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Assessment of Radiological Examinations Hazards' Knowledge among Palestinian Physicians at Al-Makassed Hospital and Ramallah Governmental Hospital

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Assessment of Radiological Examinations Hazards' Knowledge among Palestinian Physicians at Al-Makassed Hospital and Ramallah Governmental Hospital

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Dedication

This thesis is dedicated to my parents, my wife and my children Majd, Dana, Mohammad and Abed Al-Rahman with love and gratitude.

Declaration

No portion of the work referred to in this study has been submitted in support of an application for any other degree or qualification to this or any other university or other institution of learning.

Signature:…………..

Ahmad Fathi Hamarsheh

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Abstract

The current study is designed to assess the knowledge about radiation doses and possible risks associated with the use of radiological examinations among Palestinian physicians. A cross-sectional design was utilized to achieve this purpose. The data for the research was gathered using a self-reported questionnaire distributed by the researcher to 167 physicians working at Al-Makassed Hospital in East Jerusalem and Ramallah Governmental Hospital in the West Bank. A total of 163 questionnaires were retuned, for a very high final response rate of 97.6%.

Statistical analysis was performed using the Statistical Package for Social Science (SPSS), Version 15. Descriptive statistics and the chi-squared and Fisher exact tests were used to analyze the data.

The results of the current study reveal that, in general, there is a lack of knowledge regarding the radiation hazards associated with the use of radiological examinations, a level of knowledge lower than those reported in the literature from other studies. Only one-third of the physicians have received a radiation protection course during their undergraduate study or at the workplace. This result may be reflected in the low percentages of physicians who were able to answer correctly many scientific, knowledge-based questions. For example, only 6.1% of the respondents were able to identify the ALARA principle, although this principle comprises the core of radiation protection philosophy regarding the minimizing of radiation doses from radiological examinations. Also, the vast majority of respondents (98.2%) did not know that patients have no established safe dose limit according to ICRP recommendations. In addition, only 5.3% of participants were able to identify the chest X-ray equivalent of effective dose resulting from a routine lumbar spine X-ray examination, a barium enema, and an abdominal and pelvic CT scan. On average, about 20% of respondents knew the relative radio-sensitivity of five specified body organs—the lungs, stomach, gonads, bladder and kidneys—in relation to each other.

Only 32% of respondents indicated that radiological examinations should be clinically justified, and that responsibility for protecting the patient from unnecessary radiation doses lies with *both* the prescriber and the practitioner. More than two-thirds of the respondents indicated that they request routine X-ray examinations more than 25% of the time, and 58.3% reported that they request CT scan examinations more than 25% of the time. In general, the physicians who were medically trained in Arab countries reported that they requested these examinations with high frequency.

On the other hand, more than two-thirds of respondents reported that they would reduce their ordering of radiological examinations (routine x-ray, fluoroscopic, and CT scan examinations) if there is a proven increase in patients' lifetime risks of cancer from any of these examinations.

These results clearly indicate the need for greater efforts to educate physicians about the potential hazards associated with the use of radiological examinations. This in turn may help reduce the exposure of Palestinian patients to the potentially harmful effects of ionizing radiation produced by unnecessary radiological examinations.

ملخص الدراسة

تم وضع هذه الدراسة من أجل تقييم معرفة الأطباء الفلسطينيين بجرعات الأشعة الناتجة عن الفحوصات الشعاعية الطبية، وما قد ينجم عنها من مخاطر. استخدمت دراسة كمية مقطعية من أجل تحقيق هذا الهدف. جمعت المعلومات اللازمة للدراسة بواسطة استبانات. قام الباحث بتوزيع هذه الاستبانات بنفسه على 167 طبيب من العاملين في مستشفى المقاصد في القدس الشرقية ومستشفى رام اللة الحكومي في الضفة الغربية. تم إرجاع ما مجموعه 163 استبانه، مُشَكّلة بذلك نسبة مشاركه عالية بلغت 97.6%.

أُسْتخدمَ برنامج الرزم الإحصائية للعلوم الاجتماعية (SPSS) لتحليل العينة، حيث استعملت النسخة 15 من هذا البرنامج. كذلك استخدم التحليل الوصفي، بالإضافة إلى الكاي مربع (X^2) وفشر المضبوط (Fisher exact test) لتحليل المعلومات.

تظهر نتائج هذه الدراسة نقص في معرفة الأطباء بالمخاطر المصاحبة لاستعمال الفحوصات الشعاعية، وأن مستوى هذه المعرفة هو أقل مما هو عليه الحال في الدراسات الأخرى، والتي تم الإطلاع عليها من خلال أدبيات الدراسة. فقط ثلث الأطباء الذين أجريت عليهم الدراسة التحقوا بفصول لتعليم الحماية من الأشعة، سواء في مكان العمل أو أثناء الدراسة. هذه النسبة المنخفضة انعكست في إجابات الأطباء بما يتعلق بمعرفتهم بأصول الحماية من الأشعة. على سبيل المثال، فقط 6% من المشاركين في الدراسة أبدو معرفتهم بالـ (ALARA)، التي تتضمن تقليل جرعات الأشعة التي يتعرض لها المريض إلى أقل ما يمكن أثناء عمل الفحوصات الشعاعية. هذا مع العلم بأن هذا المبدأ يمثل جوهر فلسفة الحماية من الأشعة. كما أن الأغلبية الساحقة من المستجيبين (98.2%) لم يعرفوا أن المريض لم يوضع له حد معين للتعرض للأشعة من قِبَل الـ (ICRP). بالإضافة إلى أن 5.3% فقط من المشاركين في الدراسة كانوا قادرين على تحديد صور الصدر المكافئة لجرعات الأشعة الفعلية (Effective Doses) الناجمة عن كل من فحص الأشعة الروتيني للعمود الفقري السفلي، والفحص الملون للأمعاء الغليظة والفحص الطبقي المحوري للبطن. ما يقارب 20% من المستجيبين استطاعوا تحديد الحساسية من الأشعة لكل من الرئتين، والمعدة، والغدد التناسلية، والمثانة والكلى نسبة إلى الأعضاء الأخرى.

فقط 32% من المستجيبين أشاروا إلى أن الفحوصات الشعاعية يجب أن يتم تبريرها، وأن من يقوم بطلب الفحوصات الشعاعية ومن يعملها تقع على عاتقه مسؤولية حماية المريض من جرعات الأشعة غير الضرورية. أكثر من ثلثي المستجيبين أشاروا بأنهم يطلبون الفحوصات الشعاعية الروتينية لأكثر من 25% من الحالات المرضية، كما أن 58.3% ذكروا بأنهم يطلبون الفحوصات الطبقية المحورية لأكثر من 25% من الحالات المرضية. بوجه عام الأطباء الذين تلقوا علومهم الطبية في البلدان العربية أشاروا بأنهم يطلبون الفحوصات الشعاعية بنسبه عالية.

من جهة أخرى، أبدى أكثر من ثلثي الأطباء المشاركين استعدادهم لتقليل طلباتهم من الفحوصات الشعاعية (الفحوصات الروتينية، والفحوصات الملونة، والفحوصات الطبقية المحورية) إذا كان هناك ما يدل على احتمالية حدوث أورام سرطانية بسبب أي من هذه الفحوصات.

هذه النتائج تشير بشكل جلي إلى الحاجة إلى بذل المزيد من الجهد لزيادة معرفة الأطباء بالأخطار التي قد تنتج عن استعمال الفحوصات الشعاعية. هذا قد يساعد في تخفيف الأضرار التي تنتج عن تعرض المرضى الفلسطينيين إلى الأشعة الناجمة عن الفحوصات الشعاعية الغير ضرورية.

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Definitions

Theory of Planned Behavior (TPB): This theory suggests that people's behavior is determined by their intention to perform a given behavior. Intentions are the most immediate antecedents to behavior and represent the convergence of the cognitive, motivational, and affective internal processes associated with a given behavior. Behavioral intentions, according to TPB, are the result of three determinants: attitude toward the behavior, subjective norms and perceived control.

Linear no-threshold hypothesis (LNT): This hypothesis proposes that damage may be caused by ionizing radiation at *all* levels of radiation doses, and the response is linear (i.e., directly proportional to the dose), Thus LNT asserts that there is *no* threshold of exposure below which ionizing radiation is safe to the human body.

Radiation hormesis hypothesis: This hypothesis stands in contrast to the linear no-threshold (LNT) hypothesis, and suggests that ionizing radiation, at levels that occur in the natural environment, may actually *enhance* health by stimulating natural defense mechanisms, and thus low-level radiation is either harmless or may in fact be beneficial.

Knowledge: This word represents an internal relationship between the person and his environment, and distinguished in form of expertise and skills gained through education and experience.

Medical imagining: This refers to the techniques and processes used to create images of the human body for clinical purposes, in order to diagnose and detect disease or injury or to study the normal anatomy and physiology of the human body.

Myocardial perfusion stress test: It is involve the use of small amount of radioactive material which circulates in the blood stream and shows if the heart muscle is receiving adequate blood supply under stress and/or rest condition.

Abbreviations

ICRP	International Commission on Radiological Protection
UNRWA	United Nation Relief and Work Agency
C-T scan	Computed Tomography scan
U/S	Ultrasound Scanning
MRI	Magnetic Resonance Imaging
ALARA	AS Low As Reasonably Achievable
TPB	Theory of Planned Behavior
FDA	Food and Drug Administration
CR	Computed Radiology
USA	United Stats of America
UK	United Kingdom
NCRP	National Committee of Radiological Protection
SPSS	Statistical package for Social Science
LNT	Linear no Threshold Theory
LSS	Life Span Study
Sv	Seviert
Gy	Gray
L.S.	Lumbar Spine
Ba	Barium
PA	Posterior Anterior
LAT	Lateral
AP	Anterior Posterior
DNA	Deoxyribonucleic acid
SSBs	Single – stand break

CHAPTER ONE

INTRODUCTION

Chapter One
Introduction

1.1. Introduction

This study examines physicians' knowledge of radiation doses and risks associated with the use of radiological examinations. A review of the literature reveals a general lack of knowledge among physicians regarding these issues.

Before discussing the problem statement, and the aim and objectives of the current study, it is important to obtain an overview on the number of hospitals and medical centers in the West Bank, in addition to, the number and types of medical imaging equipments that exist in these settings.

The network of primary health centers (PHC) and hospitals has been considerably developed in Palestine. The total number of registered PHC centers was 511 in the West Bank. The distribution of the PHCs according to providers shows that 62% of the centers operated by the Palestinian Ministry of Health, 9% by UNRWA, and 29% by nongovernmental organizations. There were 57 hospitals in the West Bank. The utilization of the Palestinian Ministry of Health hospitals in term of occupancy rate is high (81%) in comparison with nongovernmental organization and private hospitals (38% and 36% respectively) (PCBS, 2006).

Of the health services routinely provided in Palestinian hospitals, one important category is medical imaging examinations. There are 143 medical imaging units in the West Bank, directed and staffed by 40 radiologists and 340 radio-technologists. Table 1.1 shows the various medical imaging modalities and the number of devices for each in the West Bank. These numbers include equipments existing either in medical centers or in hospitals (Palestinian Medical Imaging Association, 2008).

Table (1.1) The number and type of medical imaging equipments in the West Bank (Palestinian medical imaging association, 2008).

Medical imaging modality	Number of devices
Projection radiography	
Conventional X-ray equipment	139
Computerized X-ray machine (CR)	5
Digital X-ray machine (DR)	1
Dental X-ray machine	45
Mammography X-ray machine	6
Conventional fluoroscopic equipment	35
Angiography fluoroscopic equipment	3
CT scan	19
Nuclear medicine	1
MRI	4
Ultrasound	140

1.2. Problem statement

Ionizing radiation is used daily in hospitals and clinics to perform diagnostic imaging procedures such as X-rays which are necessary for accurate diagnosis of diseases and injuries. However, despite the positive impact of such diagnostic examinations on the health of the population, the use of ionizing radiation is also associated with potentially harmful biological effects: high radiation doses tend to kill cells, while low doses tend to damage or alter the genetic code (DNA) of irradiated cells (Scanff, et al, 2008). There are many studies that indicate the harmful effects of radiological examination, which will be discussed in chapter 2 (Brenner, 2004; Turgut, et al, 2004; Zelanna, 2004; Wang, 2006; Nezahat, 2006; Walter, 2007; Kiran, et al, 2008; Myles, et al, 2008). One of the major studies that called attention to the increased risk of radiation hazards associated with pediatric CT, looking particularly at cancer risks among children, was conducted by Brenner (2004) and published in the American Journal of Roentgenology. The significant finding of this study was that out of approximately 600,000 abdominal and head CT examinations performed annually in children under the age of 15 years in the U.S.A, it is estimated that 500 of these children might ultimately die from cancer attributable to the CT radiation (Brenner, 2004).

In view of the great potential harm associated with the use of ionizing radiation in the diagnostic field, it becomes absolutely necessary that the known hazards inherent in radiological examinations, while statistically tiny, must still always be outweighed by the expected benefits. In practice, unnecessary radiological examinations must simply be avoided or replaced with other, less harmful diagnostic techniques such as ultrasound (Pilling, 2008).

Physicians are the primary care-providers who are responsible for requesting radiological examinations, and, unfortunately, most of the studies (Quinn, 1997; Shiralkar, et al, 2003; Jacob, 2004; Chritoph, 2004; Karen, et al, 2006; Atilla, 2007; Henry, at el, 2007; Heyer, et al, 2007; Soye & Paterson, 2008) indicated that physicians are unaware of the hazards associated with the use of the radiological examinations, they underestimate the actual doses involved, and they have poor knowledge regarding the possible risks to the health of populations.

Attention has increasingly been given to conducting studies that assess physicians' level of awareness regarding the potential hazards of using radiological examinations. While this trend is true generally, the literature reveals a lack of such studies specifically among Palestinian physicians. Indeed, to our knowledge this may be the first study ever conducted among Palestinian physicians for this purpose. The results may help policy-makers and educational institutions in the health field in establishing standards of radiation safety, first in the educational system, by revising the medical curriculums, as well as in actual clinical practice in hospitals. The end result, ideally, will be better protecting the public from the hazards of unnecessary radiological examinations.

1.3. Justification of the study

As discussed formerly, this particular study was selected for the following reasons:

1. Studies indicated an underestimation, on the part of physicians, of the radiation hazards and possible risks of radiological examinations.

2. There was a seeming total lack of studies conducted in Palestinian hospitals to assess physicians' knowledge of the radiation hazards of radiological examinations.

1.4. Study aim and Objectives

1.4.1. Study aim

The main aim of this study is to assess the knowledge of radiation hazards of radiological examinations and possible risks among the Palestinian physicians in Al-Makassed Hospital and Ramallah Governmental Hospital.

1.4.2. Specific objectives

1. To assess the knowledge of Palestinian physicians regarding radiation hazards associated with different types of radiological examinations, such as chest X-ray, abdominal CT scan and barium enema.

2. To examine the relationship between physician independent variables (e.g. age, gender and medical specialty) and their knowledge of the hazards of radiological examinations.

1.5. Research hypothesis

The Palestinian physicians are not sufficiently knowledgeable about the possible risks and hazards of radiological examinations.

1.6. Feasibility of the study

1. The researcher’s interest in and professional knowledge of the radiological field facilitated the process of conducting this research.

2. The main researcher is working in Al-Makassed Hospital, which facilitated access to their physicians who participated in the study.

3. Ethical approval was obtained from Al-Quds University, and the administrations of both hospitals were approached in order to facilitate the study.

1.7. Limitations of the Study

This study may have many possible limitations, such as:

1. Data collection depended on self-reported questionnaires, so the participants' reluctance to answer or exaggeration of their knowledge regarding radiation hazards of radiological examinations are possible factors.

2. Only two Palestinian hospitals were included in the study (Al-Makassed Hospital and Ramallah Governmental Hospital) due to time limitations and lack of research funding, so the generalization of the findings to other health settings may be limited.

3. This study utilizes a cross-sectional design which, again, may raise concerns about generalizing the findings. Also, it may not enable the researcher to make causal inferences or incident estimation.

1.8. Summary

- One important category of health services provided in Palestinian hospitals is the various kinds of medical imaging examinations.

- The aim of the current study is to assess Palestinian physicians' knowledge of the hazards associated with radiological examinations.

- The chapter also presents the study objectives, research hypothesis, limitations and feasibility of the current study.

CHAPTER TWO

LITRETURE REVIEW

Chapter Two

Literature Review

2.1. Introduction

Radiation has always been present in our environment, however mankind was not directly aware of its existence until the end of the 19th century when a flurry of scientific discoveries was made. In 1895 Wilhelm Conrad Roentgen discovered X-rays, then Henri Becquerel, in 1896, discovered the spontaneous emission of radiation from uranium, which he called “radioactivity”. Two years later, Marie Curie discovered radium, which is a radioactive element formed in the Uranium-238 (^{238}U) decay process (Justin, 1967).

This newly discovered radiation was called “ionizing” radiation, meaning that it possesses sufficient energy to remove electrons from atoms, thus producing negatively-charged “free” electrons and positively-charged ionized atoms. It has been classified into two groups: the category of “photons” includes X-radiation and gamma radiation and other parts of the electromagnetic spectrum, while “particles” includes the alpha and beta particles and neutrons (Brenner, 2003).

Beyond the revolution they caused in basic physics, these discoveries were put to immediate practical use, such as in radiological medical examinations. The first diagnostic X-ray was a routine hand X-ray for Wilhelm Roentgen's wife in 1896, followed by images of other body organs, such as chest X-rays, abdominal X-rays, etc (Justin, 1967).

Radiological examinations provide images of body structure, such as soft tissue, bone, muscles, and the vascular system. Many times, pathology or injury which affects the investigated organ or body structure can be distinguished from the normal appearance of that organ or structure. One of the advantages of using such diagnostic examinations is that physicians can exclude many diseases and body lesions, determinations that would be impossible or very difficult to make via clinical examination (Thomas, et al, 2006).

Despite the positive impact of diagnostic radiological examination on the health of the population, these procedures involving ionizing radiation are also associated with potential harmful effects, even death (Ludwing, et al, 2002). The first report of the harmful effects was made in the British Medical Journal on 18 April 1896, not long after the first use of radiation as a medical diagnostic tool. It indicated that diagnostic X-rays have potentially harmful effects, both for the patients and for the medical personnel. This claim was supported in 1903, when the early workers who developed the diagnostic X-ray technique in the U.K. were found to have suffered radiation injuries, and in 1911 one died (Ludwing, et al, 2002). Still more attention was paid to the need to limit the use of radiation in the diagnostic field when the radiologist William Ironside died in 1921 in the UK (Justin , 1967).

Today radiation is widely used in the diagnosis of many diseases, but, because of its known harmful effects on the human body, it is important that this usage of radiation for medical purposes be limited. Toward this end, physicians' knowledge of radiation safety is crucial in controlling the radiation hazards of diagnostic examinations, since many unnecessary examinations are in fact performed every year (Jacob, 2004).

This chapter will discuss in more depth the topic of radiological examinations, including the following:

- The range of common medical imaging techniques
- The radiation doses connected with these radiological examination procedures
- The harmful effects of ionizing radiation from radiological examinations
- Hypotheses regarding the harmful effects of radiation doses
- ICRP recommendations and radiation safety standards
- Physicians knowledge of radiological examinations hazards

2.2. Medical imaging techniques

This refers to the techniques and processes used to create images of the human body for clinical purposes, in order to diagnose and detect disease or injury or to study the normal anatomy and physiology of the human body. Many medical imaging techniques involve the use of the ionizing radiation emitted by X-ray machines. In general, medical imaging employs the following techniques to produce images:

- Projection (plane) radiography
- Fluoroscopy
- CT scanning
- Nuclear Medicine
- Ultrasound
- MRI (Magnetic Resonance Imaging)

Each one of these will be discussed in more detail in the following sections:

2.2.1. Projection (plain film) radiography

Radiographs or Roentgen-graphs, named after the discoverer of X-rays, Wilhelm Conrad Roentgen (1845–1923), are often used for the evaluation of bony structures and soft tissues. The plain film radiography machine directs electromagnetic radiation onto a specified region of the body, radiation which passes through the less dense matter (e.g. air, fat, muscle and other tissues) but is absorbed or scattered by denser material (e.g. bones, tumors, or lungs affected by severe pneumonia), as shown in figure (2.1). In this type of medical imaging, the radiation which has passed through a patient's body strikes a cassette containing a screen of fluorescent phosphors on both sides which in turn pass to the X-ray film which is also situated in the cassette. Areas of the film exposed to higher levels of radiation will appear as black or grey on X-ray film, while areas exposed to less radiation will appear lighter or white.

Figure (2.1) Conventional plain radiography equipment

In recent years a new type of projection radiography was created, which is called Computed Radiography (CR), as shown in figure (2.2). The CR uses a sensitized plate, instead of the X-ray film used in the older method, in order to receive the X-rays which pass through the patient; this sensitized plate reads the X-rays and, via a special processor connected to a computer, produces a digitized image. There is now a still more advanced form of projection radiography called Digital Radiography, as shown in figure (2.3), in which the X-rays strike a plate covered with X-ray sensors which then produce a digital computer image directly. The X-ray machine in Digital Radiography is directly connected to a computer and there is no need for a special machine to mediate between the X-ray machine and the computer.

Figure (2.2) CR equipment

Figure (2.3) Digital X-ray equipment

The most common type of medical imaging is plain film radiography, which was the *only* imaging modality available during the first 50 years of radiology. It is still the most frequently ordered radiological examination for the evaluation of the lungs, heart and skeleton, because of its wide availability, speed and relatively low cost (Simon, 2006).

2.2.2. Fluoroscopy

Fluoroscopy and angiography are special applications of X-ray imaging in which a fluorescent screen, or image intensifier tube, is connected to a closed-circuit television system, allowing real-time imaging of structures in motion (sometimes enhanced with a radio-contrast agent), as shown in figure (2.4). Radio-contrast agents, often administered by swallowing or being injected into the body of the patient, are used to delineate the anatomy and functioning of blood vessels, the genitourinary system, the gastrointestinal tract, etc. Two radio-contrast materials are presently in use: a barium substance, which may be given orally or rectally for evaluation of the gastro-intestinal (GI) tract and iodine-contrast available in multiple proprietary forms, which may be given via oral, rectal, intra-arterial or intravenous routes. These radio-contrast agents either strongly absorb or scatter the X-ray radiation and, in conjunction with the real-time imaging, allow the observation of dynamic processes such as peristalsis in the digestive tract or blood flow through arteries and veins. Iodine-contrast may also be concentrated in abnormal areas more (or less) than in normal tissues and thus make abnormalities (tumors, cysts, inflammation) show up more distinctly. Additionally, in specific circumstances air can be used as a contrast agent for the gastrointestinal system, and carbon dioxide can be used as a contrast agent in the venous system. In these cases, the contrast agent attenuates the X-ray radiation less than the surrounding tissues (Norris, 2002).

Figure (2.4) Fluoroscopy equipment

2.2.3. Computer Tomography (CT) scanning

The first commercially viable CT scanner was invented by Godfrey Hounsfield in Britain in 1972 (Groves, et al, 2004).

CT imaging uses X-rays in conjunction with computing algorithms in order to image the body, as shown in figure (2.5). In a CT scan, an X-ray generating tube is set opposite an X-ray detector (or detectors) a ring-shaped apparatus which rotates around a patient, producing a computer-generated cross-sectional image (tomogram). Radio-contrast agents are often used with CT scanning in order to enhance the delineation of anatomy. Although radiographs provide higher spatial resolution, CT scanning detects more subtle variations in the attenuation of X-rays (Brenner & Hall, 2007).

The introduction of CT technology revolutionized medical imaging, however it also involves radiation doses greater than in most previous imaging modalities. Moreover, the radiation dose to the patient from the newer multi-slice CT scanners is higher than from the previous single-slice helical scanning devices. CT currently represents 10% of all radiological procedures but almost 70% of the overall radiation burden. For example, it is estimated that 2.7 million pediatric CT examinations are performed every year in the U.S.A. (Henry, et al, 2007). Many studies have estimated the lifetime cancer mortality associated with the radiation doses commonly involved in pediatric CT and concluded that a young child undergoing CT has an increased lifetime risk of fatal cancer of approximately 1 in 1,000 (Brenner & Hal, 2007).

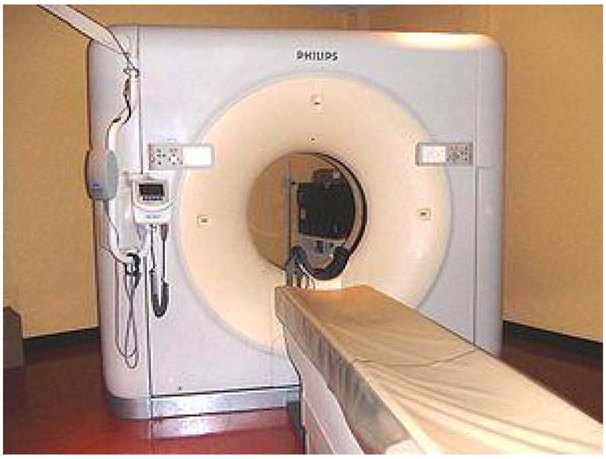

Figure (2.5) Computer Tomography (CT scan) equipment

2.2.4. Nuclear Medicine

The fourth type of diagnostic imaging is nuclear medicine, which involves the administration of radiopharmaceuticals consisting of substances with an affinity for certain body tissues and labeled with radioactive tracers. The most commonly used tracers are Technetium-99m, Iodine-123, Iodine-131 and Thallium-201. The heart, lungs, thyroid, liver, gallbladder, and bones are commonly evaluated for particular conditions using these traces. Nuclear imaging is also useful in displaying physiological function, for example the excretory function of the kidneys, the iodine concentrating ability of the thyroid, and the blood flow to the heart muscle. The principal imaging device is the gamma camera which detects the radiation emitted by the tracer in the body and displays it as an image, as shown in figure (2.6). In the most modern devices, nuclear medicine images can be fused digitally with a CT scan in order to improve diagnostic accuracy (Regulla & Eder, 2005).

Figure (2.6) Nuclear medicine equipment

2.2.5. Ultrasound

In addition to the above diagnostic technologies, ultrasonography is another modality of medical imaging. It uses ultrasound (high-frequency sound waves) to produce images of soft-tissue structures in the body in real time, as shown in figure (2.7). No ionizing radiation is involved, however the quality of the images obtained using ultrasound is highly dependent on the skill of the person performing the exam (ultrasonographer). Ultrasound is limited by its inability to image through air (e.g. the lungs or bowel loops) or bone (Cosgrove, 2003).

The use of ultrasound in medical imaging has developed mostly within the last 30 years. Because ultrasound does not utilize ionizing radiation (unlike radiography, CT scans and nuclear medicine), this imaging technique is considered generally safe and thus plays a vital role in obstetrical imaging. Fetal anatomic development can be thoroughly evaluated, allowing early diagnosis of many fetal anomalies or simply the assessment of fetal growth over time. Ultrasound is also used to measure the severity of peripheral vascular disease such as of the heart, heart valves and major vessels in the legs. It is likewise useful for image-guided interventions like biopsies, and for drainages such as thoracentesis. Ultrasound is also utilized in the treatment of kidney stones (renal lithiasis) via lithotripsy (Cosgrove, 2003).

