

BeitHanoun hospital	Basic X-ray room no. 1	Electronic	20 cm	2 mm 200-210 cm
		2011	Cement	160 cm
		400 X 260	Wood	2 mm

5. Conclusion

In the present work, radiation level measurements for radio-diagnostic centers was carried out in nine selected governmental hospitals at Gaza governorates. These include: 19 basic X-ray, 8 fluoroscopy, 1 mammography and 3 CT scan machines.

In general, the results indicate that the fluoroscopy and CT scan rooms were not efficiently lead lined and the radiation protection is not well organized. Since, the measured values at corridors during closing the doors and at patient waiting rooms in fluoroscopy and CT scan rooms suggests very high exceedance compared to the reference limit for public exposure. Thus, it is noticed that a health risk of radiation exposure for all persons who visiting these rooms. Also, the measured equivalent radiation dose rate at control panels give high doses values, but remain in the permissible limit for radiology workers. However, there is an impending risks of chronic occupational exposure to the employees.

Moreover, the equivalent radiation dose rate that measured at a different locations in basic X-ray and mammography rooms are found within the permissible limits for radio-diagnostic workers and public. This indicates that these rooms are built safe and well organized according to safety criteria. Also, the results suggest that the importance of using radiation protection techniques such as the distance from the X-ray source and X-ray beam collimators. Whereas, the recommended distance between the X-ray machines and control panels have not been achieved in some rooms.

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