Figure (2.7) Ultrasound equipment

2.2.6. Magnetic Resonance Imaging (MRI)

MRI is the sixth type of medical imaging, as shown in figure (2.8). This technique employs a strong magnetic field in order to align spinning atomic nuclei, usually hydrogen protons, within body tissues. It then disturbs the axis of rotation of these nuclei by the use of radio waves and finally detects the signals generated as the nuclei return to their baseline states once the source of radio waves is turned off. The signals are picked up by small antennae (called coils) placed near the area of interest in order to create a medical image. One advantage of MRI is its ability to produce images in axial, coronal, sagittal and multiple oblique planes, all with equal ease. It yields the best soft-tissue contrast of all the imaging modalities and has become an essential tool in musculoskeletal radiology and neuroradiology (Rosen, 2007).

One disadvantage is that the patient has to hold still for long periods of time in a noisy, cramped space while the imaging is performed. This situation may cause a type of phobia (claustrophobia) severe enough to necessitate terminating the MRI exam. Recent improvements in magnet design have made possible more “open” magnet designs permitting wider and shorter magnet bores, stronger magnetic fields (3 Teslas), and shorter exam times. As mentioned, MRI delivers great benefits in imaging the brain, spine and musculoskeletal system. However, the MRI modality is currently contraindicated for patients with pacemakers, cochlear implants, some indwelling medication pumps, certain types of cerebral aneurysm clips, metal fragments in the eyes, and some metallic hardware—due to the powerful magnetic fields and the strong fluctuating radio signals the body is exposed to (Rosen, 2007).

Figure (2.8) Magnetic Resonance Imaging equipment (MRI)

All of the above-mentioned modalities exist in the major Palestinian hospitals such as Al-Makassed Hospital and Ramallah Governmental Hospital, except for the nuclear medicine modality (Palestinian Medical Imaging Association, 2007).

Because most of these medical imaging modalities utilize ionizing radiation, it is important to understand the doses of ionizing radiation associated with the different radiological examinations, and their units of measurement.

2.3. Radiation doses related to various radiological examinations

This section describes the basic dosimetry measurements (and their units) used to express the radiation doses to which patients are exposed during radiological examinations: absorbed dose, equivalent dose and effective dose.

1) Absorbed dose: This is defined as the energy deposited in a small volume of matter (such as metal, wood, human tissue, etc) by the radiation beam passing through the matter, divided by the mass of the matter. It is thus measured in terms of energy deposited per unit of mass of material. Absorbed dose is measured in joules/kilogram. In the International System of quantities and units there is a special unit to describe the absorbed dose, which is "Gray" (Gy), with 1 gray being equal to 1 joule/kilogram. A sub-unit is the Rad, with 1 gray equaling 100 rads (UNSCEAR, 2000).

$$\textit{Absorbed dose} = \textit{deposited energy} \,/\, \textit{mass of deposited material}$$

2) Equivalent dose: The biological effects of an absorbed dose (on living tissue) of a given magnitude are dependent on both the type of radiation delivering the energy (such as X-rays, beta, or alpha radiation) and the amount of radiation absorbed. This variation in effect is due to differences in the manner in which different types of radiation interact with tissue. The variation in the magnitude of the biological effects due to different *types* of radiation is described by the radiation weighting factor (also called quality factor) for the specific radiation type. Thus, when the absorbed dose (in Gy) is multiplied by the radiation weighting factor, the result is the equivalent dose. The unit for expressing the equivalent dose is the Sievert (Sv). Equivalent dose likewise has a sub-unit called the rem, with 1 sievert equaling 100 rem (UNSCEAR, 2000).

$$H = D \times W_R$$

H = the equivalent dose in sievert

D = the absorbed dose in gray

W_R = the radiation weighting factor

3) Effective dose: An additional important concept is effective dose, which is used to give an estimate of patient risk and permit a comparison of the risks when different organs are irradiated. It is calculated by determining the equivalent dose to each organ irradiated and then multiplying this equivalent dose by a tissue-specific weighting factor for each organ or tissue type (tissue-specific weighting factors are shown in table 2.1). This tissue- or organ-specific weighting factor accounts for the variations in the risk of cancer induction or other adverse effects for various specific organs. These products of equivalent dose times tissue weighting factor are then added together for all the irradiated organs in order to calculate the effective dose (UNSCEAR, 2000).

$$E = W_T \times H_T$$

E = the effective dose

W_T = the tissue weighting factor

H_T = the equivalent dose in the tissue T

Table (2.1) Tissue weighting factor (ICRP, 1991)

Organ/ tissue	Quality factor
Gonads	0.20
Lung, Stomach, Colon, Bone marrow	0.12
Breast, Thyroid, Esophagus, Bladder, Liver, Remainder	0.05
Bone surface, Skin	0.01

Several simple and comparative ways are often used to communicate the radiation doses for different radiological examinations, such as comparing the effective dose from any radiological procedure with the dose received from naturally-occurring sources during a certain period of time in a specified part of the world, such as the USA, UK, Iran, etc. In table (2.2), the effective dose from each type of radiological examination is compared with the dose received from natural sources (in the USA), which is equivalent to 3 milli sievert per year. For example, one abdominal CT irradiates a patient with an effective dose of 10 mSv, which is equivalent to the radiation exposure from natural sources over a period of 3.3 years (Henry, at el, 2007).

Table (2.2) Comparison of Radiation doses for different types of radiological examinations (ICRP, 1991; NCRP, 2001)

Diagnostic procedure	Typical effective dose (mSv)	Number of chest X-rays (posterior anterior film) for equivalent effective dose	Time period for equivalent Effective dose from natural background radiation
Chest X-ray (PA film)	0.02	1	2.4 days
Skull X-ray	0.08	4	9.7 days
Lumbar spine	1.3	65	158 days
Pelvis (AP)	0.7	35	84 days
Dental (panoramic)	0.09	4.5	10.5 days
I.V. pyelogram	2.5	125	304 days
CT head	2.0	100	243 days
Upper G.I. exam	3.0	150	1.0 year
Barium enema	7.0	350	2.3 years
CT Chest	8.0	400	2.6 years
CT abdomen	10.0	500	3.3 years

The sources of natural background radiation include (Gilman, et al, 1998):

- The earth itself, including sources such as food and water;
- Outer space, whose radiation reaches the human body as cosmic rays;
- The atmosphere, mainly from radon gas. Another contribution comes from radioactive atoms.

The level of natural background radiation varies greatly depending on location, thus in some areas the level is significantly higher than average, such as Ramsar in Iran, Guarapari in Brazil, Kerala in India and Yangjiang in China. In Ramsar a peak yearly dose of 260 mSv has been reported (Gilman, et al, 1998).

The standard chest X-ray is also used as a convenient comparative measure of effective dose for other diagnostic procedures. The effective dose of one chest X-ray equals 0.02 mSv, which here equals one unit. Thus, one lumbar spine radiological examination, for example, exposes the patient to a total radiation dose equal to 65 chest X-rays, as shown in table (2.2).

Another important issue is the *safe* dose of ionizing radiation. Diagnostic ionizing procedures expose both patients and medical staff to significant levels of radiation. As the number of diagnostic procedures being performed has greatly increased, serious radiation hazards such as skin injuries and an excess of cataract development have been reported in exposed staff (Morrish & Goldstone, 2008).

To overcome these problems, there are defined dose limits for ionizing radiation from radiological examinations—for staff, trainees (radiological students) and the public—which should not be exceeded under any circumstances. These limits have been developed by ICRP for each group according to their familiarity with radiation exposure and according to the sensitivity of different body organs, as shown in table (2.3). For example, radiation workers are allowed the highest dose levels (20 mSv per year) because, according to their work circumstances, they might be unable to avoid radiation doses as much as other sectors of the population. Trainees or workers who are occasionally exposed to radiation are limited to lower doses (6 mSv/year), while the general public have the lowest dose limits (1 mSv/year) **(**Francis, et al, 2004).

Also, data from table (2.3) indicates that ionizing radiation affects fetuses disproportionately, so they should not receive more than 1mSv per year in either classified staff or unclassified/trainees. For women within the general public, their fetuses should not be exposed to radiation at all (Walter**,** 2007).

Table (2.3) Annual dose limits for various groups of people

	Classified staff	**Unclassified /trainees**	**Public**
Whole body	20 mSv	6 mSv	1 mSv
Eyes	150 mSv	50 mSv	15 mSv
Organs	500 mSv	150 mSv	50 mSv
Fetus	1 mSv (during the period of pregnancy)	1 mSv (during the period of pregnancy)	

Regarding the radiation dose limits set for the general public, they take into consideration that there are other radiation exposures which affect the general public, especially from the "natural background", plus an exposed individual may show greater sensitivity than within the more limited population of radiation workers **(**Francis, et al, 2004).

However, despite ICRP recommendations, the international scientific community has adopted a prudent approach, acknowledging the fact that *any* level of exposure could potentially lead to biological effects. This stance is intended to prevent any significant radiation-related public health problems, such as genetic defects. This really means that there is *no* limit dose for radiation effects, and any increase in dose, no matter how small, may result in an incremental increase in risk (Brian, et al, 2008).

Because the patient *has* no defined annual radiation dose limit, the radiation protection regulations which are recommended by ICRP place responsibility upon the prescriber and the practitioner alike to keep the radiation dose to the patient as low as possible, in order to protect patient from the harmful effect of radiological examinations (ICRP, 2008).

2.4. Harmful effects of ionizing radiation from radiological examinations

2.4.1. Introduction

Ionizing radiation is known to cause harmful biological effects. High radiation doses tend to kill cells, while low doses tend to damage or alter the genetic code (DNA) of irradiated cells (Maria, 2004). The biological effects of ionizing radiation are divided into two categories: deterministic (nonstochastic) and stochastic effects. Deterministic effects are the predictable and preventable effects of ionizing radiation, such as *erythema* (temporal redness on skin), *epilitation* (hair loss), and decreased sperm count. This type of radiation effects have a threshold dose below which the biological effect is not observed (see figure 2.9) (Tubiana, 2000). Some interventional procedures which involve long screening times and multiple image acquisition (e.g. percutaneous coronary intervention, angioplasty, etc) may give rise to deterministic effects in both staff and patients (Herzog & Rieger, 2004).

Table (2.4) provides data about several bodily symptoms known to occur as a result of deterministic effects of radiation doses. The corresponding threshold dose for each symptom or effect must be reached or exceeded before the symptom will be clinically observable. For example, dermal necrosis occurs if a radiation dose of 18 Sv reaches the skin of the human body.

Table (2.4) Deterministic effects of ionizing radiation from radiological examinations (Faulkner & Vano, 2001)

injury	Threshold dose to skin (Sv)
Transient erythema (temporary redness of skin)	2
Permanent epilation (hair loss)	17
Dry desquamation (peeling or shelling of skin)	14
Dermal necrosis (impaired tissue due to blood shortage)	18
Telangiectasia (dilatation in blood vessels and redness)	10
Cataract (clouding of the lens of the eye)	>5

The second type is a stochastic effect, which is a random and unpredictable effect of ionizing radiation and can result in cancer or genetic mutations. There is no known threshold dose for this kind of effect, but it can occur even at low levels of radiation exposure (the linear no-threshold (LNT) hypothesis), and each additional increment of dose, however small, carries an associated increment of risk (see figure 2.9). The likelihood of inducing the effect (but not necessarily its severity) increases in relation to dose, and may differ among individuals (Herzog, et al, 2004).

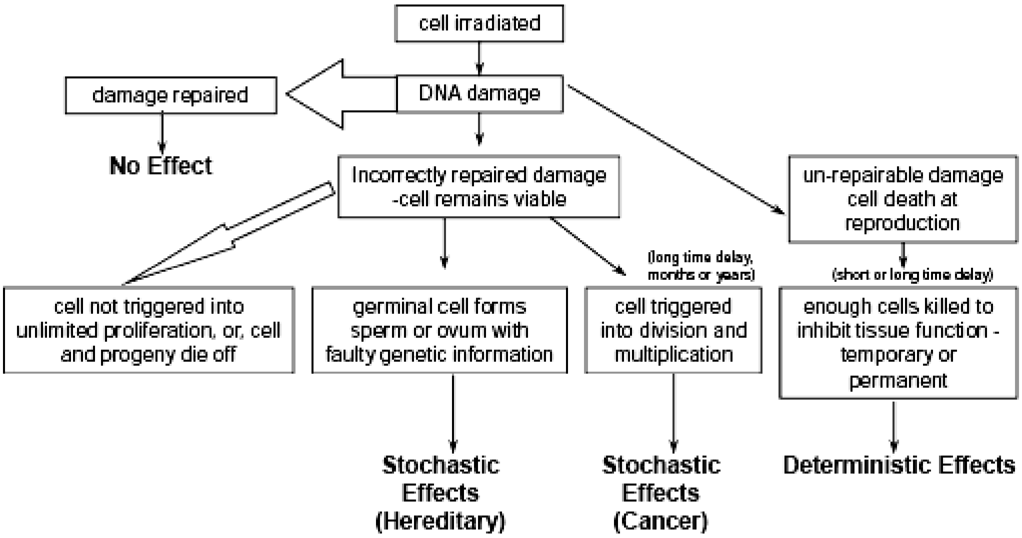

Figure (2.9) Harmful effect of ionizing radiation (ICRP, 2007)

In general, the biological effects of low-dose radiation on living cells may result in three outcomes: (1) injured or damaged cells repair themselves, resulting in no residual damage; (2) cells die; or (3) cells incorrectly repair themselves, resulting in a biological change. Such biological changes include both the development of cancer and the triggering of genetic defects in the future children of exposed parents (Brenner, 2003).

All scientists agree that high doses of radiation are hazardous to cells and tissues, but there is ongoing debate regarding the harmful effects of ionizing radiation at low doses (<100mSv). As a result, two hypotheses have emerged among scientists about the harmful effects of low radiation doses: the linear no-threshold hypothesis and the hormesis hypothesis (Henry, et al, 2008).

2.4.2. Hypotheses of harmful effects of low radiation doses

2.4.2.1. Linear no-threshold hypothesis *versus* hormesis hypothesis

As mentioned previously, there are two hypotheses that may or may not support the harmful effects of low doses of radiation from radiological examinations: The linear no-threshold hypothesis (LNT) proposes that damage may be caused by ionizing radiation at *all* levels of radiation doses, and the response is linear (i.e., directly proportional to the dose), as shown in figure (2.10). Thus LNT asserts that there is *no* threshold of exposure below which ionizing radiation is safe to the human body (Calabrese, 2003). This hypothesis has been upheld by most radiation protection organizations, such as the International Commission on Radiological Protection (ICRP), the International Atomic Energy Agency (IAEA), the United Nations Scientific Committee on the Effect of Atomic Radiation (UNSCEAR), and by other authorities worldwide, including most scientists who are concerned about radiation protection (ICRP, 2008).

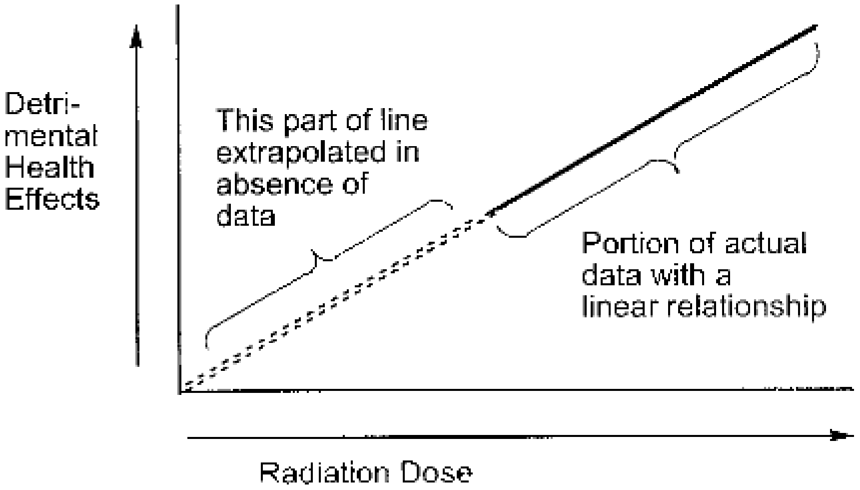

Figure (2.10) A linear no-threshold (LNT) relationship between radiation dose and health effect

The other hypothesis, which stands in contrast to the linear no-threshold (LNT) hypothesis, is the radiation hormesis hypothesis. It suggests that ionizing radiation, at levels that occur in the natural environment, may actually *enhance* health by stimulating natural defense mechanisms, and thus low-level radiation is either harmless or may in fact be beneficial, as shown in figure (2.11). However, this hypothesis does accept that radiation above natural background levels does have harmful effects; for example, they support the idea that intense artificial radiation is toxic (Calabrese & Linda, 2003). This hypothesis was adopted mainly by the French Academy of Sciences, the American National Academy of Medicine, and the American Nuclear Society, in addition to many scientists who disagree with the Linear No-Threshold Hypothesis (Miyachi, 2000).

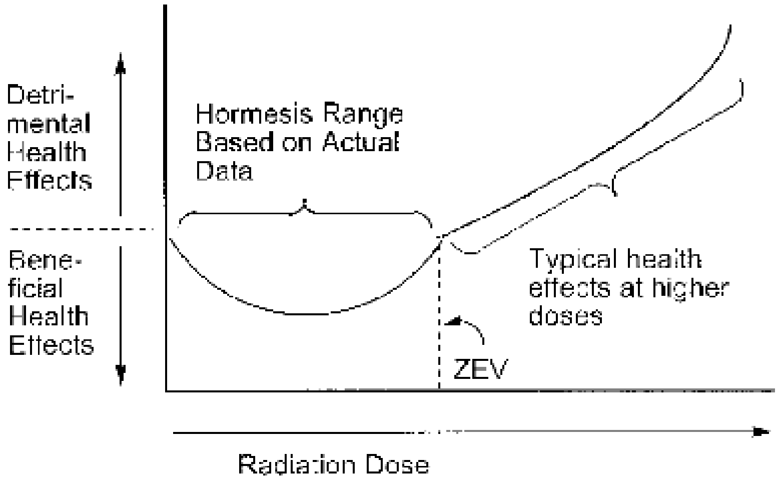

Figure (2.11) Radiation hormesis relationship. ZEV means Zero–equivalent value and supposes that all doses below this value have no harmful effect.

For example, in 2005 the French Academy of Sciences-Medicine supported the hormesis hypothesis in it's report, claiming that scientific evidence shows that the human body is not a passive accumulator of radiation damage but rather actively repairs the damage, and that the body's cells have developed a number of different mechanisms by which they are able to safeguard their DNA. It also indicates that this process not only protects the cells but provides them with some type of immunity against future radiation damage, i.e. with definite beneficial effects (Tubiana, et al, 2006). On the other hand, the ICRP argued that there are no longitudinal studies, involving many subjects over long periods of time, to prove that the subtle damage caused by very low-level doses of ionizing radiation are repaired by the body without exception. Also, it debated that the difficulty of following millions of people exposed to low level of radiation, and the existence of cancer-induced confounding factors, are the main reasons for the absence of epidemiological studies seeking to exclude the cancer risk from low doses of ionizing radiation (ICRP, 2008).

However, many animal, cellular and epidemiological studies have tried to examine the health effects of low radiation doses. Most of these studies reject the radiation hormesis hypothesis, and few studies support this hypothesis. The following section reviews many studies that support each of the two hypotheses, with critical analysis where necessary.

2.4.2.2. Studies that support the liner no-threshold hypothesis (LNT)

Studies that support the harmful effects of all ionizing radiation are of several types, according to the source of exposure, the setting or context of the exposure, and the target of exposure. These studies can be divided into:

- Animal and cellular studies
- Epidemiological studies

Animal and cellular experiments have been very useful in elucidating the biologically harmful effects of ionizing radiation, especially in the attempt to resolve the debate among researchers and others regarding the impact of low doses of such radiation. For example, in 2003 Zelanna et al conducted an experimental study in the USA by using full-thickness human skin resected (cut out) during surgery in order to assess the risk of low doses. This biopsy of skin tissue was exposed to low doses of ionizing radiation equal to doses that are used in certain low-dose radiological examinations. The findings, the result of analysis by rather complicated techniques, revealed changes in gene expression. This study provided initial evidence that ionizing radiation exposures as low as 1 centigray (cGy) are biologically active in human skin (Zelanna, et al, 2004).

Another study was conducted by Anoopkumar et al (2005) in Ireland to assess cell response to ionizing radiation doses in the diagnostic X-ray range. So-called “HeLa” cell cultures, obtained from cancerous cervical tissue and maintained for use in studying cellular processes, were irradiated between 3.5 mGy and 55.1 mGy. After seven days, the metabolic capacity of the cultures was measured via laboratory tests. The researchers noted abnormal HeLa cell proliferation and high cellular division rates as a result of radiation doses within the range of some common radiological examinations (around 7.5 mGy and greater) (Anoopkumar, et al, 2005).

One recent study was conduct in the USA by Kiran et al (2008) in order to detect the DNA damage produced as a result of exposure to ionizing radiation. The plasmid DNA was exposed to ionizing radiation by means of an X-ray tube with 70 kev and 20 mA, then the damage to DNA was detected by a special tool called gel electrophoresis. As a result of this low radiation dose, the DNA nature was changed from translated super-coiled to an open circle conformation which was detected in the form of single-strand breaks (SSBs) in DNA. This change in the shape of the DNA as a result of low radiation dose provides further evidence of the harmful effects of even these low doses (Kiran, et al, 2008).

These findings are supported by yet another experimental study, conducted in the UK by Lorimore (2001) to examine the effect of ionizing radiation on haempaietic tissues of mull mice by exposing it to ^{35}P radiation. Findings revealed an inflammatory type response in the mice that were exposed to ionizing radiation. This inflammatory response was also found to be associated with cellular genetic changes. The findings of this study support other results which reported genetic changes as a consequence of exposure to ionizing radiation (Lorimore, 2001).

The second source of data about the harmful effects of ionizing radiation is the epidemiological studies involving human subjects. This epidemiological data mainly derives from studies on:

- Atomic bomb survivors and Chernobyl nuclear accident victims
- Medical radiation
- Occupational radiation exposure of radiation workers
- Natural background radiation

Atomic bomb survivors and *Chernobyl nuclear accident studies:*

Much of what is known about the harmful effects of ionizing radiation, especially about the carcinogenic effects of radiation, is derived from studies of atomic bomb survivors of Hiroshima and Nagasaki. For example, one study was conducted by Nezahat (2006) to recheck the findings of a study conducted by Stewart and Kneale in the year 2000; the later study reported significantly higher radiation risks, for both cancers and non-cancerous diseases, among atomic bomb survivors in Japan. Nezehate, adopting the same methodology that was used by Stewart et al, analyzed data obtained from a special version of the Lifespan Study (LSS) which provided information on 75,991 Hiroshima and Nagasaki survivors. Doses were calculated by a special tool called DS86 and covered the period from 1950 to 1985. Findings indicated a highly significant, radiation-related risk of cancer among Japanese atomic bomb survivors. It was found that 5,491 out of these 75,991 survivors had solid cancers (Nezahat, 2006).

Epidemiological studies on Chernobyl nuclear accident victims are the other main source of data regarding harmful effects of ionizing radiation. Cardis et al. (2005) conducted a large population-based, case-control study in the Gomel and Mogilev regions in Belarus and the Bryansk, Kaluga orel and Tula regions in Russia. The study included 276 thyroid cancer cases that were diagnosed between 1992 and 1998, along with 1300 controls. All cases were under 15 years of age at the time of the accident. The cases and controls were examined for the thyroid doses from ^{131}I (exposure to ionizing radiation), based on previous estimates of average, age-specific doses for each subject's place of residence. In addition, questionnaires were distributed to both cases and controls regarding potential radiation exposures from external sources and possible intake of radioiodine materials (e.g. with food). Findings revealed that the risk of thyroid cancers among people who were exposed to radiation up to about 2 Gy was several times greater than for the controls (Cardis, et al, 2005).

Another retrospective cohort study was conducted by Stezhko et al. (2000) to assess the prevalence of thyroid cancer in relation to exposure from Chernobyl. The sample consisted of 25,161 participants (11,918 in Belarus and 13,243 in Ukraine) who were more than 18 years of age at the time of the accident. These participants were screened by palpation and ultrasound every 2 years, from the time of accident (1987) until the year 2000. A unique aspect of this study is that every cohort member had a direct measurement of thyroid gland activity performed within six weeks after the accident. Exposure to ionizing radiation was previously estimated for each subject's place of residence, and data about the health status of participants was collected via a personal interview. The findings revealed a strong dose-response relationship regarding the development of thyroid cancer, even for those who were exposed to less than 0.3 Gy (low doses). This result supports the LNT hypothesis which indicats that there is *no* safe dose regarding radiation hazards (Stezhko, et al, 2004).

Medical radiation studies:

The second most useful epidemiological source of data about ionizing radiation and its effects is medical radiation studies. The analysis of the data from medical sources is complicated by some confounding factors and by the presence of disease in the study subjects. Some of these medical radiation studies were conducted in the diagnostic field and others were conducted in the therapeutic field. For the studies conducted in the diagnostic field, usually the radiation doses from radiological examinations were calculated, then the harmful effects of these doses were predicted based on the harmful effects of similar radiation doses received by Japanese atomic bomb survivors (Henry, 2008). For example, a significant study which raised considerable attention to the increasing risks from radiation doses associated with pediatric CT scans was conducted by David Brenner (2004) in the USA. It aimed to assess the lifetime cancer mortality risks attributable to radiation from pediatric CT. The study looked at many pediatric CT scan examinations involving over 121 different machines, plus another 108 machines used specifically for abdominal CT scans, and the related doses were estimated theoretically via mathematical equations. Also, attributable lifetime cancer mortality risks (per unit dose) for different organ sites were estimated based on data obtained from the atomic bomb survivors of Hiroshima and Nagasaki which showed lifetime cancer mortality risk for each radiation dose. These data were obtained by the American National Academy of Sciences, the Biological Effects of Ionizing Radiations Committee and by the International Commission on Radiological Protection. Findings indicated the overuse of unnecessary radiological examinations, in addition to the exposure of children to high doses of radiation similar to adult doses. The authors concluded that in the USA, of approximately 600,000 abdominal and head CT examinations performed annually in children under the age of 15 years, a rough estimate is that 500 of these individuals might ultimately die from cancer attributable to the CT radiation. However, even though this study is considered one of the seminal studies which create debate among researchers, its findings have limitations since it depends mainly on already recorded information and statistical equations (Brenner, 2004).

Another study was conducted in the USA (2007) by Walter to assess the lifetime risk of cancer from Computed Tomography chest examinations. The researcher estimated the effective doses that are used to conduct a chest CT examination, using mathematical equations based on the data obtained from the Department of Radiology at Medical University, Syracuse, New York. The effective doses from CT examination in this American hospital were calculated and it was on average approximately 1.7 millisieverts (mSv) in newborns and approximately 5.4 mSv in adults. The attributable lifetime cancer mortality risks from these effective doses were estimated, based, again, on data obtained from the Japanese atomic bomb survivors, showing lifetime cancer mortality risk for each radiation dose. Findings indicted that there is a nominal excess risk of carcinogenesis of approximately 1.5 cancers per 10,000 individuals among 5-year-old patients exposed to 0.55 mSv from CT scan examinations (Walter, 2007).

Finally, Micheal. conducted a study (2004) in Greece to estimate the risk of cancer from skull radiography. Using a dosimeter, he estimated the radiation doses associated with 136 pediatric X-ray examinations of the skull. These estimated doses were then used to calculate the effective doses using mathematical equations. The risk of cancer from the calculated effective doses was then estimated, once again by comparing them with similar doses from the 1945 atomic bomb survivors. Based on this data, the risk of fatal cancers was found to be equivalent to 2 per million in children undergoing posterior-anterior (PA) skull X-rays (Micheal, 2004).

Despite the fact that epidemiological studies are very difficult to conduct among patients who were exposed to low doses from radiological examinations, due to the presence of confounding factors and the need for a large number of participants, some researchers have tried conducting such studies. However, the results of these studies are not strong, since they did not include a large number of participants. Most of the results supported other epidemiological studies including atomic bomb survivors and the Chernobyl accident. For example, Myles et al. conducted a case–control study in the UK (2007) to investigate whether exposure to low doses of ionizing radiation from diagnostic X-ray procedures could be established as a risk factor for prostate cancer. The sample consisted of 431 cases with prostate cancer who were at least 60 years old, and 409 controls who were matched by age. Subjects were sent a questionnaire by post which included questions on demographic characteristics, lifestyle, occupational exposures, and history of diagnostic radiology procedures. Exposures via barium meal, barium enema, hip X-rays, leg X-rays and intravenous pyelogram (IVP) were considered. Odds ratios (OR) and 95 percent confidence intervals (95% CI) were calculated for each of the exposure variables. The findings showed that exposures to barium enemas (odds ratio (OR) 2.06, (CI) 1.01–4.20) and hip X-rays (OR 2.23, CI 1.42–3.49) five years or more before the diagnosis were significantly associated with increased prostate cancer. This effect seems to be modified by a positive family history of cancer, suggesting that genetic factors may play a role in this risk association (Myles, et al, 2008).

Many studies conducted on patients who were treated with radiotherapy likewise provide evidence that ionizing radiation has associated harmful effects. The high radiation doses typically used in radiotherapy may make it difficult to compare the risk that applies to patients of radiotherapy with that from diagnostic radiology. For example, Kihyuck at el (2006) conducted a study in the USA to examine the size and significance of the observed association between radiotherapy and occurrences of secondary cancers (within five years after the radiotherapy) in a large population of men with an incident diagnosis of prostate cancer. The data obtained from the American Medicare health program registry for men who had an incident diagnosis of prostate cancer from 1973 through 1999 and who were enrolled in the Medicare program at any time either before or after their diagnosis was obtained. Researchers limited their primary analysis to men with a histologically confirmed incidence of prostate cancer diagnosed from 1973 to 1994 who survived for ≥5 years after the date of their diagnosis. The findings indicated that patients who received radiotherapy had significantly higher risk of developing second cancers, not only in the areas that were exposed to radiation but also in other areas which were not directly exposed to radiation (Kihyuck, at el, 2006).

Occupational radiation studies:

The third epidemiological source of data about ionizing radiation is occupational studies that were conducted to investigate the biological effects of X-rays among radiation workers, especially among medical diagnostic X-ray workers such as radiographers, radiologists and radiology nurses. For example, one cohort study was conducted by Wang at major hospitals in 24 provinces of China between the years 1950–1995 to assess cancer risk and the evidence for human malignant tumors being produced by ionizing radiation. The study sample included 27,011 medical diagnostic X-ray workers (radiologists and technicians) who were compared with 25,782 other medical specialists without professional radiation exposures. The first retrospective cohort study was conducted in 1981. Tables were obtained from hospital administration records of all employees in the selected occupational categories hired between 1 January 1950 and 31 December 1980. All workers who were enrolled in the study were interviewed for information concerning occupational histories and demographics. The second, third, and fourth prospective cohort studies were conducted between the years 1981 and 1995. Data was collected by interviewing the subjects (or their families) for information about the subjects' occupational history and health status, with an emphasis on the occurrence of cancer or death or periods when they stopped working due to radiation-related diseases, during the observation period. The findings indicated a significant cancer risk, such as for leukemia and cancers of the skin, breast, lung, liver, bladder, and esophagus, among medical diagnostic X-ray workers as compared to other medical specialists. It was also found that the risk of skin cancer was four times higher among medical diagnostic X-ray workers than for the other specialists, and the risk of esophagus cancer was three times higher (Wang, 2006).

Some studies showed that, in addition to cancer, many other physical diseases such as hearing problems may occur as a result of occupational radiation exposures. For example, a case-control study was conducted in Turkey by Turgut et al (2004) to evaluate the changes in hearing in workers who were exposed to low-dose ionizing radiation over a long period of time. The sample included 57 technical staff (49 males and 8 females) who worked in radiology-related jobs and were exposed to occupational radiation, for periods ranging from 4 to 23 years. The control group consisted of 32 volunteer subjects (27 male and 5 female) with normal hearing.

Several tests were carried out to determine their hearing thresholds. The findings showed that tinnitus, vertigo and hearing loss were observed more in the subjects who were exposed to the radiation than in subjects from the control group who were not exposed to occupational radiation doses. Despite the importance of this study, it had several limitations, such as a relatively small number of participants (Turgut, et al, 2004).

In the USA, Gabriel at el, conducted a prospective cohort study to determine the risk of cataracts among radiological technologists with respect to both occupational and non-occupational exposures to ionizing radiation and to personal characteristics. The study sample consisted of 35,705 cataract-free radiological technologists aged 24 to 44 years who were followed for nearly 20 years (1983–2004). Data was collected by using two follow-up questionnaires. During the study period, 2,382 cataracts and 647 cataract extractions were reported. The findings indicated that the cataractogenic dose in humans is substantially less than previously thought by the American National Council on Radiation Protection and the International Commission on Radiological Protection (2Gy), and that cataracts may occur at low levels of radiation exposure (less than 1Gy) (Gabriel, at el, 2008).

Natural background radiation studies:

The final epidemiological source of data about radiation hazards is environmental studies. Studying the long-term impact of chronic exposure to ionizing radiation from natural background sources facilitates the investigation of the potential risks to living organisms from chronic, low-intensity radiation generally. More specifically, it aids our understanding of how long-term radiobiological exposure affects populations in radioactivity contaminated areas (Alevtina, 2007).

For example, one cohort study was conducted by Gilman & Knox, to examine the geographical variation in risk for all types of childhood cancers in the UK, on a scale corresponding to the 10-km squares in the surveyed area. The effects of natural background radiation were investigated and their relative importance was assessed. Data was obtained from a national collection of all fatal cancers between 1953 and 1980 in children aged 0-15 years. The sample consisted of 9,363 children of known place of birth, from 12 complete annual cohorts, born in the period 1953-1964. For solid cancers, as well as for leukemia and lymphomas, there was a marked variation of cumulative mortality according to the place of birth. The mortality rate was found to be higher in areas of high radon exposure (Gilman & Knox, 1998).

Another cohort study was conducted by Gonzalo et al in order to examine the geographic pattern of kidney cancer mortality in Spain, to suggest possible hypotheses that would help explain these patterns, and to enhance existing knowledge about the large proportion of kidney tumors whose cause remains unknown. Researchers used individual death entries for the period 1989–1998 and the cases of kidney cancer resulting in death were calculated for both men and women nationwide, from data furnished by the Spanish National Statistics Institute. The findings of the study indicated that the excess mortality from kidney cancer observed among subjects who lived in areas with a high degree of natural radiation was higher than that for those in areas of less natural background radiation exposure (Gonzalo, et al, 2008).

One weakness of these studies is that it is difficult to study the effects of low radiation doses (below 100 mSv) via epidemiological studies because of confounding factors, and the need for millions of subjects (Henry, 2008).

2.4.2.3. Studies that support the hormesis hypothesis

There are two types of studies that support the hormesis hypothesis: experimental studies and epidemiological studies.

The first source of data is experimental studies, which include *human cellular and animal studies*:

For example, an experimental study was conducted in the USA by Sheldon et al (1993) to examine the hormetic effects of low doses of ionizing radiation on human cells. In this experiment a culture of human peripheral blood lymphocytes was irradiated with 2 mGy of ionizing radiation for 48 hours. Then the blood lymphocyte culture was exposed to radon, which represents a high radiation dose, for 72 hours. The researchers noted that the deletion in the chromatin color (colored part in the cellular nucleus) is decreased to the half as a result of radon exposure compared with chromatin that exposed directly to radon. Therefore, they concluded that the low radiation doses provided the lymphocytes with some sort of immunity against any damage which might be caused by the radon radiation exposure (Sheldon, et al, 1993).

Another experimental study was carried out by Molloi et al (2004) in the USA to examine the induction of neoplastic transformation after exposure of a culture of skin cells to low doses of radiation. The cell cultures were irradiated with low doses of ionizing radiation. The findings indicated that, over the range 0.05 to 22 cGy, there was no evidence of an increase in transformation frequency in the cells of the skin culture compared to the levels seen spontaneously. Moreover, doses in the range 0.05 to 1.1 cGy may actually result in the *suppression* of transformation frequencies, to levels *below* those seen spontaneously. This means that small doses may be used to decrease the transformation frequencies in cancer cells (a beneficial effect), which is inconsistent with the linear no-threshold hypothesis (Molloi, et al, 2004).

Other experimental studies were carried out on animals to examine the hermoteic effect of low radiation doses. For example, Yasuhiro and Kazuo (2005) conducted an experimental study in Japan to analyze the effects of chronic, whole-body, low-dose-rate irradiation on the immune systems of various wild mouse strains, in comparison with the effects from acute, high-dose-rate irradiation. Wild mouse strains were exposed to low-dose of irradiation (1.2 mGy) for 71 hours with intensive analysis of immune cells and their various surface molecules. The results indicated that antibody-producing cells introduced by immunization were significantly *enhanced* by continuous low-dose-rate irradiation at 1.2 mGy for 71 hour. The researcher concluded that chronic low-dose-rate radiation activated or stimulated the immune system of the whole body (Yasuhiro & Kazuo, 2005).

Also, Miyachi conducted an experimental study in Japan to assess the mortality rate among 15 mice exposed to low doses of X-ray radiation. The mice (10 weeks old and 33-35g in body weight) were subjected to whole-body X-ray exposure by an X-ray machine, at dose levels of 10, 20, 30 or 40 mGy. Then the mice's core body temperature was continuously monitored and acute decrease in the core body temperature following these low radiation doses was observed. The researcher concluded that this change in core body temperature was an indication of cellular stimulation in the mice's bodies as a result of radiation exposure. He also concluded that this result may explained other results from his study which show that the mortality rate among these mice was *lower* than the standard mortality rate among this type of mice (Miyachi, 2000).

The second source of data is the epidemiological studies, which include:

- Atomic bomb survivors studies
- Natural background radiation studies
- Occupational radiation studies

Atomic bomb survivor studies:

One part of the supporting evidence for radiation hormesis comes from the data on atomic bomb survivors of Hiroshima and Nagasaki, Japan. For example, one study was conducted by Preston et al (2003) to assess the mortality rates among a selected study population who were exposed to ionizing radiation from the two atomic bombs in 1945. This cohort included 86,572 people with calculated individual dose estimates, 60% of whom received doses of at least 5 mSv. The findings indicate that there had been 9,335 deaths from solid cancer and 31,881 deaths from non-cancer diseases among the study population during the 47-year follow-up period. 19% of the solid cancer deaths and 15% of the non-cancer deaths had occurred during the previous 7 years. The researchers estimated that about 440 (5%) of the solid cancer deaths and 250 (0.8%) of the non-cancer deaths were associated with the radiation exposure. However, the findings of the study indicated that there is no direct evidence of radiation effects for doses less than about 0.5 Sv (Preston, et al, 2003).

Natural background radiation studies:

Other epidemiological studies have looked at death rates in areas of high natural background radiation in order to support the hormetic effects of low doses of ionizing radiation. For example, a cohort study was conducted by Tao et al (2000) in China to estimate the cancer risk associated with the low-level radiation exposure of an average annual effective dose of 6.4 mSv (including internal exposure), in the high background radiation areas (HBRA) in Yangjiang province. The study sample was divided into three dose-groups on the basis of measured annual environmental dose-rates. The mortality statistics of the three dose-groups were compared with those for the residents of control areas by means of relative risk (RR). During the period 1987-1995, the researchers observed 926,226 subjects and they found an accumulated 5,161 deaths among them, of which 557 were from cancers. The findings of the study did not indicate an increase in cancer mortality in HBRA (RR = 96%; CI = 0.80 to 1.15). On the contrary, the mortality of all cancers in HBRA was generally *lower* than that in the control area, but the results were not statistically significant (Tao, et al, 2000).

Another environmental study that tends to support the hormesis hypothesis was carried out by Ali et al (2005) in Iran to examine the health effects of high natural background radiation. The study population consisted of two groups: The first group were inhabitants of Talesh Mahaleh which is a high natural background radiation (HBR) area; the second group was from Chaparsar, which had ordinary background radiation levels. The sample consisted of 101 families (402 people) from Talesh Mahaleh and 98 families (374 people) from Chaparsar, matching on some variables like age, sex, diet, etc. After explaining the aim of the project to the individuals and obtaining their consent, standard questionnaires were completed through interviews, and available data from local health centers was obtained. The findings indicated that the incidence of a few specific diseases like cancer and cardiac disease in the HBRA residents (Talesh Mahaleh) was *less than* that in the area with ordinary background radiation (Chaparsar) (p value = 0.011) (Ali, et al, 2005).

The study that caught the attention of the health physics community was one published by Cohen (1995) that studied the relationship between home radon levels and lung cancer rates, with the idea that he could prove or disprove the Linear No-Threshold (LNT) hypothesis at low radiation doses. Cohen used recorded data which showed the causes of death among the population of 1,600 counties in the USA (more than half of all counties in the nation, accounting for 90% of the population). In addition, he obtained data about the level of radon exposure in these countries from the American National Academy of Sciences. He then compared the lung cancer death rates with radon levels and found that the death rate from lung cancer *decreased* as a result of low doses from radon exposures in the air. A major criticism leveled at the study was that it assumed that average exposure determines average risk, whereas most epidemiological studies relate individual exposures to individual risks (Cohen, 1995). Despite the large sample size of the study, the fact that smoking is responsible for a large majority of lung cancers among the population of the USA may have influenced the results (Joel, 2003).

Occupational radiation studies:

Finally, some occupational studies supported the radiation hormesis hypothesis. The most important one is that carried out by Berrington et al (1897-1997). This cohort study was conducted to examine the patterns of mortality among radiologists in the UK from the long-term effects of fractionated external radiation exposure. British radiologists who registered with a radiological society between 1897 and 1979 had been followed up until 1 January 1997. The study compared the mortality rates among the radiologists before and after the year 1920, when the first radiological protection recommendations were published. Results indicated that the number of cancer deaths in those who registered after 1920 was similar to that expected from death rates for all medical practitioners combined, and that radiation exposure did not increase the risk of cancer among radiologists who registered after the publishing of radiological protection recommendations. The findings of the study also indicated that there was no evidence of an increase in cancer mortality among radiologists who first registered after 1954, in whom radiation exposures were likely to have been lower. There was no evidence of an effect of radiation on diseases other than cancer, even in the earliest radiologists, despite the fact that doses of the size received by them had been associated with more than a doubling in the death rate among the survivors of the Japanese atomic bombings (Berrington, et al, 2001).

Another occupational cohort study was conducted by Matanoski et al (1991) to assess the standardized mortality ratio (SMR) among workers at USA nuclear shipyards. They compared three groups of radiation workers (matched for age and job) regarding the SMR. The first group included 27,872 workers with cumulative effective doses greater than 5 mSv, the second group included 10,348 workers with doses lower than 5 mSv, and the third group consisted of 32,510 non-radiation involved shipyard workers. The findings revealed *lower* SMRs, i.e. lower mortality, in those workers with cumulative effective doses greater than 5 mSv compared with those with lower doses, and lower SMRs in the latter group compared with the non-radiation shipyard workers. The researchers indicated that selection bias might have affected the results of this study, since workers selected to work on nuclear-powered ships (radiation shipyard workers) were given a physical examination prior to assignment and so are likely to be healthier than those working elsewhere in the shipyard (non-radiation shipyard workers). In addition, self-selection bias was suggested for those workers who were employed for longer periods of time, as they might have been seeking to participate in the study in order to obtain a medical examination (Cameron, 2005).

However, most studies that support the hormesis hypothesis had many other limits, such as: (Mossman, 2001; ICRP, 2008)

1) They have a relatively small sample size;
2) Most of the studies were conducted on animals, and much of the research is based on re-evaluation of selected epidemiological data that was used to test a different hypothesis and not focused on testing the hormesis hypothesis;
3) Hormetic effects are weak and inconsistent, and are subject to large statistical uncertainties;
4) There is no consensus on how hormesis should be defined and quantified.

In order to overcome the harmful effects of ionizing radiation discussed previously, the International Commission on Radiological Protection (ICRP) was founded in UK (1928). It was established with the main intention of maintaining an essential role in radiological protection against the risks associated with ionizing radiation, through a series of scientific, evidence-based recommendations and guidelines. The next section discusses the ICRP recommendations in more detail.

2.5. ICRP recommendations and radiation safety standards

The ICRP activities aim to set radiation safety standards including all types of radiations: the artificial (man made) radiation sources widely used in medicine, radiation used in general industry and nuclear enterprises, and radiation from naturally occurring sources (ICRP, 2008).

The ICRP publishes its reports and recommendations four times each year. Each issue provides in-depth coverage of specific subjects based on scientific evidence, as soon as it is made available, so that professionals are kept up-to-date on the latest developments in this important field (ICRP, 2007).

Since its establishment, the ICRP has constantly struggled to correct many radiation misconceptions, trends and practices all over the world concerning radiation safety standards and radiation protection in general. The greatest challenge which faced the ICRP recommendations was raised by many radiation biologists and medical practitioners who claimed that low doses of radiation stimulate all organisms, usually resulting in *beneficial* health effects (Calabrese & Linda, 2003). The ICRP rejected this threshold theory, and instead adopted the concept that *no* radiation level can be regarded as absolutely safe. The basis for this assumption is the epidemiological evidence of excess cancer incidence among the survivors of the Japanese atomic bombings, and other epidemiological studies (ICRP, 2008).

The ICRP approved its newest recommendations at its meeting in Essen, Germany in March 2007. These new recommendations are based on the 1990 ICRP recommendations, but with great consideration given to developments in ICRP guidelines since 1990, when the previous set of recommendations was adopted (ICRP, 2008).

These new recommendations include the three key principles for protection from ionizing radiation: justification, optimization and dose limits.

1. Justification, in radiology, means that medical exposures should be justified by weighing the diagnostic or therapeutic benefits they produce against the radiation hazards that they might cause, taking into account both the benefits and risks of available alternative techniques which do not involve medical exposure (ICRP, 2007).

This principle holds that any radiological examination undertaken without reference to clinical indications is *not* a justified examination unless it is expected to provide useful information on the health of the individual, and unless this benefit exceeds the hazard stemming from the examination itself. It should be justified by those requesting it, in consultation with relevant professional bodies (ICRP, 2007).

2. Optimization of protection, which means that practitioners must pursue all possibilities in order to protect people from unnecessary radiation doses, by practicing or carrying out the following (ICRP, 1990; 1999; 2007; 2008):

(a) Minimizing human errors which may lead to undesired radiation doses, by operating X-ray equipments only from a high level of knowledge and with proper information, and ensuring that all X-ray equipment is maintained in a proper state.

(b) The selection of suitably qualified personnel; setting of adequate procedures for the calibration of devices; quality assurance regarding the operational aspects of radiation protection in the course of diagnostic procedures; and an appropriate training regime for personnel, including protection and safety aspects.

(c) Adopting the standards provided by relevant international bodies (such as the International Standards of Quality (ISO)) regarding performance of the diagnostic procedures and the operation and maintenance of the X-ray equipment.

(d) Using collimating devices to direct the exposure only to the area being examined.

(e) Exposure rates outside the examination area due to radiation leakage or scattering should be as low as reasonably achievable.

(f) Operational parameters used in generating radiation, such as kilo-voltage, filtration, focal spot position, source-image receptor distance, field size of radiation and tube current and time— should all be strictly observed by radiological staff, in order to limit unnecessary radiation exposure to both patient and personnel.

(g) Ensure that the exposure of patients is the minimum level required to achieve the diagnostic objective, by determining and administering only the minimum patient exposure consistent with acceptable image quality and with the clinical purpose of the examination.

(h) Portable and mobile radiological equipment are to be used only for examinations where it is impractical or not medically acceptable to transfer patients to a stationary radiological installation, and only after proper attention has been given to the radiation protection measures required for its use.

(I) Radiological examinations which cause exposure to the abdomen or pelvic area of women who are pregnant, or likely to be pregnant, are to be avoided *unless* there are strong clinical reasons for such examinations.

(j) Whenever feasible, the shielding of radiosensitive organs, such as the gonads, lens of the eye, the breast and the thyroid, should be provided as appropriate.

3. Dose limit, which means that there are annual radiation doses which should not be exceeded under any circumstances, as discussed previously in this chapter. However, radiation protection regulations do not state an annual radiation limit for *the patient*, but assign responsibility to both the prescriber and the practitioner to keep the radiation dose to the patient as low as possible (ICRP, 2008).

These three principles summarize all of the radiation protection requirements intended to keep exposures from radiation as low as possible, in order to reduce the risks to patients and personnel. To achieve this purpose the ALARA principle (As Low As Reasonably Achievable) was developed by the ICRP (NCRP, 1990). The ALARA principle for diagnostic radiology consists of four components as follows:

A. Source eliminating: Eliminating the source of radiation can be accomplished by practicing a sound clinical justification for radiological examinations, in the sense of doing more good than harm. Physicians daily prescribe a large number of diagnostic tests which involve the use of ionizing radiation, and the literature shows that many of these examinations either can be avoided because they are clinically not well-justified or they can be replaced with other appropriate technologies, such as ultrasound and magnetic resonance imaging (MRI), which do not utilize ionizing radiation in the acquisition of medical images (Jacob, 2004).

B. Distance: Increasing the distance from the source (i.e. fluoroscopic unit) provides the greatest protection from radiation exposure during X-ray examinations. This protection occurs because the radiation coming from an X-ray tube is dispersed, thus there are fewer radiation photons per unit of area as the distance from the source increases. Personnel standing near a beam will receive progressively less scatter radiation and secondary radiation as they step away from it (Carlton, et al, Adler, 2001). For example, if a radiologist is stands 60 cm away from the radiation source, this will decrease exposure to one-fourth of the original exposure, and if he/she stands 120 cm from the radiation source, this will decrease exposure to one-sixteenth of the original exposure (Saia & Lange, 2003).

C. Time: Time (duration) is another important factor in reducing exposure, especially from fluoroscopic examinations. The less time spent in a radiation field, the lower the dose. To meet ALARA goals, no more time should be spent in a radiation field than is necessary to perform the required X-ray procedures. By notifying the physician about the cumulative fluoroscopic time during X-ray procedures, the operator or assistant is helping to keep the time factor low (Sherer, 2002).

D. Shielding: Shielding involves the use of various materials placed between the individual and the source, in order to absorb the radiation. Leaded aprons (a minimum thickness of 0.5 mm of lead) are a very useful means of radiation protection during X-ray examinations. Leaded thyroid shields are also available for use during fluoroscopy; these shields contain the recommended 0.5 mm of lead and can be wrapped around the neck and attached using a strip on the back of the shield (Bushong, 2001). Leaded eyeglasses can also be worn as protection during procedures, because the lens of the eye is very radiosensitive, and with repeated radiation exposure can develop cataracts (Sherer, 2002).

In summary, the most effective means of achieving the ALARA standard are to avoid unnecessary radiological examinations and to increase physicians' awareness of radiation hazards. In general, physicians are responsible for requesting radiological exams, so they should be aware that any unnecessary radiological procedure carries a potential hazard to both patients and personnel.

2.6. Physicians' knowledge of Radiological examinations Hazards

2.6.1. Introduction

Despite the increase in understanding radiation in recent years, studies have shown that most people, even health professionals, are not sufficiently informed concerning the hazards of radiation or even familiar with the different kinds of radiation. For example, there is confusion between ionizing radiation and the electromagnetic radiation emitted by domestic appliances like microwave ovens and other instruments such as radar, and even with radiation-free medical devices such as ultrasound. The majority of the public is conscious of the damaging effects inflicted by overexposure to the sun, but public awareness about radiation from medical tests is limited (Ludwing & Turner, 2002).

Also, increasing concern has recently been expressed in the literature that the referring physicians' knowledge of radiation doses and possible risks incurred during radiological procedures is inadequate. Because of this lack of knowledge, physicians may order unjustified radiological examinations, or they may be unable to adequately answer the questions of patients and their families about radiation risks and benefits (Karen, et al, 2004).

Several studies have been conducted among health professionals in many countries of the world (e.g. the USA, UK, Germany and Turkey), particularly among physicians, regarding their awareness of radiation hazards of radiological examinations.

2.6.2. Radiation knowledge studies among physicians

Studies conducted in the USA

One cross-sectional study was conducted by Renston et al (1996) to investigate physicians' use of chest Computed Tomography (CT), and their attitudes toward it's risks and benefits, in the Metro Health Medical Center. Self-administered mail questionnaires were distributed to 1,000 physicians from several specialties of medicine with a response rate of 31%. The findings showed that more than 90% of physicians either did not know or significantly underestimated the radiation doses associated with CT (Rrenston, et al, 1996).

Another study was conducted by Christoph. (2004) in order to investigate the level of awareness among Emergency Department (ED) physicians at the U.S.A. Academic Medical Center. The sample included 60 physicians, 45 of whom completed the study; the data was collected by interview questionnaires. The findings showed that ED physicians were not able to provide accurate estimates of CT doses, regardless of their experience level. However, this study has many weaknesses such as its small sample size and its dependence on self-reported questionnaires (Christoph, 2004).

Also, a cross-sectional study was conducted by Henry et al. (2007) to assess pediatric surgeons' knowledge of the potential risks of radiation exposure from CT scans. An e-mail questionnaire was sent to 753 physicians who were members of the American Pediatric Surgical Association (APSA) with a response rate of about 20%. The results indicated that: more than 75% of respondents underestimated the radiation dose from a CT scan compared to a chest radiograph; the pediatric surgeons' knowledge of the potential risks of radiation exposure from CT scans was generally limited; and most respondents did not generally discuss the potential risks of CT scans with their patients (Henry, at el, 2007).

Studies conducted in the UK

One cross-sectional study was conducted by Quinn (1997) to assess radiation protection awareness among physicians. A questionnaire including items regarding radiation protection awareness was distributed in two teaching hospitals and one district general hospital (D.G.H.). Out of the 120 physicians, 82 physicians (68%) responded. The findings revealed that the respondents were likely to underestimate the radiation doses associated with various radiological procedures, and they generally lacked knowledge regarding the possible risks of radiation. For example, the majority of respondents were not aware that patients have no annual dose limit, nor did they know the relative radiosensitivity of different body organs such as the kidneys, gonads and stomach (Quinn, 1997).

Another important cross-sectional study was conducted in 2003 by Shiralkar et al to assess physicians' knowledge of radiation exposure. Questionnaires were distributed to 130 physicians of different specialties (40 senior house officers, 40 specialist registrars, 40 consultants and 10 consultant radiologists) from two separate hospitals, in South Wales and Oxford. The response rate was 100%. Findings indicated that 97% of the participants' answers underestimated the actual doses; 5% of these physicians did not realize that ultrasound does not use ionizing radiation; and 8% did not realize that Magnetic Resonance Imaging does not use ionizing radiation (Shiralkar, et al, 2003).

Yet another cross-sectional study was conducted by Jacob (2004) to assess radiation exposure knowledge among physicians of various grades and specialties in Derriford Hospital, which is a large district general hospital in UK. The sample included 375 physicians who were asked to complete a multiple-choice questionnaire with a total of 11 questions about knowledge of terrestrial and medical radiation exposure. The response rate was 64%. The results indicated a lack of knowledge regarding radiation exposure among physicians in clinical practice. For example, only 20% of respondents were aware of the risk of inducing a fatal cancer from a CT scan examination of the abdomen (Jacob, 2004).

Furthermore, another cross-sectional study was conducted in 2006 by Ashley et al. to assess physicians' knowledge regarding the fetal doses involved in the radiological examination of pulmonary embolism. The sample included 161 physicians from 14 hospitals (seven university and seven community hospitals) in the United Kingdom. Data was collected by questionnaire and the response rate was 80%. Findings revealed that there was a lack of knowledge of fetal doses in the imaging of pregnant women suspected of having a pulmonary embolism. Also, 43% of respondents knew the adult radiation dose from CT scan pulmonary angiography, yet only 11% of them were able to state the fetal dose from this same examination (Ashley, at el, 2007).

Studies conducted in Germany

In 2004, Karen et al conducted a cross-sectional study in Germany to identify the level of knowledge among pediatric physicians regarding the radiation doses and risks associated with radiological investigations in children. Questionnaires were distributed to 550 pediatric physicians and surgeons, and the response rate was 40%. Results showed a lack of knowledge regarding radiation protection principles and underestimation of relative doses associated with radiological examinations. For example, 87% of respondents were not aware of the actual chest X-ray equivalent of the effective dose of different radiological examinations, and 85% of respondents were not familiar with the ALARA principle (Karen, et al, 2006).

Also, a cross-sectional study was conducted by Heyer et al (2007) to assess the knowledge of physicians concerning radiation exposure during radiological procedures on the thorax. Out of 124 physicians from the surgical, internal medicine, anesthesiology, and neurology departments of a university hospital, 119 (96.0%) participated, having work experience averaging 8.2 years (range: 0.3 - 32 years). Data was collected over a period of four weeks via a questionnaire about the effective doses of different radiological procedures performed on the thorax. The findings indicated that, on average, only about 29% of physicians were able to select the correct answers regarding radiation doses and possible risks associated with some selected radiological examinations, regardless of the length of their professional experience or their field of clinical training (Heyer, et al, 2007).

Studies conducted in Turkey

In 2005, a cross-sectional study was conducted by Atilla et al to investigate the level of physicians' awareness and knowledge of the patient's radiation exposure doses during common radiological examinations. This study included 177 physicians and residents from teaching and research hospitals and three outpatient clinics. Data was collected by questionnaires and the response rate was high (95%). Similar to the results of other studies, findings indicated that most physicians did not know the radiation doses and possible risks associated with radiological examinations. For example, 93.1% of the respondents did not know the actual radiation doses associated with different radiological examinations such as an abdominal radiograph, abdominal CT scan or barium meal (Atilla, et al, 2007).

Studies conducted in Northern Ireland

A cross-sectional study was conducted by Soye & Paterson (2007) to assess the awareness of radiation doses and risks among physicians in Northern Ireland.

Questionnaires were distributed to 100 consultants and 200 junior physicians. Out of the 300 questionnaires, 153 questionnaires were returned, for response rate of 51%. Participants were asked about the radiation dose of a chest radiograph as well as the annual dose of background radiation, and to estimate chest X-ray equivalent of several common radiological procedures such as a barium enema, abdominal X-ray and abdominal CT scan. Findings revealed that only 26% of doctors achieved a score of 50% or more, and only 20% of respondents knew the effective dose of a chest radiograph. The results also indicated that physicians who had received radiation training were the most knowledgeable about radiation doses and possible risks (Soye & Paterson, 2008).

Studies conducted in Italy

Maria at el Conducted a cross-sectional study (2005) to assess the level of radiological awareness among physicians in a tertiary care referral center for adult-pediatric cardiology. The sample included 100 physician subjects, and the response rate was 100%. Data was collected via a one-page, multiple choice questionnaire dealing with the ionizing radiation doses associated with some radiological examinations and with radiation protection responsibility. Findings indicated that 71% of the respondents did not know the exposure dose of a myocardial stress perfusion scintigraphy. Also, they were generally unaware of the adverse health effects of the ionizing examinations which they prescribed and performed daily. For example, 95% of the respondents were not able to estimate the risk of fatal cancer associated with stress myocardial perfusion scintigraphy (Maria, at el, 2005).

Studies conducted in Romania

Finally, a cross-sectional study was conducted by Mihail et al (2005) to assess the knowledge and perceptions of ionizing radiation hazards among three population groups. Seventy-seven (26%) of the respondents were radiation workers, 35 (12%) were physicians without professional exposure, and 177 (68%) belonged to the general population. Data was collected via a self-reported questionnaire and the response rate was 73%. Findings indicated an overall lack of knowledge among all three groups but a higher level of knowledge among radiation workers compared to both the general population and the non-radiologist physicians. These results may indicate that specific radiation training is crucial in obtaining knowledge regarding radiation doses and risks (Mihail, et al, 2005).

2.7. Summary

- Most medical imaging techniques, such as routine X-ray machines and CT scan equipment, involve the use of ionizing radiation. However, some imaging procedures, such as MRI and ultrasound, do not employ ionizing radiation.

- Several simple and comparative methods are commonly used to communicate the relative doses of different radiological examinations, such as the chest X-ray equivalent and comparing the effective dose from a particular type of exam with the dose received from natural sources during a certain period of time and in a certain geographical region.

- There are defined dosage limits for ionizing radiation from radiological examinations—for staff, trainees (radiological students) and the public—which should not be exceeded under any circumstances.

- The biological effects of ionizing radiation are divided into two categories: deterministic (nonstochastic) and stochastic effects. Deterministic effects are predictable and preventable effects of ionizing radiation. Stochastic effect is a random and unpredictable effect of ionizing radiation, and can result in cancer or genetic mutations.

- There is much debate among scientists regarding the harmful effects of ionizing radiation at low doses (<100mSv). As a result, two hypotheses have emerged among scientists about the harmful effects of low radiation doses: (a) the linear no-threshold hypothesis and (b) the hormesis hypothesis.

  a) The linear no-threshold hypothesis (LNT) suggests that damage may be caused by ionizing radiation at *all* levels of exposure, and the response is linear.

b) The radiation hormesis hypothesis proposes that low levels of ionizing radiation is harmless or may actually be beneficial.

- According to the ICRP recommendations there are three principles for protection from ionizing radiation: justification, optimization and dose limits.

- The ALARA principle (As Low As Reasonably Achievable) which was developed by the ICRP comprises the core of radiation protection philosophy. The main ALARA principles for diagnostic radiology are: source eliminating, time, distance and shielding.

- Many studies have been conducted worldwide to assess the knowledge among physicians regarding the radiation doses and possible risks associated with radiological examinations. In general, these studies indicate a lack of knowledge among physicians.

- There is a lack of such studies in Palestine. To our knowledge, this study will be the first to attempt to assess the knowledge of Palestinian physicians regarding the radiation hazards of radiological examinations and their possible risks on the health of both patients and professionals.

CHAPTER THREE

THEORITICAL FRAMEWORK

Chapter Three

Theoretical Framework

3.1. Theory of Planned Behavior

3.1.1. Introduction

This theory was developed by Ajzen to include both volitional and non-volitional behaviors based on his Theory of Reasoned Action (TRA). The TRA suggests that a person's behavior is determined by his or her intention to perform the behavior and that this intention is, in turn, a function of the person's attitude and subjective norm toward the behavior (Fishbein & Ajzen, 1975). The Theory of Planned Behavior (TPB) model extends from the TRA model by incorporating an additional construct, namely perceived behavioral control, to account for situations in which an individual lacks substantial control over the targeted behavior (Ajzen, 1991).

TPB suggests that people's behavior is determined by their intention to perform a given behavior. Intentions are the most immediate antecedents to behavior and represent the convergence of the cognitive, motivational, and affective internal processes associated with a given behavior. Behavioral intentions, according to TPB, are the result of three determinants: attitude toward the behavior, subjective norms and perceived control, as seen in figure (3.1) (Ajzen, 1991; Susan, 1996; Bruce, et al, 1997; Seewon, et al, 2003; Keiko & Sherri, 2006; Edward, 2007).

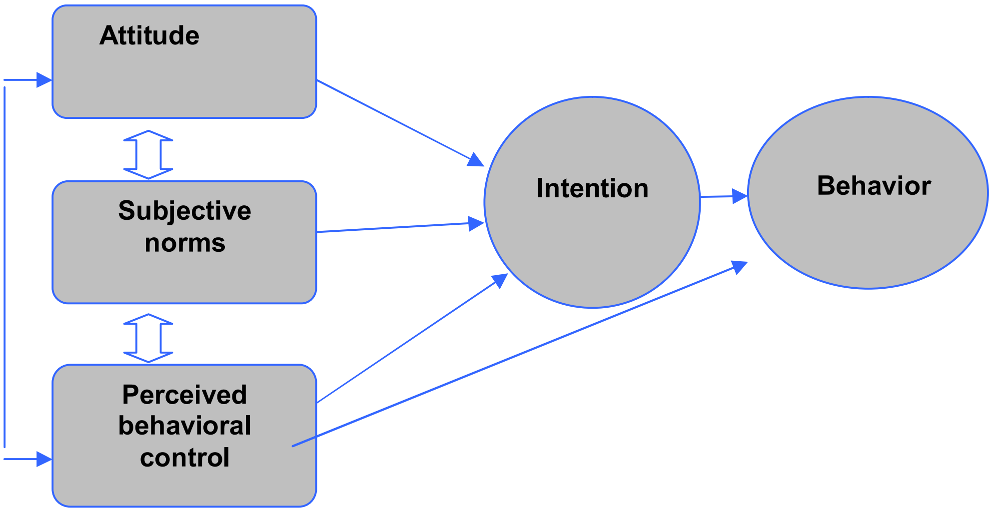

Figure (3.1) The Theory of Planned Behavior (Ajzen, 1991)

Attitudes refer to one's beliefs about the outcomes associated with performing a particular behavior, i.e. the belief that this behavior will lead to specific positive or negative outcomes. Subjective norms refer to one's perceptions about how others would judge a person for performing the behavior, according to social pressure from those who are important to him/her (e.g. parents, friends and peers) and the person's motivation to act in line with the preferences of these people (Ajzen, 1991; Bruce, et al, 1997; Seewon, et al, 2003; Keiko & Sherri, 2006; Natalie, et al, 2007; Edward, 2007).

Perceived control is the person's self-assessment of both his/her skill or capability of performing the behavior and his/her opportunity to perform it. Positive attitudes, social approbation, self-efficacy, and decisional autonomy combine to strengthen the intention and therefore the likelihood of performing behavior. These factors may affect individuals' intention to perform the behavior, either directly or indirectly. They are divided into internal control factors (e.g. information, skills and personal abilities) and external control factors (e.g. opportunities and dependence on others). People are more likely to perform a behavior if they have control over it, and they are more likely to avoid a behavior if they have little or no control (Edward, 2007).

In summary, this model suggests that there is a strong relationship between intention and behavior: People are more likely to engage in behavior if they have a strong *intention* to perform it. In addition, people tend to engage in a behavior if they have a positive attitude toward the likely outcomes and if they think that they have control over the behavior. So, intention is a key predictor of actual behavior.

3.1.2. The application of the Theory of Planned Behavior to predicting physicians' behaviors:

Many studies indicate the benefits of using this model to predict physicians' behaviors, such as knowledge-sharing behavior, and their delivery of preventive services (Edward, 2007). For example, Seewon, et al. investigated the factors that affected physicians' "knowledge-sharing" behavior among 286 physicians practicing in the Graduate Medical Education departments of the 43 tertiary hospitals in Korea.

Data was collected by questionnaires, and the response rate was 33.4%. Nineteen measured variables were used to reflect the components of the TRA and TPB models. Responses to items were elicited following a Likert scale which focused on four points:

- Physicians' attitudes toward knowledge-sharing behavior;
- Physicians' intention to share knowledge;
- Physicians' subjective norm to knowledge sharing;
- Physicians' perceived behavioral control.

Subjective norm was found to be the most important factor influencing physicians' intentions, followed by attitude. Perceived behavioral control was also found to affect the intention to share knowledge, though to a lesser degree than subjective norms or attitudes (Seewon, et al, 2003).

These findings were supported by Susan, who conducted a study in the USA (1996) to assess the applicability of TPB models to predicting physicians' behavior in relation to educating their adolescent patients about sexually transmitted diseases (STD). The sample consisted of 765 primary care physicians. Data was collected by questionnaire *twice*, and analyzed by use of multiple regression, in order to measure the *change* in physicians' behavior regarding educating adolescents. The results revealed that the addition of perceived behavioral control to the TRA model significantly improved the ability of the model to predict the physicians' educating of their adolescent patients. Perceived behavioral control had direct effects on behavior and interacted with social norms and behavioral intentions. The results suggest that the TPB model has relevance for studying the behavior of healthcare providers (Susan, 1996).

Another experimental study was carried out by Edward (2007) to evaluate the effects of a continuing education class designed to apply TPB to the intentions and behavior of mental health physicians. A total of 94 mental health physicians were randomly selected to be guided by the principles of the Theory of Planned Behavior through special educational courses (interventional group), and 94 other physicians were assigned as a control group with a standard continuing education program. The participants' intentions to write detailed reports about their mental illness patients were evaluated before and after each interventional educational course. Findings indicated that the group that was guided by the Theory of Planned Behavior significantly and substantially increased the participants' intentions to do the self-report in comparison to the standard class. Also, the results emphasized the importance of educational courses in enhancing physicians’ behaviors (Edward, 2007).

In 2007, Shannon et al conducted an experimental study in Canada to examine physicians’ uptake of a certain intervention called the Healthy Heart Kit (HHK) designed as a risk management tool to prevent cardiovascular disease (CVD). The Theory of Planned Behavior was used to predict physicians’ behavior regarding their uptake of the Healthy Heart Kit. The sample consisted of 153 physicians registered with the College of Physicians within the province of Alberta, Canada. Data was collected using a self-reported questionnaire, and the response rate was 75%. Questionnaires were distributed both before, and after an educational course about the importance of the uptake of the Healthy Heart Kit in the prevention of cardiovascular disease. Findings of the study revealed that the educational course about HHK was associated with intention to use the HHK, and that the Theory of Planned Behavior was able to predict, via their behavioral intention, physicians’ later behavior regarding use of the Healthy Heart Kit (Scott, et al, 2008).

Another, cross-sectional study was conducted by Bruce in order to identify attitudinal and social normative factors associated with the prescribing of oral antibiotics to ambulatory patients in managed care settings. The sample consisted of 25 physicians from ambulatory care clinics in a major Midwestern American city. The numbers of prescriptions per physician issued in the fourth quarter of 1994 were estimated for each of seven selected antibiotics. Multiple regression analysis revealed that behavioral intentions were significantly associated with both attitudes and subjective norms. Also, it was found that patients’ beliefs about antibiotics affected the physicians’ request for these antibiotics (Bruce, 1997).

These studies were supported by another cross-sectional study that was conducted by Mun (2005) in the USA, in order to measure the ability of the Theory of Planned Behavior to predict physicians’ behaviors regarding acceptance of new technology in the workplace. The sample consisted of 301 physicians in seven family practice residency programs located in an eastern state of the USA. Of the 301 questionnaires delivered, 224 were returned, for a response rate of 74.4%. All of the items were measured on a seven-point Likert scale ranging from “strongly disagree” to “strongly agree”. The findings revealed that one’s attitude toward the acceptance of new technology was the most significant determinant of the physicians’ intention. Also, subjective norms and perceived behavioral control had significant effects on behavioral intention, but less so than attitude (Mun, 2005).

The effectiveness of the Theory of Planned Behavior in predicting physicians’ behaviors was further examined by Keiko & Sherri (2006) in the USA. The study aimed to test the impact of an educational course for primary care physicians on subsequent levels of colorectal cancer screening among their patients. The sample consisted of 235 physicians who were practicing in diverse urban sub-communities in New York City. The data was collected by questionnaires and the response rate was 100%. The findings revealed that perceived behavioral control, subjective norms and attitudes are the most important variables in predicting physicians’ behaviors for colonoscopy recommendation (Keiko & Sherri, 2006).

Finally, in 2007 an experimental study was conducted by Susan et al. to evaluate the effects of the behavioral intention of general physicians (GPs) in the management of uncomplicated upper respiratory tract infection (URTI). The sample consisted of 397 physicians as an interventional group and another 397 as a control group. All of the participants were working in 13 primary care clinics in the northeastern part of the UK. Data was collected via questionnaires, and the response rate was 86%. The beliefs and attitudes of the GPs regarding the management of URTI without antibiotics were measured before and after two educational courses (Course 1 and Course 2). The results indicated that perceived behavioral control was best able to predict the physicians’ behavior, followed by normative believe and attitude (Susan, et al, 2008).

In summary, evidence has indicated that the Theory of Planned Behavior is able to predict physician behavior (Susan, 1996; Bruce, et al, 1997; Seewon, et al, 2003; Mun, et al, 2006; Keiko, 2006; Natalie, et al, 2007; Edward, 2007; Shannon, et al, 2008; Susan, et al, 2008). The current study utilized the Theory of Planned Behavior because this theory has been used to examine and predict physician behaviors such as attending educational courses and management of diseases. However, this model has not been applied to physicians' awareness of the hazards and risks of radiological examinations.

3.2. Summary

- The Theory of Planned Behavior has been used in many studies to predict physicians' behaviors.

- The findings of these studies revealed that perceived control, subjective norms and attitude are the most important factors in predicting physicians' behaviors.

- The model was adopted for the purpose of the current thesis.

CHAPTER FOUR

METHODOLOGY

Chapter Four
Methodology

4.1. Introduction

This study aims to assess physicians' knowledge regarding the risks and the hazards of radiological examinations. To address this aim, a quantitative approach has been used. Also, a proper instrument, data collection method, and data processing and analysis have been followed. This chapter was discussed all these issues and other methodological aspects of the current study with detail.

4.2. Quantitative research

Quantitative research is the systematic scientific investigation of quantifiable properties and phenomena and their relationships. It involves a collection of numerical information, where often there is considerable control, with analysis of the information using statistical procedures (Polit & Hunger, 1995). The objective of quantitative research is to develop and employ mathematical models, theories and hypotheses. This type of research is widely used in both the natural sciences and social sciences, from physics and biology to sociology. It is also used as a way to research various aspects of education (Polit & Hunger, 1995).

4.2.1. Types of quantitative research

There are two types of quantitative research: experimental and non-experimental designs. Experiments are characterized by manipulation, control and randomization. Manipulation involves making an intervention on the independent variable in order to examine its effect on the dependent variable. Experimental research has the potential to provide the greatest evidence for the strength of associations between variables, so experiments are essential for testing hypotheses and establishing causality (Abramson J & Abramson Z, 1999). True experiments always require the use of a control group, whose performance on the dependent variable is used as a basis for assessing the performance of the experimental group. Subjects are assigned to control *versus* experimental groups by a process known as randomization. The random assignment procedure can be accomplished by any method that allows every subject an equal chance of being included in any group, such as by flipping a coin or using a table of random numbers. However, the required control and manipulation makes the experimental design an inappropriate choice for many research problems, especially in organizational behavior (Burns, et al, 1997).

Quasi-experimental design is another type of experimental research. It involves manipulation of the independent variable but lacks a comparison (control) group or randomization. Therefore, it is subject to ambiguity and multiple interpretations of the results (Tablot, 1995).

The second type of quantitative research is non-experimental research which includes two broad categories: correlational research and descriptive research. The correlational investigations are designed to examine the relationships among variables, without active manipulation of the independent variable. Because correlational studies are conducted after the variations in the independent variable have occurred in the natural situation, it is therefore difficult to draw cause and effect conclusions (Polit & Hunger, 1995). It examines relationships between variables and can be used for describing a relationship, predicting relationships among variables or testing the relationships proposed by the theoretical framework. A representative sample of the study population is essential, and a large variance in the variable score is necessary to determine the existence of a relationship (Burns, et al, 1997).

The descriptive researches, such as surveys, case studies, documentary analyses and developmental studies, are designed to summarize the status of phenomena of interest as they currently exist by observing, describing and documenting aspects of the situation as they naturally occur. Sometimes this approach is used as a starting point for hypothesis generation or theory development (Abramson J & Abramson Z, 1999). Examination of types and degrees of relationship is not the primary purpose of a descriptive study. Rather, it is used for justifying current practice and determining the behaviors of the others in similar situations. In the descriptive research design, there is no manipulation of variables involved. Protection against bias is achieved by (1) linkage between conceptual and operational definitions of variables, (2) sample selection and size, (3) valid and reliable instruments and (4) data collection procedures that achieve some environmental control (Abramson J & Abramson Z, 1999).

4.3. Study design

As discussed previously, the main aim of this study is to assess physicians' knowledge regarding the hazards of radiological examinations in two referral hospitals in the West Bank and East Jerusalem. Therefore, a cross-sectional study was utilized, because it is highly useful for descriptive purposes. It shows both the determining factors and the outcome at the same time, an especially beneficial aspect of conducting and evaluating this type of study. Moreover, it is less costly and saves time and effort. In our case, the chosen design can give some indications about the association among the different factors under investigation and their outcomes (Polgarr & Thomas, 1997). On the other hand, the cross-sectional design has many limitations: It does not lend itself to generalization of the results, it may not enable researchers to make causal inferences, and it is not appropriate for incident estimation, especially in the case of long-lasting outcomes (Dimer, 1997).

4.4. Study population and sample

Purposive sampling of hospitals was utilized in the current study since the investigator’s knowledge about the population could be used to hand-pick the cases to be included in the sample and to ensure that the selected subjects were typical of the study population (Polit & Hunger, 1995). This method of sampling is easier than other types of sampling, plus it can examine the participants' beliefs, practices and experiences. However, subsequent generalizations from the findings of this method of sampling may not be valid (Polit & Hunger, 1995).

The study included all physicians working in the Al-Makassed Hospital and the Ramallah Governmental Hospital who have direct contact with the patients from different units, such as medical units, general surgery orthopedics, neurosurgery, cardiosurgery, intensive care, coronary care, gynecology, etc. Table (4.1) categorizes and quantifies the human resources of Al-Makassed and Ramallah Governmental Hospitals. The study population consisted of 167 physicians (107 from Al-Makassed Hospital and 60 from Ramallah Governmental Hospital.

Table (4.1) Human resources of Al-Makassed Hospital and Ramallah Governmental Hospital

Types of employees	No. of employees / Makassed	No. of employees / Ramallah
Administration and support services	207	138
Nurses	274	176
Specialties	42	40
Residents	65	20
Technicians	66	36
Total	654	401

Source: Personal contact with hospital management, May 2008.

The inclusion criteria include:

- All physicians working at Al-Makassed Hospital and Ramallah Governmental Hospital, both male and female physicians.

- Physicians who are registered as regular employees in both hospitals and are authorized to request radiological examinations.

The exclusion criteria include:

- Internship physicians who are working at Al-Makassed Hospital and Ramallah Governmental Hospital, since they are not authorized to request radiological examinations.

- Physicians who are specialized in radiology or working in radiology departments, because they have participated in many radiation courses, which would possibly cause result bias.

4.5. Settings of the study

The study was conducted in Al-Makassed Hospital and Ramallah Governmental Hospital. These two settings were selected because they are appropriate for the purpose of the study. Moreover, these are the largest and also the chief referral hospitals serving the Palestinian people of the West Bank and East Jerusalem. Also, these two hospitals have training programs for physicians seeking specialization in various medical sciences such as internal medicine orthopedics, pediatrics, etc.

4.5.1. AL- Makassed Hospital

Al-Makassed hospital is located on the Mount of Olives in Jerusalem. It was built in 1964 by Makassed Islamic Charitable Society, a non-profit, non-governmental organization that provides diversified human services and offers its services without distinction of any kind as to color, religion or political belief (Al-Makassed Hospital, 2008).

This hospital was officially inaugurated in 1968 as a small community hospital with only a few departments and a limited number of beds. Now it is the leading medical center in Palestine providing secondary and tertiary health services for the Palestinian population. It has 250 beds (see table 4.2) and offers both in-patient and out-patient services, including: internal medicine, normal nursery, general surgery, cardiovascular and neuro-surgery orthopedics, urology, pathology, pediatrics, obstetrics, gynecology, general laboratory, cardiac catheterization laboratory, X-ray facilities, blood bank, physiotherapy, metabolic, genetic lab, laparoscopic open-heart surgery, plastic and reconstructive surgery, and shock wave resolution. In addition, intensive care units and six operating theaters are also available. The hospital treated 11,579 inpatients, 20,764 emergency cases and 30,000 outpatients in 2008 (Al-Makassed Hospital, 2008).

The main financial resources which keep the hospital functioning properly are donations from various countries and benevolent institutions all over the world, in addition to the income from insured and paying patients (Al-Makassed Hospital, 2008).

Al-Makassed Hospital is fully accredited for postgraduate training in six medical specialties, by both Jordanian and Palestinian Medical Councils. These specialties are: internal medicine, general surgery, pediatrics, obstetrics and gynecology orthopedics and anesthesia. In addition, certain specialties are accredited by the Arab Medical Council (Al-Makassed Hospital, 2007).

4.5.2. Ramallah Governmental Hospital

Ramallah Governmental Hospital is located in the center of Ramallah city. It was built in 1961 as a small facility and has now become the main medical referral center for the West Bank. Having 150 beds, it treated 20,550 inpatients and 41,387 emergency cases in 2008 (Ramallah Governmental Hospital, 2008). Its health services include: internal medicine, normal nursery, general surgery orthopedics, urology, pediatrics, obstetrics and gynecology, laboratory, cardiac catheterization, X-ray facilities, blood bank, and physiotherapy (see table 4.2). In addition, intensive care units and operating theaters are also available.

Ramallah Governmental Hospital is also fully accredited for postgraduate training in five medical specialties by both Jordanian and Palestinian medical councils. These specialties are: internal medicine, general surgery, pediatrics orthopedics and anesthesia.

Table (4.2) Number of beds per department at Al-Makassed Hospital and Ramallah Governmental Hospital

Department	No. of beds/ Al-Makassed	No. of beds/ Ramallah
General surgery and urology	30	35
Orthopedic	35	-
Open-heart surgery	18	-
Adult ICU	6	6
Internal medicine	34	28
CCU and cardiac cath.	26	-
Pediatric and peds. I.C.U.	39	34
Neonate	32	15
Gynecology	40	32
Total	250	150

Source: Personal contact with hospital management, May 2008.

In addition, the two hospitals operate the main medical imaging departments in the West Bank. Table (4.3) illustrates the types and the number of medical imaging examinations that were conducted in each hospital in 2008.

Table (4.3) Number of X-ray examinations at Al-Makassed Hospital and Ramallah Governmental Hospital in 2008

Type of medical imaging examination	**No. of examinations/ Al-Makassed**	**No. of examinations/ Ramallah**
Routine X-ray examinations	32,014	70,312
Fluoroscopy	621	-
CT scan	1516	5214
MRI	1148	-
U/S	4066	4135
Total	39365	79661

Source: Personal contact with hospital management, May 2008.

4.6. Instrument of the current study

The data collection tool used in this study was a self-reported questionnaire. The questionnaire items were derived from five previous studies, as shown in table (4.4).

Table (4.4) Studies from which the items of the questionnaire were taken.

Question number	Source of question
Q5; Q7; Q21; Q22; Q23; Q24	Quinn study (1997)
Q6; Q12; Q13; Q18; Q20	Karen et al study (2004)
Q9; Q10; Q11; Q14; Q15; Q16; Q19	Henry et al study (2007)
Q17	Maria et al study (2004)
Q8	Mohamed, study (2005)
Q25	ICRP recommendations

After the development of the questionnaire by the main researcher and the supervisor and before conducting the main study, the managerial directors of two other hospitals, Augusta Victoria and Al-Hussein, were approached for the purpose of testing the relevance of the instrument. They agreed to nominate physicians to participate in a committee, which consisted of nine physicians and four other experts and met in May

2008. The members of the committee looked at the content, clarity and relevance of the instrument. The questionnaire was written in the English language, according to their request. They made a number of comments which were incorporated into the final form of the questionnaire, mainly language-related changes which were not judged to substantially alter the instrument.

The questionnaire for the current study consists of two sections, as shown in appendix (E): Section One included six items about independent variables such as work place, gender, occupation, specialty, country of medical graduation, and years of clinical practice, while Section Two included 29 items related to the physicians' knowledge of radiation doses and risks. The content of this part was based on three types of questions:

1. Questions which were responded to by selecting yes or no answers (questions 11, 13-16, 18 and 25).

2. One mixed question, in which the answer to the second part of the question depended on the answer given to the first part, whether yes or no (question 7).

3. Multiple-choice questions, with each question having just one correct answer (questions 8-10, 12, 17, 19 and 20-24).

4.7. Validity and reliability of the instrument

Reliability refers to the stability or consistency of information that is obtained when a measurement is performed more than once. It also can be defined as the degree to which an instrument yields the same data each time it used under the same conditions and with the same subjects (Polgarr & Thomas, 1997).

There are two ways by which reliability is commonly estimated: (1) test/retest, which checks whether repeating the test/questionnaire under the same conditions produces the same results; and (2) internal consistency. For the purpose of the current study, the second method, internal consistency, is utilized: It estimates reliability by first grouping questions in a questionnaire into various groups according to the concepts being measured, then the responses are correlated by using Cronbach's Alpha (Polgarr & Thomas, 1997). Cronbach's Alpha coefficient is one of the most common means of estimating the internal consistency of items in a scale. Popularized in a 1951 article by Cronbach, Alpha measures the extent to which item responses obtained at the same time correlate highly with each other. Commonly, an Alpha level of 0.7 or higher indicates acceptable reliability, and 0.8 or higher indicates good reliability. An Alpha level of 0.95 or higher is considered as indicating high reliability but is not necessarily desirable (Cronbach & Richard, 2004). In this study Cronbach's Alpha was calculated to assess the instrument's reliability (by using SPSS) and was found to be 0.76.

The reliability of the instrument does not necessarily mean that it is satisfactory, until it is associated with validity. Validity refers to the adequacy with which the method of measurement is able to measure the issues or phenomena under study. Cook and Campbell (1979) define validity as the "best available approximation to the truth or falsity of a given inference, proposition or conclusion" (Abramson J & Abramson Z, 1999).

There are several types of validity (Abramson J & Abramson Z, 1999), including:

- Face Validity (logic validity) - In this type of validity the relevance of the measurement appears obvious to the investigator. This validity is largely considered as a common-sense assessment. A questionnaire has face validity if it yields information of real relevance to what the investigators want to measure.
- Content Validity – If the variable to be measured is a composite one, the validity is achieved by ensuring that all the component elements of the variable are measured.
- Criterion Validity – This type compares the results of the questionnaire with a criterion that is known to be close to the truth.
- Predictive Validity – It asks whether the questionnaire can successfully predict a future event. For example, does a questionnaire used in selecting executives predict the success of those executives after they have been appointed?
- Concurrent Validity – It assesses whether the results of a new questionnaire are consistent with the results of established measures.

- Consensual Validity – This is achieved when a number of experts agree together that a measure is valid.

The questionnaire items of the current study were used in many previous studies which sought to assess physicians' knowledge of radiation doses and risks, as mentioned previously in this chapter. In addition, the validity of this study questionnaire was examined by a committee of four experts in radiology and medicine plus a focus group of nine physicians of various medical specialties from Al-Hussein Hospital in Bethlehem and Augusta Victoria in Jerusalem, in order to test the content of the questionnaire.

Use of this focus group produced several benefits (William, 2006), including:

- Production of data, insight and ideas;
- Sharing of experiences, which provides better understanding of the issues or phenomena under study; and
- Feedback as to the clarity and validity of the study instrument.

Augusta Victoria Hospital is a non-profit general hospital located in Jerusalem city. It has 253 employees, consisting of 115 nurses, 32 physicians, 18 technicians, and 87 other employees working in administration and support services. The total number of beds is 164 (Augusta Victoria Hospital, 2008).

Al-Hussein Hospital is a Palestinian government-run hospital located in Bethlehem in the West Bank. It has a total of 113 beds. It has 352 employees, of whom 110 are nurses, 48 are physicians, 26 are technicians, and 55 other employees work in administration and support services (Al-Hussein Hospital, 2008).

4.8. Ethical considerations

In order to gain access to Ramallah Governmental Hospital and Al-Makassed Hospital, the General Director of Hospitals for the Palestinian Ministry of Health and the general director of Al-Makassd Hospital were both formally approached via an introductory letter which presented information about the proposed study and its purpose. These individuals were asked to give their permission to conduct the study among their personnel, and their responses were positive. Before starting the survey, the proposal was also submitted to the Public Faculty at Al-Quds University who likewise gave approval to conduct this study according to the thesis preparation guide of the Factually of Graduate Studies.

In order to maintain ethical standards in this study, the researcher introduced the questionnaire to the participants along with a cover letter about its objectives and importance. An accompanying statement assuring the voluntary nature of participation in the study, and that participants had the right to decline to participate. In addition, the participants were assured that anonymity and confidentiality would be maintained at all times, and that the data provided by the participants would be used for research purposes only and would be expressed only in general terms. No names or codes or any other mechanisms would be used to trace responses back to an individual participant.

4.9. Data collection

After sending a formal letter to the Palestinian Ministry of Health and to Al-Makassed Hospital explaining the purpose of the study, permission was granted in May 2008 by the general directors.

In order to qualify for the inclusion in the study, physicians had to be registered as regular employees in one of the two hospitals and authorized to request (i.e. order and prescribe) radiological examinations. After receiving permission to conduct the study, the researcher personally distributed the self-reported questionnaire to physicians from various medical specialties, such as: surgery, internal medicine orthopedics, anesthesiology, gynecology, pediatrics and general physicians, in both hospitals. The data collection process took three weeks, starting at the beginning of June 2008 and ending on 21 June 2008. The general directors of the two hospitals played a very important role in facilitating and encouraging the physicians to participate in the study, and this was a crucial factor in obtaining the high response rate of 97.6%. The general director of Ramallah Governmental Hospital also assisted the researcher in distributing the questionnaire, and the general director at Al-Makassed Hospital asked all the heads of medical departments to facilitate the conducting of the study. More than 80% of the questionnaires were collected during the morning report at both hospitals on the first day of data collection. Physicians who were on leave during the first day of data collection responded to the questionnaire mainly through direct contact with the researcher after their return to work.

4.10. Statistical analysis

The data was analyzed by using the Statistical Package for Social Science (SPSS), Version 15.0. The data were checked for entry errors (data clearance). Characteristics of the sample were obtained through descriptive analysis (frequencies). Relationships between selected variables was analyzed by use of the chi-squared and Fisher exact tests.

4.11. Summary

- There are two types of quantitative research: experimental and non-experimental designs. Non-experimental research includes correlational research and descriptive research. Descriptive research involves observing, describing and documenting aspects of the situation as they naturally occur.

- A cross-sectional design was utilized in the current study because it is useful for the descriptive purposes. All physicians (167) working in Al-Makassed hospital or Ramallah Governmental Hospital who have direct contact with patients from different units (medical, general surgery orthopedics, neurosurgery, etc.) were included.

- The data collection tool used in this study was a self-reported questionnaire whose items were derived from five previous studies. The questionnaire consisted of six items about demographic and personality variables and 29 items related to physicians' knowledge of radiation doses and risks.

- The validity of the questionnaire was assessed by a committee of nine physicians and four other experts, from Al-Hussein Hospital in Bethlehem and Augusta Victoria in Jerusalem. The reliability of the instrument was tested by using Cronbach's Alpha coefficient and the result was acceptable 0.76. The data was analyzed by using Statistical Package for Social Science, Version 15.0.

CHAPTER FIVE

RESULTS

Chapter Five

Results

5.1. Introduction

As discussed previously, in order to achieve the main aim of the current study of assessing physicians' knowledge of the radiation hazards associated with radiological examinations, a cross-sectional study was utilized and a self-reported questionnaire about radiation protection knowledge was distributed to 167 physicians from Al-Makassed Hospital and Ramallah Governmental Hospital.

This chapter presents the findings of this study as follows:

- Description of the characteristics of the study participants
- Physicians' responses to the knowledge-based questions

5.2. Characteristics of the study participants

Physicians of Ramallah Governmental Hospital and Al-Makassed Hospital were targeted for participation in this study. The sample consisted of 167 physicians (107 from Al-Makassed Hospital and 60 from Ramallah Governmental Hospital). Out of the 167 questionnaires distributed 163 were returned back. The response rate was 97.6% (for Ramallah Governmental Hospital (98.33%) and Al-Makassed Hospital (97.17%)).

The vast majority of the respondents were males (85.3% (n=139), whereas only 14.7% (n=24) were females (see Figure 5.1).

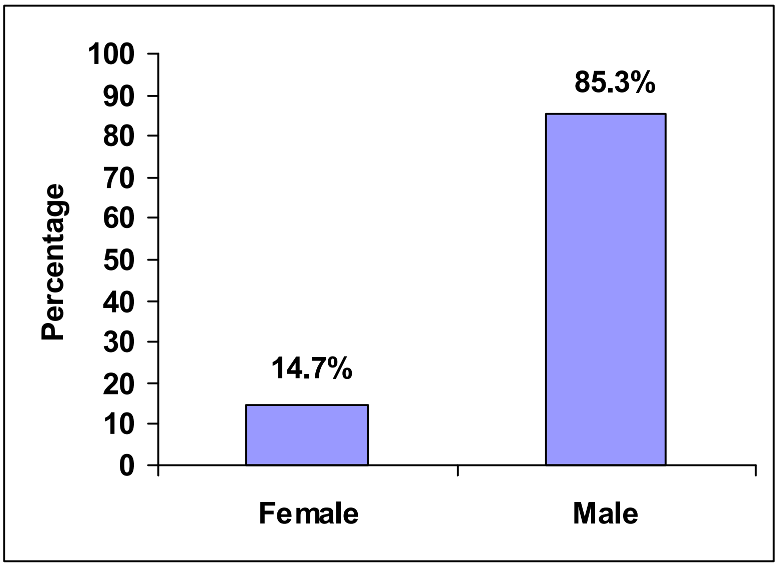

Figure (5.1) Distribution of participants by gender

Of the 163 participants, 43.6% (n=71) were consultants, 47.9% (n=78) were residents who were then attending medical qualification programs under consultants' supervision and 8.6% (n=14) were from other medical categories (9 emergency physicians, 2 internal medicine consultant assistants, 1 cardiologist consultant assistant and 2 anesthesiologist consultant assistants) (see Figure 5.2).

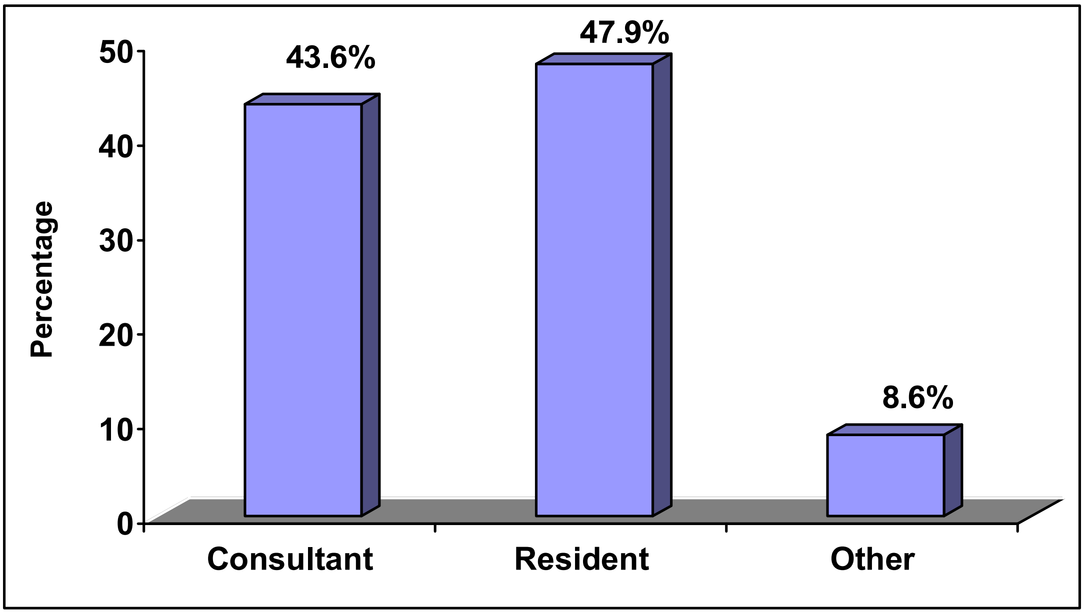

Figure (5.2) Distribution of participant physicians by occupation

With regard to specialty, 18.4 % (n=30) of respondents were surgeons, 19.6 % (n=32) were internal medicine specialists, 8.6% (n=14) were orthopedists, 8% (n=13) were anesthesiologists, 8.6% (n=14) were gynecologists, 13.5% (n=22) were pediatricians and 5.5% (n=9) were general practitioners. However, 17.8% (n=29) of the respondents did not state their specialty (see Figure 5.3).

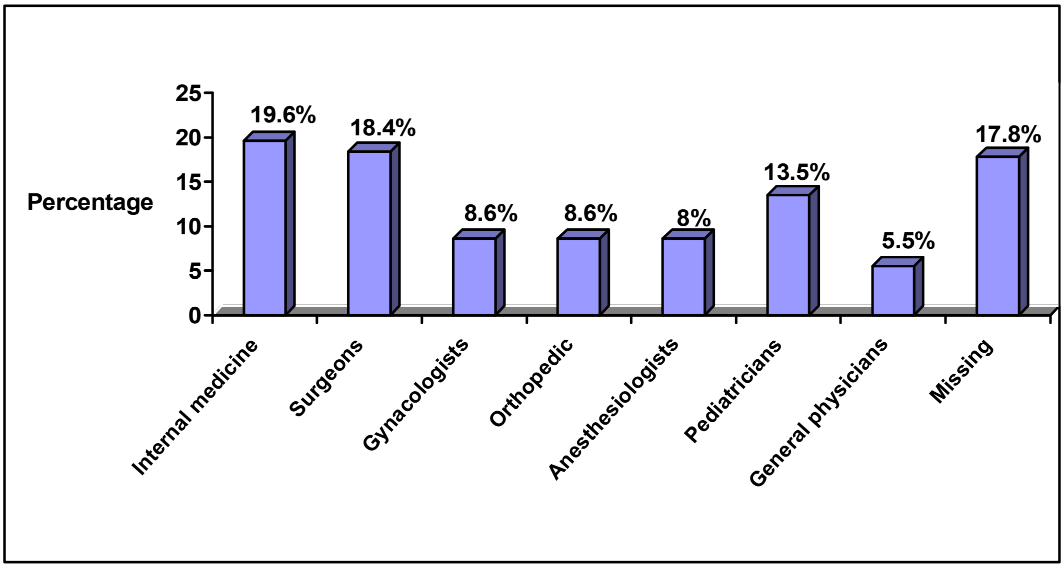

Figure (5.3) Distribution of participants by speciality

The majority of respondents (43.6% (n=71)) graduated from medical programs in Arab countries, 19.6% (n=32) gradated from former Soviet Union countries, 12.3% (n=20) graduated from Western countries, and 4.9% (n=8) graduated from other countries (five from Pakistan and one each from Brazil, Israel and Turkey). However, 19.6% (n=32) of the respondents did not indicate the country of their graduation (see Figure 5.4).

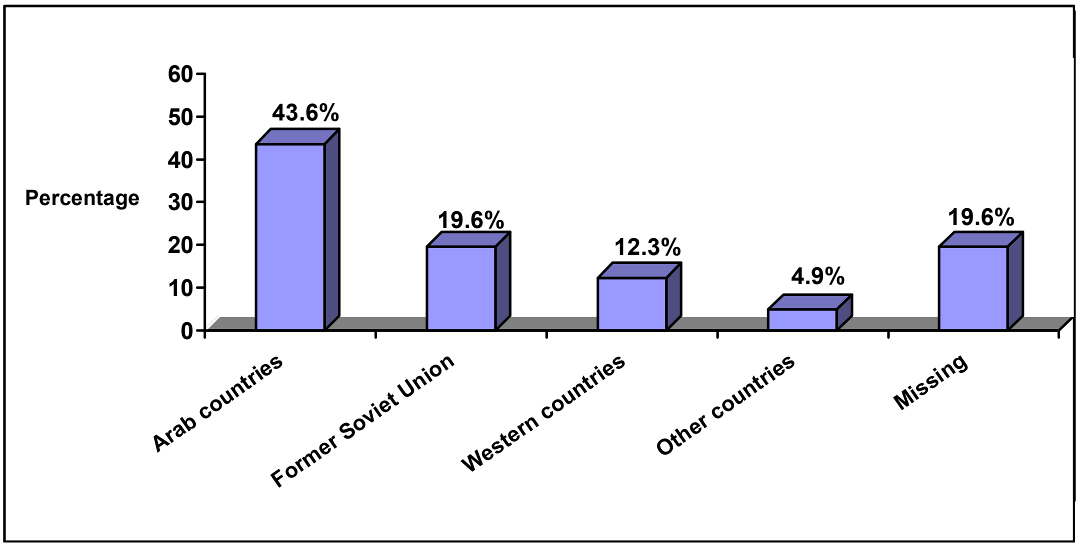

Figure (5.4) Distribution of participants by country of medical graduation

The work experience of the respondents ranged from less than 5 years to more than 20 years. Figure (5.5) indicates that more than one-third of participants (35% (n=57)) had work experience of less than 5 years, 31.9% (n=52) had work experience between 5 and 10 years, 14.1% (n=23) had work experience between 11 and 20 years, and 19% (n=31) had over 20 years of work experience.

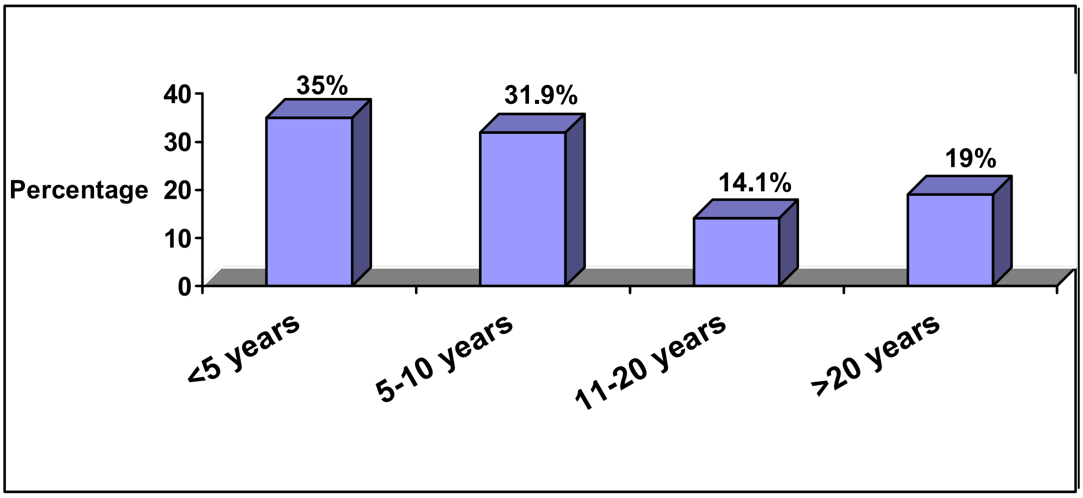

Figure (5.5) Distribution of participants by years of clinical practice

5.3. Participants knowledge of radiological examination hazards

The knowledge-based questions included 29 items related to participants' knowledge of radiation hazards from radiological examinations.

Participants were asked if they attended any radiation protection course during their medical studies. Interestingly, most of the respondents (70.6% (n=115)) indicated that they did not attend any radiation protection course during their medical studies (see Table 5.1).

Table (5.1) Participants' attendance of a radiation course during study

Participants' attendance of radiation course(s) during their medical study	Freq	%
Yes	48	29.4
No	115	70.6
Total	163	100.0

Cross-tabulation between different independent variables and the attendance of a radiation course during their medical study was done by using the chi-squared and Fisher exact tests. The statistical significance was defined as a *P*-value of less than 0.05 (see Table 5.2).

As shown in Table (5.2), 32.2% (n=19) of respondents from Ramallah Governmental Hospital and 27.9% (n=29) from Al-Makassed Hospital reported that they had attended such a course during their studies. However, the chi-squared test results were not significant *(p=0.561).*

More obvious variations were seen among respondents of different specialties. For example, 50% (n=7) of orthopedic physicians reported that they attended a radiation protection course during their formal studies, whereas only 13.6% (n=3) of pediatric physicians reported that they attended such a course. However, the Fisher exact test did not reveal any statistical significance *(p=0.143).*

With regard to gender, 31.7% (n=44) of male respondents and 16.7% (n=4) of female respondents reported that they attended a radiation protection course during their studies. However, once again, the chi-squared test results were not significant *(p=0.137).*

The findings in (table 5.2) illustrate that attendance of a radiation course during formal studies produced no statistically significance findings when compared to occupation, country of medical training and years of clinical practice.

Table (5.2) Distribution of participants' responses regarding receiving radiation course during study by independent variables:

	Yes		No		P*
	Freq	**%**	**Freq**	**%**	
Workplace					
Makassed	29	27.9%	75	72.1%	.561
Ramallah	19	32.2%	40	67.8%	
Occupation					
Consultant	16	22.5%	55	77.5%	.238^{b}
Resident	27	34.6%	51	65.4%	
Others	5	35.7%	9	64.3%	
Specialty					
Surgery	14	46.7%	16	53.3%	.143^{b}
Medicine	11	34.4%	21	65.6%	
Pediatric	3	13.6%	19	86.4%	
Gynecology	3	21.4%	11	78.6%	
Orthopedics	7	50.0%	7	50.0%	
Anesthesia	3	23.1%	10	76.9%	
Emergency (ER)	3	33.3%	6	66.7%	
Country of medical graduation					
Western countries	7	35%	13	65%	.412^{b}
Arab countries	19	26.8%	52	73.2%	
Former soviet Union countries	12	37.5%	20	62.5%	
Others	4	50.0%	4	50.0%	
Gender					
Male	44	31.7%	95	68.3%	.137
Female	4	16.7%	20	83.3%	
Years of clinical practice					
< 5	20	35.1%	37	64.9%	.457^{b}
5-10	16	30.8%	36	69.2%	
11-20	4	17.4%	19	82.6%	
>20	8	25.8%	23	74.2%	

**** P values* marked with the letter (b) were derived using the Fisher exact test; all others were done using the chi-squared test.**

More than two-thirds (n=113) of the respondents reported that after graduation and during their practice they did not attend a radiation protection course, while 30.7% (n=50) indicated that they had received such a course at their workplaces (see table 5.3).

Table (5.3) Participants' attendance of a radiation course during work

Attendance of radiation course during work	Freq	%
Yes	50	30.7
No	113	69.3
Total	163	100

The fifty respondents who reported that they received a radiation teaching at their workplace were asked to indicate how they obtained access to this teaching. More than half of them (58.0% (n=29)) stated that they took it as part of their formal postgraduate training, while 24.0% (n=12) reported that they got it through self-education. Ten percent (n=5) indicated that they received it through informal discussion, and 2.0% (n=1) indicated other sources such as radiation protection conferences. However, 6% (n=3) did not indicate the source of this training (see Figure 5.6).

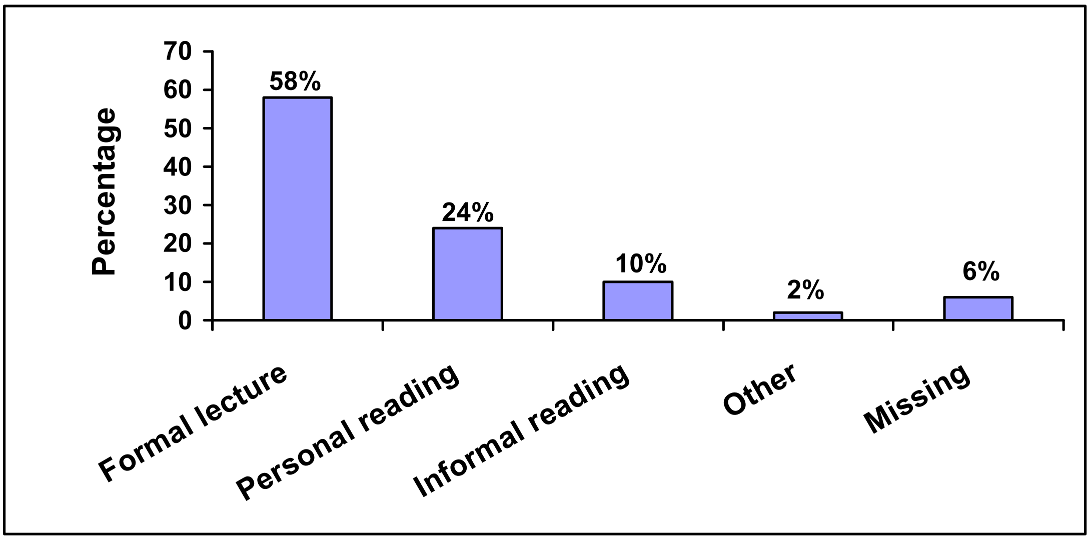

Figure (5. 6) Distribution of participants by source of radiation training during work

Also, cross-tabulation between respondents' different independent variables and their attendance of a radiation course at work place was done by using the chi-squared and Fisher exact tests. No statistically significant findings were found (see table 5.4).

Some variations were seen among respondents of different specialties in relation to attendance of a radiation protection course at their workplace. For example, 50.0% (n=16) of the internal medicine physicians reported that they had attended such a course, while only 18.2% (n=4) of pediatricians reported that they had attended such a course. However, Fisher exact test results were not significant *(P = 0.235).*

As to place of employment, 35.6% (n=21) of the respondents from Ramallah Governmental Hospital reported that they had received such a course in the workplace, while 27.9% (n=29) of Al-Makassed hospital respondents reported that they had received such a course in the workplace. However, chi-squared tests revealed no statistically significant association *(p = 0.305).*

Interestingly, 31.7% (n=44) of male respondents reported that they attended a radiation protection course at the workplace, while 25.0% (n=6) of female respondents reported that they attended such a course. However, this result was statistically not significant *(p=0.514).*

Table (5.4) Distribution of participants' responses regarding receiving a radiation course in the workplace, by independent variables:

	Yes		No		P*
	Freq	%	Freq	%	
Workplace					
Makassed	29	27.9%	75	72.1%	.305
Ramallah	21	35.6.%	38	64.4%	
Occupation					
Consultant	21	29.6%	50	70.4%	.903^{b}
Resident	24	30.8%	54	69.2%	
Others	5	35.7%	9	64.3%	
Specialty					
Surgery	7	23.3%	23	76.7%	.235^{b}
Medicine	16	50.0%	16	50.0%	
Pediatric	4	18.2%	18	81.8%	
Gynecology	4	28.6%	10	71.4%	
Orthopedics	4	28.6%	10	71.4%	
Anesthesia	3	23.1%	10	76.9%	
Emergency (ER)	3	33.3%	6	66.7%	
Country of medical graduation					
Western countries	6	30.0%	14	70.0%	.775^{b}
Arab countries	20	28.2%	51	71.8%	
Former soviet Union countries	12	37.5%	20	62.5%	
Others	3	37.5%	5	62.5%	
Gender					
Male	44	31.7%	95	68.3%	.514
Female	6	25.0%	18	75.0%	
Years of clinical practice					
< 5	12	36.8%	36	63.2%	.663^{b}
5-10	14	26.9%	38	73.1%	
11-20	7	30.4%	16	69.6%	
>20	8	25.8%	23	74.2%	

*** *P values* marked with the letter (b) were derived using the Fisher exact test; all others were done using the chi-squared test.**

Participants were asked if they knew the ALARA principle, which is considered as constituting the basic principles of radiation protection. Surprisingly, the majority of the participants (93.9% (n=153)) indicated that they did not know this principle, and only 6.1% (n=10) of the respondents reported that they knew it (see figure 5.7).

Also, respondents who reported that they knew the ALARA principle were asked to indicate what this principle means. Eight respondents out of 10 were able to identify it.

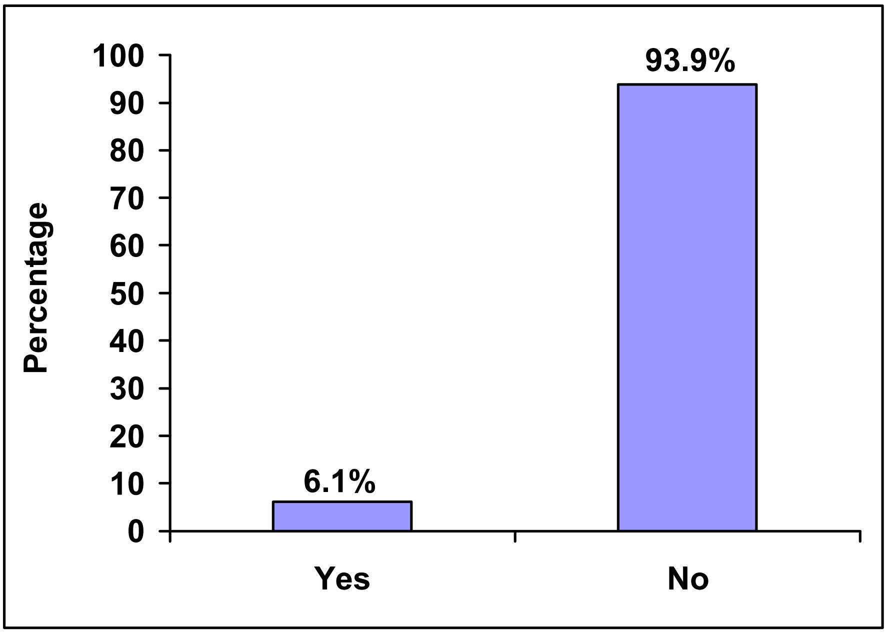

Figure (5.7) Distribution of respondents' knowledge of ALARA principle

Cross-tabulating using the chi-squared and Fisher exact tests was utilized to assess the respondents' knowledge of ALARA principle as a function of workplace, occupation, medical specialty, country of medical graduation, years of clinical practice and gender, as shown in table (5.5).

According to specialty, internal medicine physicians most often reported being familiar with the ALARA principle (21.9% (n=7)), however *none* of the pediatric, anesthesia, gynecology or emergency physicians reported that they know it. The results were statistically significant *(P=0. 023)* (see table 5.5).

As to country of medical graduation, 25% (n=5) of physicians who graduated from Western countries reported that they knew the ALARA principle, as did 6.2% (n=2) of physicians who graduated from Former Soviet Union countries and 1.4% (n=1) of those who graduated from Arab countries. These results were statistically significant *(P=0.005).*

No statistically significant results were found regarding ALARA for work place, occupation, years of clinical practice or gender, as shown in table (5.5).

Table (5.5) Cross-tabulation of respondents' knowledge of the ALARA principle, by independent variables:

	Yes		**No**		P*
	Freq	**%**	**Freq**	**%**	
Workplace					
Makassed	4	3.8%	100	96.2%	.106
Ramallah	6	10.2%	53	89.8%	
Occupation					
Consultant	6	8.5%	65	91.5%	.456^{b}
Resident	3	3.8%	75	96.2%	
Others	1	7.1%	13	92.9%	
Specialty					
Surgery	1	3.3%	29	96.7%	.023^{b}
Medicine	7	21.9%	25	78.1%	
Pediatric	0	0.0%	22	100%	
Gynecology	0	0.0%	14	100%	
Orthopedics	2	14.3%	12	85.7%	
Anesthesia	0	0.0%	13	100%	
Emergency (ER)	0	0.0%	9	100%	
Country of medical graduation					
Western countries	5	25.0%	15	75.0%	.005^{b}
Arab countries	1	1.4%	70	98.6%	
Former Soviet Union countries	2	6.2%	30	93.8%	
Others	0	0.0 %	8	100%	
Gender					
Male	10	7.2%	129	92.8%	.175
Female	0	0.0%	24	100%	
Years of clinical practice					
< 5	3	5.3%	54	94.7%	.314^{b}
5-10	3	5.8%	49	94.2%	
11-20	0	0.0%	23	100%	
>20	4	12.9%	27	87.1%	

**** P values* marked with the letter (b) were derived using the Fisher exact test; all others were done using the chi-squared test.**

Furthermore, respondents were asked if they were aware of any articles that had been published in recent years in the main scientific journals concerning radiation hazards associated with CT scan examinations, especially among children. Fewer than half of the respondents (46% (n=75)) indicated that they were aware of such articles, whereas 54% (n=88) of respondents reported that they did not know about them (see figure 5.8).

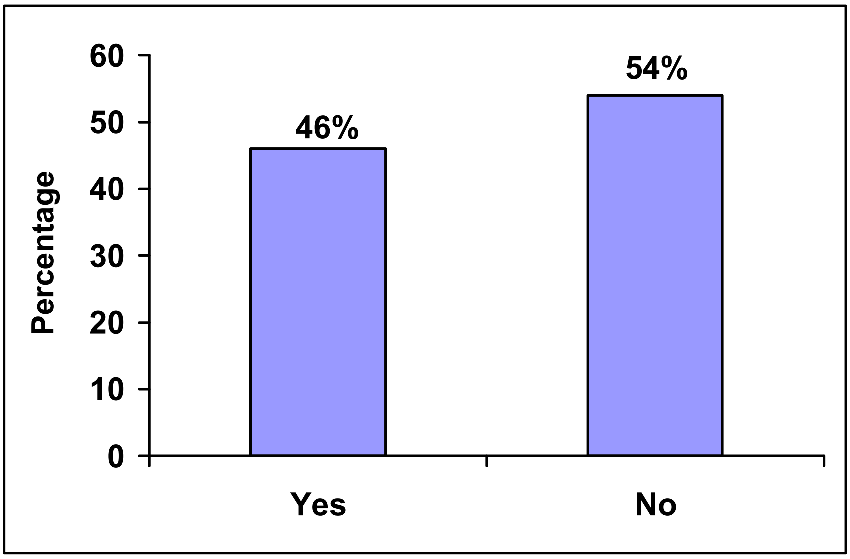

Figure (5.8) Distribution of respondents' knowledge of radiation hazards articles

Cross-tabulation by means of chi-squared and Fisher exact tests was used to assess the respondents' knowledge of radiation hazards articles in the recent past, in relation to independent variables, as shown in table (5.6).

Findings indicated a significant statistical relationship between participants' gender and their knowledge of these articles, where 50.4% (n=70) of male respondents but only 20.8% (n=5) of female respondents reported that they were aware of these articles *(P=0.007).*

According to medical specialty, variations among physicians were seen in relation to their awareness of these articles. For example, 60% (n=18) of surgical physicians reported that they aware of these articles, while only 23.1% (n=3) of anesthesiologists indicated that they were aware of them. However, Fisher exact tests revealed no statistically significant association *(P= 0.21).*

Table (5.6) shows no significant statistical relationship between respondents' knowledge of these articles and their workplace, occupation, country of medical graduation or years of clinical practice.

Table (5.6) Cross-tabulation of respondents' knowledge of radiation articles and independent variables:

	Yes		No		P*
	Freq	%	Freq	%	
Workplace					
Makassed	45	43.3%	59	56.7%	.351
Ramallah	30	50.8%	29	49.2%	
Occupation					
Consultant	32	45.1%	39	54.9%	.347[b]
Resident	39	50.0%	39	50.0%	
Others	4	28.6%	10	71.4%	
Specialty					
Surgery	18	60.0%	12	40.0%	.210[b]
Medicine	16	50.0%	16	50.0%	
Pediatric	9	40.9%	13	59.1%	
Gynecology	4	28.6%	10	71.4%	
Orthopedics	8	57.1%	6	42.9%	
Anesthesia	3	23.1%	10	76.9%	
Emergency (ER)	3	33.3%	6	66.7%	
Country of medical graduation					
Western countries	13	65.0%	7	35.0%	.134[b]
Arab countries	28	39.4%	43	60.6%	
Former Soviet Union countries	16	50.0%	16	50.0%	
Others	2	25.0%	6	75.0%	
Gender					
Male	70	50.4%	69	49.6%	
Female	5	20.8%	19	79.2%	.007
Years of clinical practice					
< 5	29	50.9%	28	49.1%	.719[b]
5-10	22	42.3%	30	57.7%	
11-20	9	39.1%	14	60.9%	
>20	15	48.4%	16	51.6%	

*** *P values* marked with the letter (b) were derived using the Fisher exact test; all others were done using the chi-squared test.**

In addition, respondents were asked if they knew that the Food and Drug Administration (FDA) in the USA has listed medical X-rays as a known carcinogen. 54.6% (n=89) of the respondents indicated that they knew this, whereas 45.4% (n=74) indicated that they did not know it (see figure 5.9).

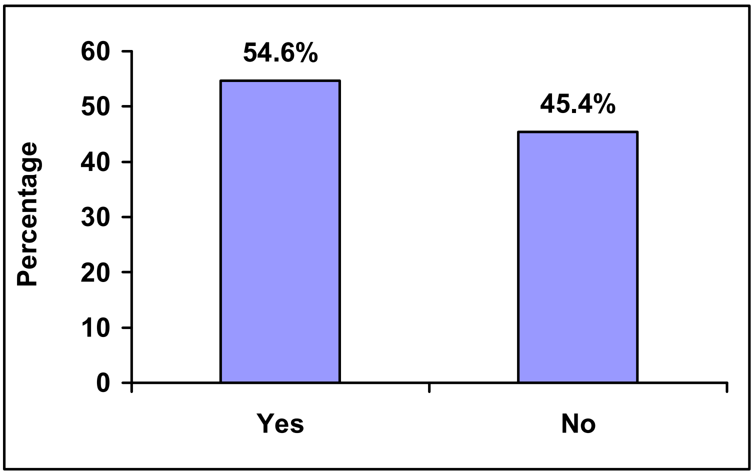

Figure (5.9) Distribution of respondents' knowledge of FDA listing about radiation as a carcinogen

To examine this question further, chi-squared and Fisher exact tests were used to compare the respondents' knowledge of the FDA classification of medical X-rays as a known carcinogenic according to their different independent variables, as shown in table (5.7).

This analysis revealed that 60.4% (n=84) of male respondents but only 20.8% (n=5) of female respondents reported that they are aware of this listing. This difference was found to be highly significant (*p=0.000).*

Also, 64.4% (n=38) of respondents from Ramallah Governmental Hospital reported that they are aware of the FDA radiation carcinogenetic listing, compared to 49.0% (n=51) respondents from Al-Makassed Hospital. However, no statistically significant relationship was found *(p=0.058).*

Likewise, no statistically significant relationships were found on this point for respondents' occupation, country of medical graduation, years of clinical practice or medical specialty, as shown in table (5.7).

Table (5.7) Cross-tabulation of respondents' knowledge of the FDA listing of medical X-rays as carcinogenic, by independent variables:

	Yes		No		P*
	Freq	%	Freq	%	
Workplace					
Makassed	51	49.0%	53	51.0%	.058
Ramallah	38	64.4%	21	35.6%	
Occupation					
Consultant	44	62.0%	27	38.0%	.251[b]
Resident	38	48.7%	40	51.3%	
Others	7	50%	7	50.0%	
Specialty					
Surgery	17	56.7%	13	43.3%	.896[b]
Medicine	19	59.4%	13	40.6%	
Pediatric	11	50.0%	11	50.0%	
Gynecology	8	57.1%	6	42.9%	
Orthopedics	7	50.0%	7	50.0%	
Anesthesia	7	53.8%	6	46.2%	
Emergency (ER)	3	33.3%	6	66.7%	
Country of medical graduation					
Western countries	13	65.0%	7	35.0%	.286[b]
Arab countries	34	47.9%	37	52.1%	
Former Soviet Union countries	21	65.6%	11	34.4%	
Others	4	50.0%	4	50.0%	
Gender					
Male	84	60.4%	55	39.6%	.000
Female	5	20.8%	19	79.2%	
Years of clinical practice					
< 5	30	52.6%	27	47.4%	.683[b]
5-10	27	51.9%	25	48.1%	
11-20	12	52.2%	11	47.8%	
>20	20	64.5%	11	35.5%	

*** *P values* marked with the letter (b) were derived using the Fisher exact test; all others were done using the chi-squared test.**

Respondents were asked about the best form of radiation protection for individuals who are routinely exposed to radiation (such as radiation workers). Only 11% (n=18) of respondents selected the answer that distance is the best form of radiation protection; 30.1% selected lead screen/apron; 16.6% selected film badge; and 17.2% selected time. Another 25.1% (n=41) of respondents indicated that they did not know the answer, as shown in figure (5.10).

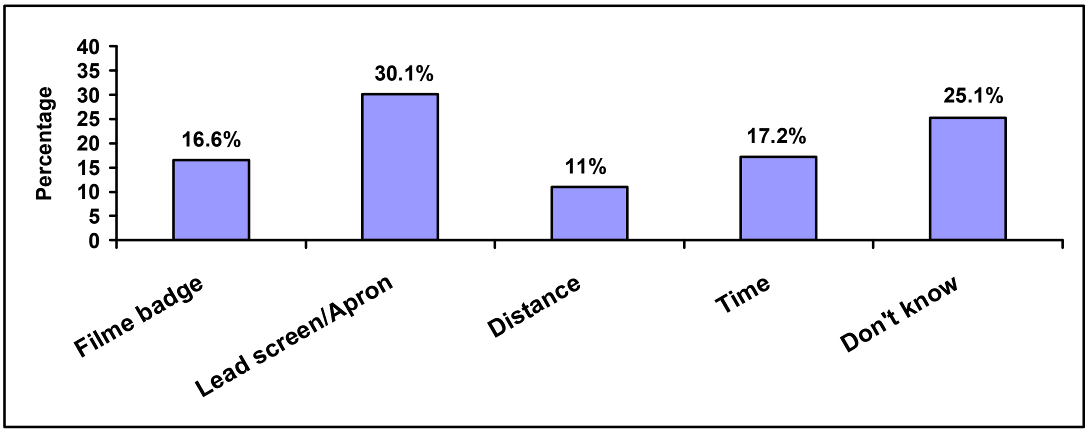

Figure (5.10) Distribution of respondent's knowledge of the best radiation protection methods

Regarding the ICRP recommendations defining professional responsibility for protecting patients from unnecessary radiation doses, one-third of the respondents (31.9% (n=52)) selected the correct answer, that ICRP recommendations forbid unjustified exposure to ionizing radiation and place responsibility for protecting patients from unnecessary radiation doses on both the prescriber and the practitioner. More than half of the respondents (57.7% (n=94)) indicated that they did not know the answer, and 10.4% (n=17) selected the other unscientific answers, as shown in figure (5.11).

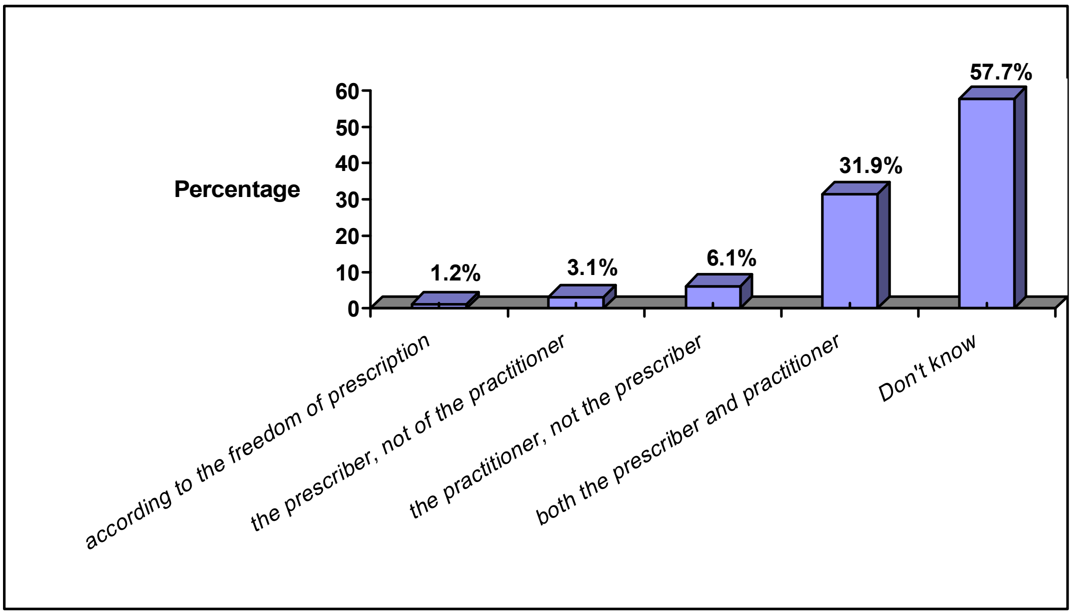

Figure (5.11) Distribution of respondents knowledge of radiation protection responsibility

Scientific research has calculated and reported the increase in lifetime risk for the development of cancer, for a child, from a *single* abdominal and pelvic CT scan. Only 9.2% (n=15) of respondents selected the correct answer for this statistic: an increased lifetime risk of cancer of 1:1,000; 74.8% (n=122) of respondents indicated that they did not know the correct answer and 16% (n=26) of respondents selected incorrect answers, as shown in figure (5.12).

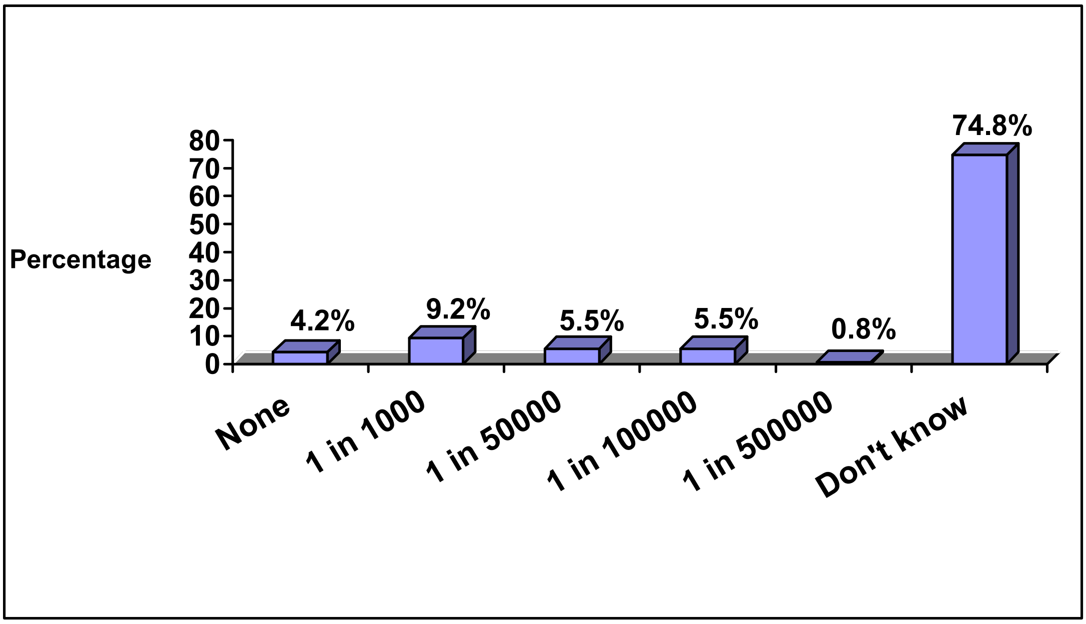

Figure (5.12) Distribution of respondents' knowledge of the risk from one abdominal and pelvic CT scan for a child:

It is known that the radiation dose delivered to the patient by multi-slice CT scanners is higher than that from single-slice helical scanners. However, only 13.5% (n=22) of the respondents selected the correct answer, that multi-slice CT is higher in radiation dose than the single-slice helical scanners, while 28.8% selected one of the other unscientific answers, similar to previous results. More than half of the respondents (57.7% (n=94)) indicated that they did not know the answer (see figure 5.13).

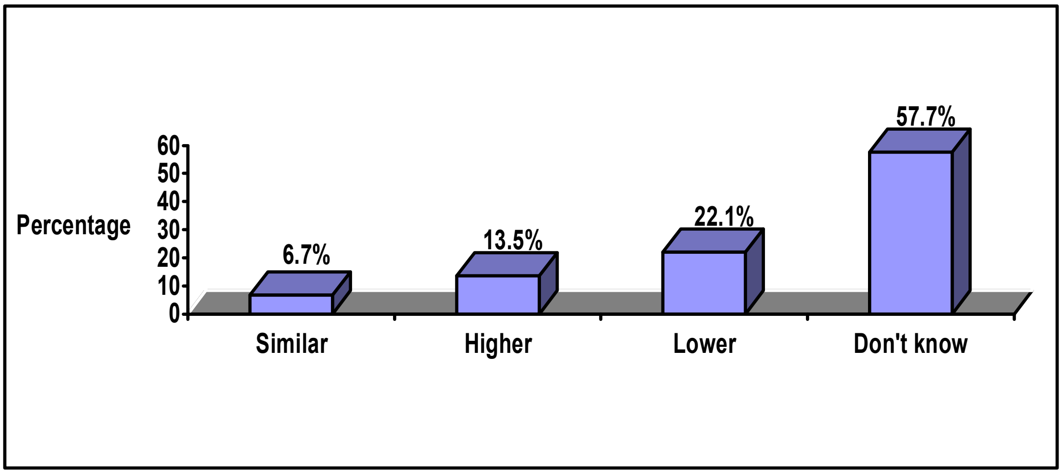

Figure (5.13) Distribution of respondent's knowledge of radiation doses from multi-slice CT scan and single-slice helical scanners

Concerning the percentage of ionizing radiation which comes to the general public from 'medical radiation', only 8% (n=13) of respondents selected the correct answer (15% to 30% of radiation), while the majority of the respondents (63.2% (n=103)) indicated that they did not know the answer and 28.8% (n=47) selected wrong answers, as shown in figure (5.14).

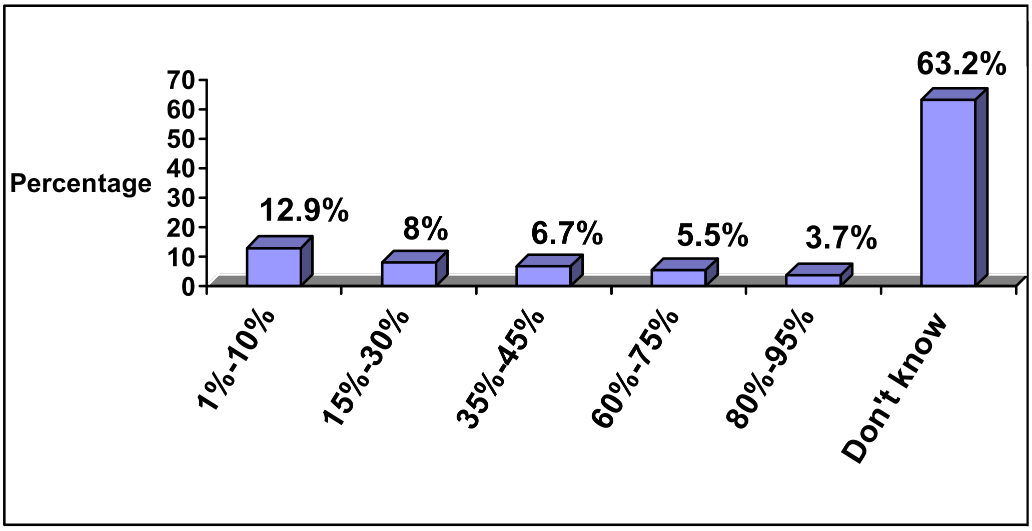

Figure (5.14) Distribution of respondent's knowledge of medical radiation as a percentage of the general public's total radiation exposure

Furthermore, respondents were asked about the whole-body dose limit for a patient which has been determined by radiation protection regulations. Only 1.8% (n=3) of the respondents were able to select the correct answer, that there is in fact *no* dose limit defined for the patient. The majority of the respondents (81% (n=132)) indicated that they did not know the correct answer and 17.2% (n=28) selected other answers, as shown in figure (5.15).

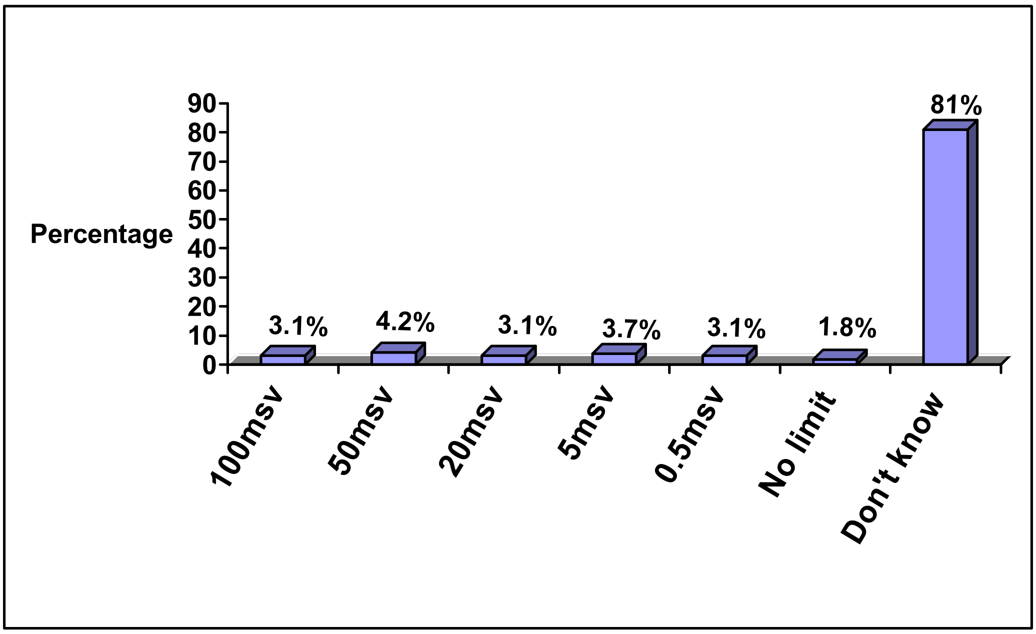

Figure (5.15) Distribution of respondent's knowledge of patient dose limit as determined by radiation protection regulations

Cross-tabulation using chi-squared and Fisher exact tests was done to compare participant response to this question with independent variables (see table 5.8).

In relation to workplace, two respondents (1.9%) from Al-Makassed Hospital and one respondent (1.7%) from Ramallah Governmental Hospital were able to identify the correct answer and this finding is statistically significant *(P=0.034).*

In terms of occupation, two medical residents (2.6%) were able to give the correct answer while none of the consultants knew it. This finding was not statistically significant *(P=0.382).*

As to specialty, one pediatrician, one orthopedic physician and one emergency physicians were able to give the correct answer, while no respondents of the other specialties was able to identify it. This finding was not statistically significant *(P=0.389).*

No statistically significant results were found for country of medical graduation, years of clinical practice or gender, as shown in table (5.8).

Table (5.8) Distribution of respondents' knowledge of patients dose limit, by independent variables:

	150msv	100msv	50msv	20msv	5msv	0.5msv	No limit	Don't know	P*
	freq/%	freq/%	freq/%	freq/%	freq/%	freq/%	freq/%	freq/%	
Workplace									
Makassed	0/ 0.0%	1 /1.0%	7/6.7%	3/2.9%	2/1.9%	2/1.9%	2/1.9%	87/83.7%	.034^b
Ramallah	0/ 0.0%	4/6.7%	0/0.0%	2/3.4%	4/6.8%	3/5.1%	1/1.7%	45/76.3%	
Occupation									
Consultant	0/ 0.0%	2/2.8%	3/4.3%	4/5.6%	2/2.8%	3/4.2%	0/0.0%	57/80.3%	.382^b
Resident	0/0.0%	3/3.8%	2/2.6%	1/1.3%	3/3.8%	2/2.6%	2/2.6%	65/83.3%	
Others	0/0.0%	0/0.0%	2/14.4%	0/0.0%	1/7.1%	0/0.0%	1/7.1%	10/71.4%	
Specialty									
Surgery	0/0.0%	0/0.0%	1/3.3%	2/6.7%	0/0.0%	1/3.3%	0/0.0%	26/86.7%	.389^b
Medicine	0/0.0%	3/9.4%	1/3.1%	1/3.1%	1/3.1%	3/9.4%	0/0.0%	23/71.9%	
Pediatric	0/0.0%	0/0.0%	2/9.1%	0/0.0%	0/0.0%	0/0.0%	1/4.5%	19/86.4%	
Gynecology	0/0.0%	0/0.0%	0/0.0%	0/0.0%	2/14.3%	0/0.0%	0/0.0%	12/85.7%	
Orthopedics	0/0.0%	0/0.0%	0/0.0%	0/0.0%	0/0.0%	1/7.1%	1/7.1%	12/85.8%	
Anesthesia	0/0.0%	0/0.0%	2/15.4%	1/7.7%	0/0.0%	0/0.0%	0/0.0%	10/76.9%	
Emergency (ER)	0/0.0%	0/0.0%	0/0.0%	0/0.0%	0/0.0%	0/0.0%	1/11.1%	8/ 88.9%	
Country of medical graduation									
Western countries	0/0.0%	1/5.0 %	2/10%	1/5.0%	0/0.0%	1/5.0%	0/0.0%	15/75.0%	.669^b
Arab countries	0/0.0%	1/1.4%	2/2.8%	3/4.2%	3/4.2%	1/1.4%	1/1.4%	60/84.6%	
Former soviet Union countries	0/0.0%	1/3.1%	2/6.2%	0/0.0%	0/0.0%	1/3.1%	0/0.0%	28/87.6%	
Others	0/0.0%	0/0.0%	0/0.0%	0/0.0%	0/0.0%	1/12.5%	0/0.0%	7/87.5%	
Gender									
Male	0/0.0%	5/3.6%	6/4.3%	4/2.9%	6/4.3%	4/2.9%	3/2.2%	111/79.8%	.928^b
Female	0/0.0%	0/0.0%	1/4.2%	1/4.2%	0/0.0%	1/4.2%	0/0.0%	21/87.4%	
Years of clinical practice									
< 5	0/0.0%	2/3.5%	2/3.5%	1/1.8%	2/3.5%	4/7.0%	2/3.5%	44/77.2%	.778^b
5-10	0/0.0%	2/3.8%	1./1.9%	1/1.9%	3/5.8%	0/0.0%	1/1.9%	44/84.7%	
11-20	0/0.0%	0/0.0%	2/8.7%	2/8.7%	0/0.0%	0/0.0%	0/0.0%	19/82.6%	
>20	0/0.0%	1/3.2%	2/6.5%	1/3.2%	1/3.2%	1/3.2%	0/0.0%	25/80.7%	

All *P values* were derived using the Fisher exact test.

To assess in more depth the participants' knowledge, the respondents were asked to assess five bodily organs (the lungs, bladder, gonads, kidneys and stomach) according to their radiation sensitivity, on a scale from 1 to 4 as shown in table (2.1) chapter 2, with the most sensitive organ indicated by the number (1) and the least sensitive by (4). The respondents' answers were as follows (see table 5.9).

Less than half of the respondents (44.8% (n=73)) selected the correct answer that the gonads are the most radiosensitive organ, while 44.2% (n=72) of respondents indicated that they did not know the answer and 11.0% (n=18) of them chose one of the other, incorrect answers.

Only 19.6% (n=32) of the respondents identified the lungs as the second most radiosensitive of the five organs. Forty-six percent (n=75) indicated that they did not know, 3.7% (n=6) did not select any answer, and 30.7% (n=15) selected one of the other answers.

A small percentage of respondents (5.5% (n=9)) were able to select the answer that the stomach is the second most radiosensitive organ, but the majority (49.7% (n=81)) indicated that they didn't know the answer. Eight percent (n=13) of respondents did not select an answer and 36.8% selected one of the incorrect answers.

For the bladder, only 14.1% (n=23) of the respondents knew that bladder is the third most radiosensitive organ, 44.8% (n=73) reported that they did not know the answer, 4.9% (n=8) did not select an answer, and 36.2% (n=59) selected an incorrect answer.

Finally, only 19.6% (n=32) of the respondents were able to select the answer that the kidneys were the third most radiosensitive organ, 47.2% (n=77) reported that they did not know the answer, 4.3% (n=7) didn't select any answer, and 28.9% (n=47) selected another, incorrect answer.

Table (5.9) Distribution of respondents' knowledge of body organs relative radio-sensitivity, on a scale of 1 to 4:

	Lungs %	Bladder %	Gonads %	Kidneys %	Stomach %
Percentage of respondents indicated it /them as most radiosensitive	9.2	3.7	44.8	2.5	6.1
Percentage of respondents indicated it /them as second most radiosensitive	19.6	15.3	3.7	9.8	5.5
Percent of respondents indicated it /them as third most radiosensitive	10.4	14.1	1.8	19.6	9.2
Percentage of respondents indicated it the /them as fourth most radiosensitive	11.0	17.2	5.5	16.6	21.5
Percentage of respondents who indicated don't know	46.0	44.8	44.2	47.2	49.7
Missing	3.7	4.9	0	4.3	8.0
Total	100	100	100	100	100

Another aspect of physicians' knowledge examined in this study was their estimation of the effective doses of selected radiological examinations, including lumbar spine, abdominal CT scan and barium enema, expressed in terms of units equivalent to a single frontal (PA) chest X-ray, as shown in table (5.10).

Only 4.3% (n=7) of the respondents were able to select the correct answer, that the relative effective dose from one lumbar spine (L.S.) radiograph is approximately 65 times that of a frontal chest X-ray, while the vast majority of the respondents (76.1% (n=124)) indicated that they did not know the answer and 19.6% (n=32) selected one of the other answers.

Also, a small percentage of respondents (8.6% (n=14 out of 163)) selected the correct answer that the relative effective dose of one abdominal CT scan is more than 250 times that of a frontal chest X-ray. The majority of the respondents (65.6% (n=107)) indicated that they didn't know the answer, and 25.8% (n=42) of respondents selected another answers.

In addition, only 3.1% (n=5) of the respondents selected the correct answer that the relative effective dose of one barium enema is more than 250 times that of a frontal chest X-ray, while 71.8% (n=117) indicated that they didn't know the answer and 25.1% (n=41) selected another, incorrect answer (see table 5.10).

Table (5.10) Distribution of respondents' knowledge of chest X-ray equivalent for three radiological examinations:

Number of chest X-ray equivalent	Lumbar spine		Abdominal CT scan		Barium enema	
	Freq	%	Freq	%	Freq	%
Less than1 chest X-ray	6	3.7	7	4.3	6	3.7
10 chest X-rays	24	14.7	6	3.7	10	6.1
65 chest X-rays	7	4.3	15	9.2	14	8.6
120 chest X-rays	0	0	7	4.3	9	5.5
250 chest X-rays	0	0	7	4.3	2	1.2
Greater than 250 chest X-rays	2	1.2	14	8.6	5	3.1
Don't know	124	76.1	107	65.6	117	71.8
Total	163	100	163	100	163	100

When respondents were asked how often they would request routine X-ray examinations such as chest X-ray, abdominal X-ray, extremity X-rays, etc. for the diagnosis of their patients, more than one-third (35% (n=57)) reported that they “often” requested routine X-ray exams (more than 75% of the time), 39.3% (n=64) indicated that they requested them "sometimes" (25% to 75% of the time), 24.5% (n=40) stated that they "rarely" requested them (less than 25% of the time), while only 1.2% (n=2) indicated that they never used routine X-ray examinations for diagnosis of their patients (see table 5.11).

Table (5.11) Distribution of respondents' request of routine X-ray examinations:

Routine X-ray examinations request	Freq	%
Never	2	1.2
Rarely (less than 25% of the time)	40	24.5
Sometimes (25% - 75% of the time)	64	39.3
Often (more than 75% of time)	57	35

Cross-tabulation by using chi-squared and Fisher exact tests was done to compare respondents' answer to this question with different independent variables, as shown in table (5.12).

Physicians' request of routine X-ray examinations was found to be influenced by their specialty. For example, 56.7% (n=17) of surgeons reported that they request routine X-ray examinations often, as did 53.1% (n=17) of internal medicine physicians and 7.7% (n=1) of anesthesiologists. This relationship was statistically significant (*p=0.001).*

Respondents' request for routine X-ray examinations was also examined with regard to country of medical training. Those reporting that they request routine X-rays "often" constituted 43.1 % (n=31) of physicians who graduated from Arab countries, 40.0% (n=8) of those who graduated from Western countries, and 28.1% (n=9) of physicians who graduated from Former Soviet Union countries. This result was, however, statistically not significant (*p=0.785).*

No statistically significant results were found for the variables of workplace, occupation, length of clinical practice or gender, as shown in table (5.12).

Table (5.12) Distribution of participants' responses in regard to their request of routine X-ray examinations, by independent variables:

	Never		Rarely		Some time		Often		
	Freq	%	Freq	%	Freq	%	Freq	%	P*
Workplace									
Makassed	1	1.0%	25	24.0%	37	35.6%	41	39.4%	.371^{b}
Ramallah	1	1.7%	15	24.4%	24	25.8%	16	27.1%	
ccupation									
Consultant	2	2.8%	16	22.5%	32	35.1%	21	29.6%	.520^{b}
Resident	0	1.3%	24	25.7%	26	33.3%	31	39.7%	
Others	0	0.0%	3	21.4%	6	42.9%	5	35.7%	
Specialty									
Surgery	0	0.0%	4	13.3%	9	30.0%	17	56.7%	.001^{b}
Medicine	0	0.0%	6	18.6%	9	28.3%	17	53.1%	
Pediatric	0	0.0%	4	18.2%	13	59.1%	5	22.7%	
Gynecology	1	7.1%	9	64.3%	2	14.3%	2	14.3%	
Orthopedics	0	0.0%	2	14.3%	7	50.0%	5	35.7%	
Anesthesia	0	0.0%	7	53.8%	5	38.5%	1	7.7%	
Emergency (ER)	0	0.0%	3	33.4%	2	22.2%	4	44.4%	
Country of medical graduation									
Western countries	0	0.0%	4	20%	8	40.0%	8	40.0%	.785^{b}
Arab countries	1	1.4%	15	21.7%	24	33.8%	31	43.1%	
Former soviet Union countries	0	0.0%	12	37.5%	11	34.4%	9	28.1%	
Others	0	0.0%	2	25.0%	3	37.5%	3	37.5%	
Gender									
Male	2	1.4%	35	25.2%	57	41.0%	45	32.4%	.448^{b}
Female	0	0.0%	5	20.8%	7	29.2%	12	50%	
Years of clinical practice									
< 5	0	0.0%	14	24.6%	23	40.4%	20	35.0%	.406^{b}
5-10	0	1.9%	16	30.8%	22	42.3%	14	26.9%	
11-20	0	0.0%	4	17.4%	8	34.8%	11	47.8%	
>20	2	6.5%	6	19.9%	11	35.5%	12	38.1%	

All *P values* were derived using the Fisher exact test.

For CT scan examinations, somewhat less than half of the respondents (44.8% (n=73)) reported that they "sometimes" requested CT scan examinations for the diagnosis of their patients, while 13.5% (n=22) indicated that they did so "often".

Only 1.2% (n=2) of the respondents reported that they "never" used CT scan examinations and 40.5% (n=66) indicated that they "rarely" requested them (see table 5.13).

Table (5.13) Distribution of respondents' request of CT scan examinations:

CT scan examinations request	Freq	%
Never	2	1.2
Rarely (less than 25% of the time)	66	40.5
Sometimes (25%- 75% of the time)	73	44.8
Often (more than 75% of the time)	22	13.5

Cross-tabulation using chi-squared and Fisher exact tests was performed to assess the relationships between different independent variables and how often physicians requested routine CT scans, as shown in table 5.14.

The results revealed that 21.9% (n=7) of internal medicine physicians reported requesting CT scans “often”, as did 20.0% (n=6) of surgical physicians and 18.2% (n=4) of pediatric physicians, while *none* of the gynecological, emergency, and orthopedic physicians reported requesting such examinations “often”. This result was found to be statistically significant *(p=0.000*).

Looking at respondents’ length of time in practice, 26.1% (n=6) of physicians who had been practicing medicine from 11 to 20 years reported that they request CT scan “often”, as did 5.3% (n=3) of physicians who had been practicing medicine less than 5 years. This finding was statistically significant *(p=0.003*).

Moreover, 10.8% (n=15) of male physicians *versus* 29.2% (n=7) of female physicians reported that they request CT scans “often”. However, this result is not statistically significant (P=0.117).

Also, 20.0% (n=4) of physicians who graduated from medical programs in Western countries reported that they request CT scan examinations “often”, as did 15.5% (n=11) of those who graduated from Arab countries and 9.4% (n=3) of physicians who graduated from former Soviet Union countries. However, this result was found to be not statistically significant *(P=0.452).*

No statistically significant results were found on this item for workplace or occupation, as shown in table (5.14).

Table (5.14) Distribution of participants' responses about frequency of requesting CT scan examinations, by independent variables:

	Never		Rarely		Some time		Often		P*
	Freq	%	Freq	%	Freq	%	Freq	%	
Workplace									
Makassed	1	1.0%	42	40.1%	45	43.3%	16	15.6%	.752^{b}
Ramallah	1	1.6%	24	40.7%	28	47.5%	6	10.2%	
Occupation									
Consultant	1	1.4%	24	33.8%	32	45.1%	14	19.7%	.297^{b}
Resident	1	1.2%	36	46.2%	33	42.3%	8	10.3%	
Others	0	0.0%	6	42.9%	8	57.1%	0	0.0%	
Specialty									
Surgery	0	0.0%	5	16.7%	19	63.3%	6	2 0.0%	.000^{b}
Medicine	0	0.0%	10	31.2%	15	46.9%	7	21.9%	
Pediatric	0	0.0%	10	45.4%	8	36.4%	4	18.2%	
Gynecology	0	0.0%	12	85.7%	2	14.3%	0	0.0%	
Orthopedics	0	0.0%	3	21.4%	11	78.6%	0	0.0%	
Anesthesia	2	15.4%	8	61.5%	2	15.4%	1	7.7%	
Emergency (ER)	0	0.0%	4	44.4%	5	55.6%	0	0.0%	
Country of medical graduation									
Western countries	0	0.0%	4	20.0%	12	60.0%	4	20.0%	.452^{b}
Arab countries	1	1.4%	28	39.4%	31	43.7%	11	15.5%	
Former soviet union countries	0	0.0%	17	53.1%	12	37.5%	3	9.4%	
Others	0	0.0%	2	25.0%	5	62.5%	1	12.5%	
Gender									
Male	2	1.4%	57	41.0%	65	46.8%	15	10.8%	.117^{b}
Female	0	0.0%	9	37.5%	8	33.3%	7	29.2%	
Years of clinical practice									
< 5	0	0.0%	26	45.6%	28	49.1%	3	5.3%	.003^{b}
5-10	1	1.9%	28	53.8%	16	30.8%	7	13.5%	
11-20	1	4.3%	6	26.1%	10	43.5%	6	26.1%	
>20	0	0.0%	6	19.3%	19	61.3%	6	19.4 %	

All *P values* were derived using the Fisher exact test.

Despite the physicians' over request of these radiological examinations, the majority of them (55.2% (n=90)) reported that they did not outline all the attendant risks and benefits of X-ray examinations to patients and their families prior to conducting these examinations, and 44.8% (n=73) indicated that they did so (see figure 5.16).

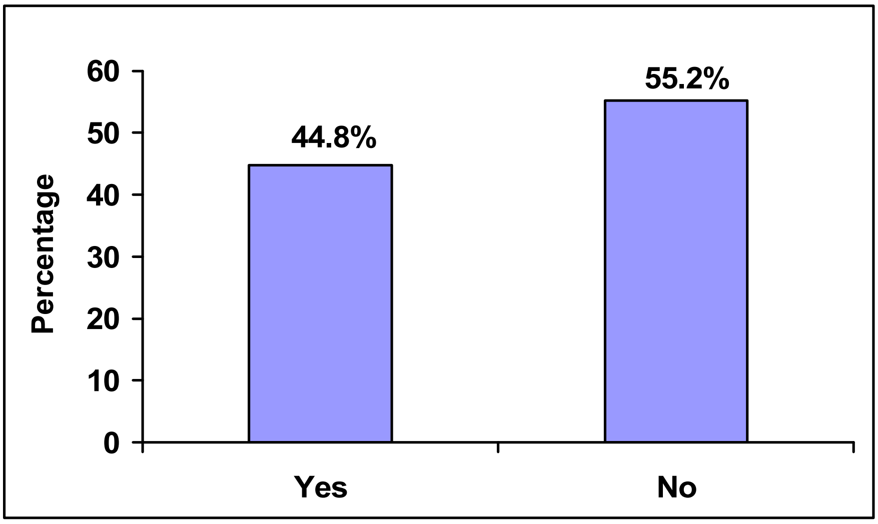

Figure (5.16) Distribution of respondents' responses regarding explaining risks and benefits of X-ray examination to patients and families

In addition, respondents were asked if the patients and their families *asked* about radiation doses and risks before consenting to undergoing radiological examinations. More than one-third of the respondents (38.7% (n=63)) indicated that it happened "rarely" (approximately 1 in 100 patients); 16% (n=26) reported that they could not remember the last time such question had been asked; 29.4% (n=48) indicated that neither patients nor patients' families had ever asked them about radiation doses and risks; 12.9% (n=21) reported being asked "sometimes" (approximately 1 in 10); and only 3.1% (n=5) reported that it happened “frequently” (more than 1 in 10), as shown in figure (5.17).

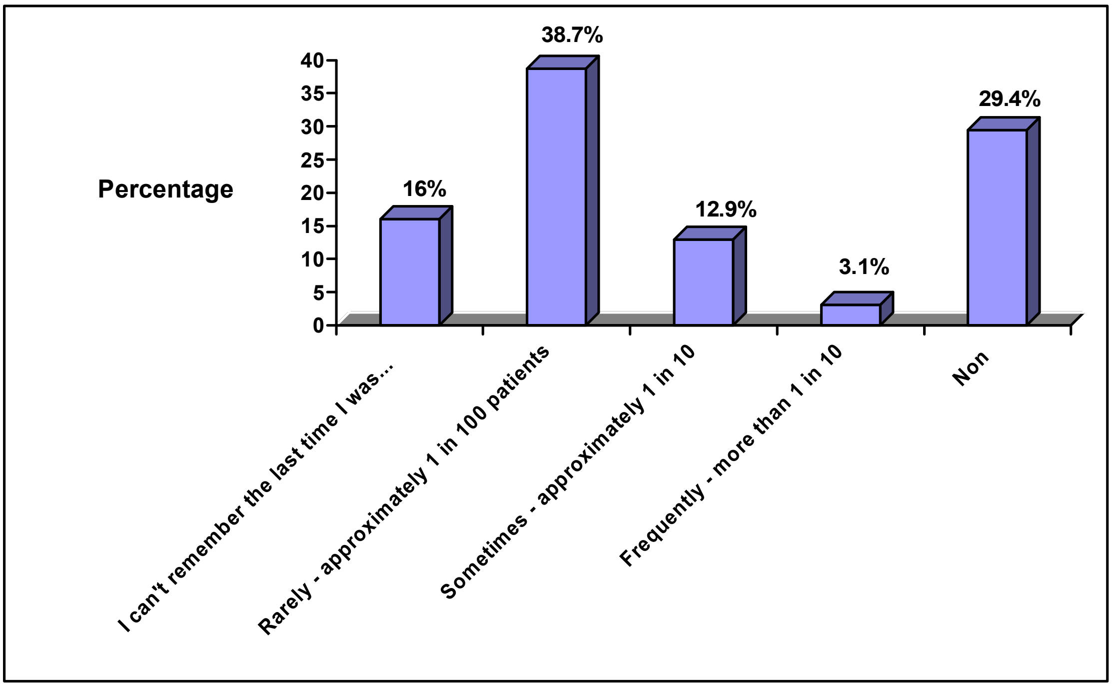

Figure (5.17) Distribution of participants' responses regarding patients' and patients' families inquiring about radiation doses and risks prior to radiological examinations

The study also asked physicians about their intention to reduce requests for various types of radiological examinations, including routine X-ray exams, CT scans and fluoroscopy, *if* there were a proven increase in lifetime risk of cancer associated with these procedures.

The majority of the respondents (61.4% (n=100)) indicated that they would change their ordering of routine X-ray examinations, whereas 38.6% (n=63) indicated that they would not do so (see table 5.15).

Table (5.15) Distribution of respondents' attitudes toward reducing routine X-ray examinations

Reduce routine X-ray examinations?	Freq	%
Yes	100	61.4
No	63	38.6
Total	163	100

Chi-squared and Fisher exact tests were used to examine the relationships between physicians' responses to this question and different independent variables, as shown in table (5.16).

A high percentage (74.6% (n=44)) of respondents from Ramallah Governmental Hospital reported that they would reduce their requests for routine X-ray exams if there were a proven increase in lifetime risk of cancer. Among respondents from Al-Makassed Hospital, 53.8% (n=56) expressed this intention. This difference was statistically significant *(p=0. 009).*

Also, 64.7% (n=90) of male respondents, but only 41.7% (n=10) of female respondents, reported that they would reduce their requests for these examinations. This result was found to be of statistical significance (*P=0.032).*

No statistically significant relationships were found for occupation, medical specialty, country of medical graduation or years of clinical practice.

Table (5.16) Cross-tabulation of respondents' attitude toward reducing routine X-ray examination orders, by independent variables:

	Yes		No		P*
	Freq	%	Freq	%	
Workplace					
Makassed	56	53.8%	48	46.2%	.009
Ramallah	44	74.6%	15	25.4%	
Occupation					
Consultant	46	64.8%	25	35.2%	.686[b]
Resident	45	57.7%	33	42.3%	
Others	9	64.3%	5	35.7%	
Specialty					
Surgery	15	50.0%	15	50.0%	.857[b]
Medicine	18	56.2%	14	43.8%	
Pediatric	15	68.2%	7	31.8%	
Gynecology	9	64.3%	5	35.7%	
Orthopedics	7	50.0%	7	50.0%	
Anesthesia	8	61.5%	5	38.5%	
Emergency (ER)	6	66.7%	3	33.3%	
Country of medical graduation					
Western countries	14	65.0%	6	35.0%	.460[b]
Arab countries	43	47.9%	28	52.1%	
Former soviet union countries	18	65.6%	14	34.4%	
Others	3	50.0%	5	50.0%	
Gender					
Male	90	64.7%	49	35.3%	.032
Female	10	41.7%	14	58.3%	
Years of clinical practice					
< 5	32	56.1%	25	43.9%	.634[b]
5-10	34	65.4%	18	34.6%	
11-20	13	56.3%	10	43.5%	
>20	21	67.7%	10	32.3%	

*** *P values* marked with the letter (b) were derived using the Fisher exact test; all others were done using the chi-squared test.**

For fluoroscopic examinations, the majority of the respondents (60.1% (n=98)) indicated that they would reduce their ordering of fluoroscopic X-ray examinations, whereas 39.9% (n=65) of the respondents reported that they would not change their ordering frequency (see table 5.17).

Table (5.17) Distribution of respondents' attitude toward reducing fluoroscopic examinations:

Reduce fluoroscopic exams?	Freq	%
Yes	98	60.1
No	65	39.9
Total	163	100

Chi-squared and Fisher exact tests were used to examine the relationships between physicians' responses to this question and different independent variables, as shown in table (5.18).

A high percentage of pediatric physicians (77.3% (n=17)) reported that they would reduce their requests for fluoroscopic examinations, followed by emergency physicians (66.7% (n=6)), while a percentage of 50.0% (n=7) was found among orthopedic physicians. However, these differences were not statistically significant *(P=0.453).*

No statistically significant relationships were found for workplace, gender, occupation, country of medical graduation or years of clinical practice, as shown in table (5.18).

Table (5.18) Cross-tabulation of respondents' attitude toward reducing fluoroscopic examination orders, by independent variables:

	Yes		No		P*
	Freq	%	Freq	%	
Work Place					
Makassed	58	55.8%	46	44.2%	.132
Ramallah	40	67.8 %	19	32.2%	
Occupation					
Consultant	41	57.7%	30	42.3%	.862[b]
Resident	48	61.5%	30	38.5%	
Others	9	64.3%	5	35.7%	
Specialty					
Surgery	14	46.1%	16	53.3%	.453[b]
Medicine	19	59.4%	13	40.6%	
Pediatric	17	77.3%	5	22.7%	
Gynecology	8	57.1%	6	42.9%	
Orthopedics	7	50.0%	7	50.0%	
Anesthesia	8	61.5%	5	38.5%	
Emergency (ER)	6	66.7%	3	33.3%	
Country of medical graduation					
Western countries	12	60.0%	8	40.0%	.879[b]
Arab countries	45	63.4%	26	36.6%	
former soviet union countries	19	59.4%	13	40.6%	
Others	4	50.0%	4	50.0%	
Gender					
Male	84	60.4%	55	39.6%	.846
Female	14	58.3%	10	41.7%	
Years of clinical practice					
< 5	35	61.4%	22	38.6%	.844[b]
5-10	31	59.6%	21	40.4%	
11-20	12	52.2%	11	47.8%	
>20	20	64.5%	11	35.5%	

*** *P values* marked with the letter (b) were derived using the Fisher exact test; all others were done using the chi-squared test.**

For CT scan examinations, the vast majority of the participants (69.9% (n=114)) reported that they would reduce their requests, whereas 30.1% (n=49) of participants indicated that they would not do so (see table 5.19).

Table (5.19) Distribution of respondents' attitude toward reducing CT scan examinations:

Reduce CT scans?	Freq	%
Yes	114	69.9
No	49	30.1
Total	163	100

Once again, chi-squared and Fisher exact tests were used to examine the relationships between physicians' responses to this question and different independent variables, as shown in table (5.20).

Regarding country of medical graduation, 80.0% (n=16) of physicians who graduated from Western countries reported that they would reduce their requests for CT scans, as did 69% (n=49) of those who graduated from Arab countries and 62.5% (n=20) of those who graduated from Former Soviet Union countries. These results were not statistically significant *(P=0.174).*

As for length of work experience, 82.6% (n=19) of respondents who had been practicing between 11 and 20 years reported that they would reduce their requests for CT scan examinations, as did 71.0% (n=22) of those who had work experience of more than 20 years and 65.4% (n=34) of those with work experience between 5 and 10 years. However, these differences were statistically not significant *(P=0.525).*

Moreover, no statistically significant relationships were found for workplace, gender, occupation or medical specialty, as shown in table (5.20).

Table (5.20) Cross-tabulation of respondents' attitude toward reducing CT scan examination orders, by independent variables:

	Yes		No		P*
	Freq	%	Freq	%	
Workplace					
Makassed	70	67.3%	34	32.7%	.331
Ramallah	44	74.6 %	15	25.4%	
Occupation					
Consultant	50	70.4%	21	29.6%	.763^b
Resident	53	67.9%	25	32.1%	
Others	11	78.6%	3	21.4%	
Specialty					
Surgery	18	60.0%	12	40.0%	.901^b
Medicine	22	68.8%	10	31.2%	
Pediatric	17	77.3%	5	22.7%	
Gynecology	9	64.3%	5	35.7%	
Orthopedics	10	71.4%	4	28.6%	
Anesthesia	9	69.2%	4	30.8%	
Emergency (ER)	7	77.8%	2	22.2%	
Country of medical graduation					
Western countries	16	80.0%	4	20.0%	.174^b
Arab countries	49	69.0%	22	31.0%	
Former soviet union countries	20	62.5%	12	37.5%	
Others	3	37.5%	5	62.5%	
Gender					
Male	98	70.5%	41	29.5%	.705
Female	16	66.7%	8	33.3%	
Years of clinical practice					
< 5	39	68.4%	18	31.6%	.525^b
5-10	34	65.4%	18	34.6%	
11-20	19	82.6%	4	17.4%	
>20	22	71.0%	9	29.0%	

*** *P values* marked with the letter (b) were derived using the Fisher exact test; all others were done using the chi-squared test.**

Finally, respondents were asked about the need for the presence of radiation protection officers in the Palestinian hospitals. The great majority of respondents (93.3% (n=152)) indicated that there is a need for such officers, whereas only 6.7 % (n=11) indicated that there is no need, as shown in figure (5.18).

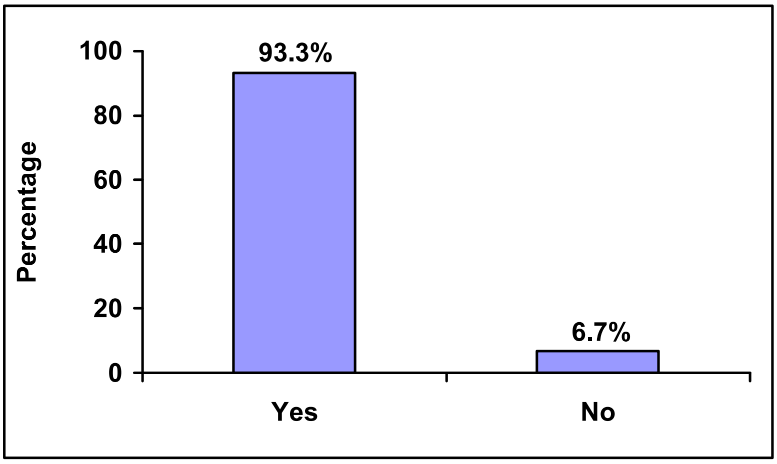

Figure (5.18) Distribution of respondents' attitude towards the need for radiation protection officers in Palestinian hospitals

5.4. Summary

- One hundred sixty-three physicians participated in the current study. The majority of the respondents were from Al-Makassed Hospital (65.64%) and the balance (34.36%) from Ramallah Governmental Hospital and (85.7%) were males.

- The participants belonged to seven different medical specialties and the majority (43.6%) graduated from Arab countries. Two-thirds of the participants had work experience of less than 10 years.

- About one-third of the physicians had taken a radiation protection course, either during their undergraduate studies or at their workplace.

- A low percentage of physicians were able to report the correct, scientific answers to many knowledge-based questions. For example:

  a) Only 6.1% of the respondents were able to identify the ALARA principle.

  b) The vast majority of respondents (98.2%) did not know that patients have no set safe dose limit, according to ICRP recommendations.

c) On average, only 5% of participants were able to identify the chest X-ray equivalent of effective dose associated with a lumbar spine X-ray examination, a barium enema or an abdominal and pelvic CT scan.

d) On average, only 20% of respondents were able to rank according to their relative radio-sensitivity five specified bodily organs: the lungs, stomach, gonads, bladder and kidneys.

- Thirty-two percent of respondents indicated that radiological examinations should be clinically justified and that responsibility for protecting the patient from unnecessary radiation doses lies with both the prescriber and the practitioner.

- More than two-thirds of the respondents indicated that they request routine X-ray examinations more than 25% of the time and 58.3% reported that they request CT scan examinations more than 25% of the time.

- More than two-thirds of respondents reported that they would reduce their ordering of radiological examinations (routine X-rays, fluoroscopic examinations and CT scans) if there is a proven associated increase in lifetime risk of cancer from any of these procedures.

CHAPTER SIX

DISCUSSION

Chapter Six

Discussion

6.1. Introduction

This chapter includes critical analysis of the major findings of the present study and interpretation of those findings in relation to previously conducted studies. Also, the relationship between some selected dependent variables and independent variables are highlighted.

6.2. Physicians' knowledge of radiation hazards of radiological examinations

Medical examinations and tests are the largest single man-made source of radiation exposure, and the medical field relies heavily on these examinations. Annually, just in the UK, about 250 people die as a result of cancer secondary to medical radiation exposure (Atilla, et al, 2007). However, few physicians were aware of the risks associated with such examinations. According to ICRP reports, up to half of all radiation exposures in the medical field could be *avoided* with good clinical justification (Berrington & Darby, 2004), but to achieve this purpose physicians must first be aware of the radiation hazards associated with the use of radiological examinations. So, increased awareness among physicians would help in reducing the number of inappropriate examinations and preventing the harmful biological effects that may result from their use.

In general, the results of the current study are similar to the findings of other previous studies which appear in the literature. These show that physicians lack adequate knowledge regarding radiation doses and the possible risks that can result from using radiological examinations in the diagnosis of patients (Renson, et al, 1996; Jacob, et al, 2004; Heyer, et al, 2007; Atilla, et al, 2007; Soye & Paterson, 2008).

Mandatory courses in radiation protection issues are necessary for physicians, both in medical schools and in the workplace. They should include knowledge of the nature of ionizing radiation, the risks connected with ionizing radiation, the range of doses associated with particular procedures, and the principle of dose reduction. These courses must take into consideration the frequent changes in the available biological and physical information as well as the latest trends in setting radiation safety standards (ICRP, 2007). Results of this study reveal that fewer than one-third of the physicians had participated in a radiation protection course during their undergraduate study or at their workplace (29.4% and 30.7% respectively). Also, 38.3% of the respondents who had taken a radiation protection course at their workplace reported that they did not receive it as part of their formal training. These results are in line with the findings from a study conducted by Quinn et al (1997) which found that only 37% of physicians had attended radiation protection courses (Quinn, et al, 1997). This may indicate the need to conduct such training workshops or courses about radiation hazards both at medical schools and in hospital workplaces in Palestine.

The study's findings reveal some differences among various categories of physicians regarding their attendance of radiation protection courses. Despite the fact that these differences were statistically not significant, they may still yield important information. For example, the physicians who were trained in former Soviet Union countries reported an incidence of 37.5% of attending radiation protection courses during their medical studies, but those who trained and graduated in Western countries reported 35%. The percentage of attending such courses that reported by those who graduated from medical schools in Arab countries was 26.8%. This may indicate the need to revise the medical curriculum at local universities, since the majority of the respondents graduated from Arab universities. Moreover, 32.2% of the respondents from Ramallah Governmental Hospital reported attendance of radiation protection courses during their studies and 27.9% of the respondents from Al-Makassed Hospital.

Also, the physicians who had less than 5 years of work experience reported an incidence of 35.1% of attending radiation protection courses during their studies, but those who had work experience between 5-10 years reported 30.8%. This may reflect the new trend worldwide toward including more information about radiological examinations in medical sciences training. In addition, physicians with less than 5 years of work experience also reported attendance of radiation protection courses in the workplace. One possible explanation is that these physicians, being more recently graduated, have some awareness of radiation issues from their undergraduate training and thus are inclined to attend such courses given in the workplace or to seek out the needed information on their own, from other sources.

Furthermore, 31.7% of male physicians reported attendance of such courses during their medical training and 16.7% of female physicians. This obvious difference may represent the fact that most female physicians (80%) undertake their medical studies in Arab universities nowadays due to cultural and family perspectives.

A lack of knowledge of radiological issues was evident among the physician respondents. For example, only 6.1% were able to identify the ALARA principle, although this principle comprises the core of radiation protection philosophy, i.e. minimizing the doses received from radiological examinations (Lopez, et al, 2007). This percentage is significantly lower than those found in other studies (15% to 48%) (Karen, et al, 2004; Quinn, et al, 1997). The physicians' knowledge of the ALARA principle was related to independent factors such as specialty and country of medical graduation. For example, the highest percentage of knowledge was among the physicians specializing in internal medicine (21.9%) which is considered a broad and wide-ranging field. As a consequence, these practitioners may have access to a broader spectrum of radiological information as compared to other specialties.

Also, physicians trained in Western countries were the most aware of this principle (25%). This might be explained by the increasing interest of physicians in these countries in radiation protection information, especially in recent years, or may be because of the language since ALARA is an English abbreviation. On the other hand, many studies which were conducted in the USA and other Western countries such as the UK and Germany indicated a lack of knowledge in general (Shiralkar, et al, 2003; Maria, et al, 2004; Henry, et al, 2007; Soye & Paterson, 2008). In addition, 10.2 % of respondents from Ramallah Governmental Hospital reported awareness of the ALARA principle and 3.8% of those from Al-Makassed Hospital but this difference is not statistically significant. Moreover, this finding should be taken with caution since the current study utilized self-reported questionnaires.

Various means of radiation protection are employed to achieve the ALARA principle. Increasing the distance from the radiation source is the most effective form of radiation protection for individuals who are routinely exposed to radiation (Brian, et al, 2008). The results of the present study showed that only 11% of respondents knew that distance is the best form of radiation protection. Another study showed that none of the radiological nurses in a sample were able to identify the best form of radiation protection (Muhammad, 2006).

Another aspect of radiation knowledge is safe dose limits. Diagnostic ionizing procedures can expose both patients and medical staff to high levels of radiation, and as the number of diagnostic procedures performed has greatly increased, this may cause negative health effects on the human body (Lautin, 2008). To overcome this problem, there are dosage limits for ionizing radiation for staff, trainees (radiological students) and the general public which were defined by ICRP and should not be exceeded under any circumstances (NCRP, 2001). Our study found that the majority of respondents (98.2%) did not know, however, that *patients* have *no* defined safe dose limit, according to ICRP recommendations. Another study showed a lower percentage (70%) than the current study (Quinn, et al, 1997).

In addition, physicians should be knowledgeable about the various medical imaging modalities. In multislice CT scan modality, for example, the radiation dose to the patient is higher than for the older single-slice scanners, but the new modality allows faster scanning and decreases the need for anesthesia in children (Iball, et al, 2008). Only 13.5% of respondents of the current study knew this. This corresponds to a large degree with the results reported by Karen et al (18.5%) (Karen, et al, 2004).

Furthermore, physicians should have the ability to *compare* the radiation doses associated with various medical imaging modalities and to express the effective doses in terms of CXR equivalent units. This not only has proven useful in previous physician-based studies but is important in helping patients and their families understand relative risks (Quinn, at el, 1997; Jacob, et al, 2004; Atilla, et al, 2007). Therefore, a comparative format was used in this study to assess the respondents' knowledge of the effective doses connected with various types of radiological examination. On average, only 5.3% of participants in the current study were able to identify the effective dose equivalent for a chest X-ray, as compared to those for a routine lumbar spine X-ray examination, a barium enema, and an abdominal and pelvic CT scan. The literature indicates similar results, that on average less than 6% of physicians were able to distinguish the chest X-ray effective dose equivalent from these other selected radiological examinations (Shiralkar, et al, 2003, Maria, et al, 2004 and Henry, et al, 2007).

Another crucial element of physicians' knowledge is the *public's* exposure to ionizing radiation. This study tried to examine respondents' knowledge of the percentage of background ionizing radiation exposure attributable to medical radiological procedures. Only 8% of respondents knew that medical radiation accounts for 15% to 30% of the general public's total exposure to ionizing radiation from all sources. The results from other previous studies on this point were varied and inconsistent. For example, some studies showed a nearly similar result (9%) (Quinn, et al, 1997) while other studies reported higher percentage (11%; 15%) (Maria, et al, 2005; Karen, et al, 2004).

Physicians were also asked generally about articles that have been published in scientific journals and in the media regarding radiation hazards associated with CT scan examinations. 46% of respondents in this study indicated that they were aware of these articles, a result similar to another study (48%) (Karen, et al, 2004). This percentage is not considered high, since these two hospitals are the largest referral hospitals in Palestine and they both offer 5-year clinical training programs leading to specialty certification. This may indicate that physicians in Palestinian hospitals have difficulty accessing scientific journals and related electronic resources. So, greater access should be offered to journals and electronic databases. At the same time, this result suggests a discrepancy between the high percentage of respondents indicating that they *knew about* radiation hazard *articles* and, on the other hand, the lack of actual, demonstrable knowledge regarding radiation doses and risks.

Interestingly, the results indicated that male physicians were more aware of published articles about radiation hazards than were female physicians (50.4% and 20.8% respectively). Possible explanations for this finding are that male physicians may read more than female physicians or male physicians may exaggerate their answers. These results should be taken with caution because female physicians accounted for only 14.7% of the study population. So, further study to examine the relationship between physicians' gender and their knowledge regarding radiation doses and risks is recommended. Surprisingly, anesthesiologists request radiological examinations with high frequency, especially before operations, yet the findings showed that they had low knowledge of radiation hazards articles (23.1%).

An especially important publication is the listing of medical X-ray radiation as a known carcinogen by the U.S.A. Food and Drug Administration (FDA). More than half of respondents of the current study reported that they were aware of this listing. This percentage is higher than the findings of other previous studies (11%) (Karen, et al, 2004). However, again, this study utilized a self-reported questionnaire, so it is difficult to validate the accuracy of this finding.

The question arises: If these physicians knew about the carcinogenic effects of radiological examination, why did they not reduce their requests for these examinations in order to protect their patients, since the majority of the respondents indicated that they did request them often. For example, one-third of respondents reported that they order routine X-ray examinations more than 75% of the time, and two-thirds indicated that they request these examinations more than 25% of the time. For CT scan examinations, 58.3% of respondents reported that they requested them more than 25% of the time, a level significantly higher than that found in previous similar research (32%) (Henry, et al, 2007).

Also, findings revealed that 43.1% of physicians who graduated from medical schools in Arab countries were requesting routine X-ray examinations often and 40% of those who trained in Western countries, while the percentage seen among graduates of programs in former Soviet Union countries was 28.1%. For CT scans, the percentage of requesting such examinations often was found 20% among those who received their medical education in Western countries and 15.5% among those trained in Arab countries, while the level of such requests was 9.4% among those coming from graduates of programs in the former Soviet Union countries. However, this result is not statistically significant. This result is expected because of the low percentages of the physicians who reported attending radiation protection courses, either during their studies or in the workplace.

Also, the results revealed that the emergency physicians do not request CT scans very often, although many of these examinations are requested in the emergency department. A possible explanation for this finding is that most CT scan examinations are ordered by physicians from other specialties (e.g. internal medicine, surgery orthopedics, etc.) when they are called in for consultation by emergency physicians.

In addition, physicians who had work experience ranging between 11 and 20 years reported requesting more CT scan examinations than other groups. Other findings in the current study revealed that these same physicians were found to have very low percentage of participation in radiation protection courses during their studies or in the workplace.

The general lack of knowledge among physicians about the carcinogenic effects of radiological examinations was supported by another measure: When the physicians were asked to estimate the increased cancer risk from radiation exposure connected with an abdominal and pelvic CT scan, only 9.2% of them reported correctly (1:1000). This result is consistent with the findings of at least one other study (6%) (Thomas, et al, 2004), while yet another study show a higher percentage (31%) (Henry, et al, 2007). The difference could be due to the recent focus in the media in the USA on the risks from CT scans, as well as an increase in concern among medical faculties about radiation issues (Henry, et al, 2007).

To be knowledgeable regarding the risks associated with different types of radiological examinations, physicians should know about the radio-sensitivity of various organs of the human body. In this study the respondents' knowledge of the radio-sensitivity of five different organs (lungs, bladder, gonads, kidneys, and stomach) was examined by asking them to rank these five organs according to their radiation sensitivity, according to the Lickret scale, from 1 (most sensitive) to 4 (least sensitive). In general, the findings indicated a lack of knowledge among the physicians regarding this question. On average, only about 20% of the respondents were able to correctly give the relative radio-sensitivity of the five bodily organs in relation to the others. This is inconsistent with the findings of other studies, which showed a higher percentage (40%) completing this task accurately (Quinn, at el, 1997). The ICRP report for 2008 indicated that thousands of radiological examinations are carried out that are not well justified, due to physicians lacking adequate knowledge concerning the radio-sensitivity of body organs (ICR, 2008).

The importance of having knowledge about radiation protection is that it enables physicians to present the risks and benefits of radiological examinations to their patients and the patients' families. Besides the lack of knowledge demonstrated by the physicians' answers to most of the questions, 55.2% of the respondents reported that they did not explain to their patients the risks and benefits of X-ray examinations. Previous studies showed even higher percentages (60%-77%) (Cristoph, et al, 2003, Henry, et al, 2007).

One further radiation protection principle was developed by ICRP and has been adopted in many countries all over the world, especially Western countries. Based on this principle, a person directing a medical exposure, either clinically or physically, is responsible for protecting patients from unnecessary radiation doses associated with radiological examinations. "Clinically directing" is defined as having clinical responsibility for the decision to order radiological examinations, i.e. a prescriber role, while "physically directing" is defined as the conducting of these examinations, which is the responsibility of a practitioner (Brian, 2008). The present study showed that only 31.9% of respondents indicated that radiological examinations should be clinically justified and that responsibility for protecting the patient from unnecessary radiation doses lies with both the prescriber and the practitioner, which is incongruent with findings of previous research (42%) (Maria, et al, 2004). This finding may support the ICRP reports that many radiological examinations worldwide are ordered with out adequate justification (ICRP, 2008).

Finally, in order to control the radiation hazards associated with X-ray examinations, many Western countries appoint radiation protection officers in their hospitals. In this study the vast majority of the respondents (93.3%) reported that there is a need for such officers in the Palestinian hospitals. This could help physicians to better understand radiation science, particularly the doses and the risks connected with radiological examinations (Morin, 2003).

6.3. Application of the Theory of Planned Behavior to this study

The Theory of Planned Behavior (TPB) was selected as the theoretical framework for this study. The theory suggests that people's behavior is determined by their intention to perform a given behavior. This suggestion was supported by previous research which indicated that behavioral intention was found to be the strongest predictor of physicians' behavior (Susan, 1996; Bruce, et al, 1997; Seewon, et al, 2003; Mun, et al, 2006; Keiko, 2006; Natalie, et al, 2007; Edward, 2007; Shannon, et al, 2008; Susan, et al, 2008). According to TPB, behavioral intentions are the product of three determinants: attitude toward the behavior, subjective norms, and perceived control (Ajzen, 1991; Bruce, et al, 1997; Keiko & Sherri, 2006; Edward, 2007).

Behavior is considered one of the crucial elements of the model. In the current study, physicians' behavior related to the requesting (i.e. prescribing) of radiological examinations was assessed. About one-third of respondents reported that they ordered routine X-ray examinations more than 75% of the time, and two-thirds indicated that they request these examinations more than 25% of the time. For CT scan examinations, 58.3% of respondents reported that they requested these examinations more than 25% of the time, which is higher than was found in previous research (32%) (Henry, et al, 2007). This may support the ICRP report for the year 2008 which showed that radiological examinations were requested more than necessary in all countries worldwide (ICRP, 2008).

Physicians' behavior is affected by their attitudes. "Attitudes" refers to beliefs about the outcomes associated with performing a particular behavior (i.e. the belief that this behavior will lead to specific positive or negative outcomes). On average, more than two-thirds of respondents reported that they would reduce their ordering of all radiological examinations (routine X-ray examinations, fluoroscopic examinations and CT scan examinations) *if* there were an increase in lifetime risk of cancer connected with any of these tests. This result supports the findings of Henry et al (2007) in which 73% of respondents indicated that they would do so. Also, the current findings reveal that physicians are more willing to reduce CT scan examinations than the other two types of radiological examinations. This might be because CT scanning is more expensive than other examinations and is not available in all hospitals. In addition, male respondents indicated that they would reduce their requests for routine X-ray examinations more than female respondents. The literature indicated similar results: that physicians' attitudes are one of the chief factors that may change their behaviors (Reneston, 1996; Ashely, et al, 2006; Edward, 2007; Shannon, et al, 2008; Susan, et al, 2008). So, it is necessary to increase physicians' awareness about the negative outcomes that are associated with inappropriate use of such examinations.

Furthermore, physicians' behavior is influenced by subjective norms. "Subjective norms" refers to a person's perceptions about how others would judge him/her for performing the behavior, according to social pressure from those who are important to him/her (e.g. parents, friends and peers), and the person's motivation to act in line with the preferences of these people (Ajzen, 1991; Bruce, et al, 1997). For physicians, the doctors' own patients and the patients' families could be one important source of subjective norms—by questioning physicians about their request of radiological examination, about the risks involved, and the relative advantages and disadvantages. Physicians' responses indicated that their patients and the patients' families showed a low level of interest in asking physicians about radiation doses and risks, with more than one-third of the respondents (38.7%) indicating that this type of inquiry happened rarely. These findings are consistent with those of other studies, which showed a somewhat higher percentage (42%) (Karen, et al, 2004). However, since one limitation of this study is the use of a self-reported questionnaire, it may be difficult to validate the accuracy of this result. So, further studies on patients and their families might be recommended, especially to assess patient/family knowledge and physicians' actual practices regarding explanation of radiation risks and benefits.

Finally, perceived control is the third component of the theory of planned behavior which may affect physicians' requests for radiological examinations. "Perceived control" involves a person's self-assessment of both their capability or skill and the opportunity to perform the behavior. Previous studies indicated that increasing physicians' level of knowledge assisted them in carrying out the desired behaviors (Edward, 2007; Shannon, et al, 2008; Susan, et al, 2008). In this study, many questions were utilized to assess physicians' knowledge about radiation doses and possible risks associated with the use of radiological examinations (e.g. Q7, Q8, Q17 and Q19 to Q24). In general, the findings indicated a lack of knowledge among

Palestinian physicians regarding theses issues. This may adversely affect their perceived behavioral control and in turn their intention to reduce the ordering of such examinations. Thus, radiation protection courses may be needed to increase physicians' knowledge about radiation hazards, in order to encourage the desired physician behaviors and, specifically, to reduce their requests for unnecessary radiological examinations.

In summary, deficit of physicians' knowledge about the negative outcomes of requesting un-necessary radiological examination, lack of subjective norms and perceived control may attribute to physicians' over-request of radiological examinations.

6.4. Summary

- Discussion and interpretation of the current study results, and comparison of those results with previous research findings was done.

- Many ICRP recommendations directly relevant to some of the study findings were highlighted.

- In general, the findings of the current study showed a lack of knowledge among the Palestinian physicians at Al-Makassed Hospital and Ramallah Governmental Hospital regarding radiological examinations hazards.

- These findings generally supported the results of other, previous studies from several different countries: that there is a significant lack of knowledge among physicians regarding radiation hazards. However, the literature showed a higher level of knowledge among physicians in other countries in comparison with the Palestinian physicians.

Conclusion

This might be the first study in Palestine assessing physicians' knowledge and awareness regarding radiological examinations, including radiation doses and possible risks. The findings indicate a lack of knowledge in general and a low level of participation in radiation protection courses, both during their general medical studies and later in their workplaces. In addition, it shows that physicians are not up-to-date with regard to publications and articles concerning radiation doses and the possible risks of radiological examinations. This lack may adversely affect the frequency with which physicians request these examinations and, as consequence, may expose Palestinian patients to the harmful effects of ionizing radiation, from unnecessary diagnostic examinations.

There is a need to increase physicians' knowledge about ionizing radiation associated with medical imaging, given their legal responsibility as prescribers of these procedures under the ionizing radiation (medical exposure) regulations. There is thus a need to provide physicians with ongoing, up-to-date training on issues of radiation safety. There is also a need to sensitize the public to radiation safety, equipping them not only to discuss radiation doses and risks with their physicians but also to make more informed choices about proposed diagnostic procedures and possible alternatives.

Recommendations

The results of the current study indicate a general lack of knowledge among physicians regarding the potential hazardous impact of radiological examinations upon the health of their patients. To overcome this problem, several Palestinian parties could be collaborated to carry out the following changes and actions:

1. *Academic institutions / universities:*

a. Revising the curriculum of the medical schools of Palestinian universities to include more radiation protection information, such as: the nature of ionizing radiation, the risks connected with ionizing radiation, protection measures, the range of doses associated with particular procedures, and the principles of dose reduction.

b. Further research is required to assess the level of radiological knowledge among medical students in their final year of medical studies at Palestinian universities, in order to identify the strengths and weaknesses of the curriculum of undergraduate studies.

c. There is a need to conduct further studies to examine, in more detail, the relationship between physicians' demographic factors such as gender and their knowledge regarding the radiation hazards of radiological examinations.

d. More studies are required involving a greater number of hospitals from the West Bank and Gaza Strip, as well as institutions from a variety of different settings (governmental, private, charitable and non-governmental hospitals and medical clinics).

e. There is a need to conduct further studies to assess the level of radiological information among other health professionals, besides physicians, i.e. practitioners such as radiological technologists.

f. Further qualitative study may be needed to explore in depth the factors that may contribute to physicians' lack of knowledge, the physicians' actual practices, and their level of experience with radiological examinations.

2. *Palestinian Hospitals*

a. Integrating radiation protection courses into the various postgraduate medical training programs at hospital workplaces in Palestine. These courses should include general aspects of patient protection, such as biological effects, justification of medical exposures, risks *versus* benefits of radiological examinations, etc., together with basic knowledge of the advantages and disadvantages of the uses of ionizing radiation in medicine.

b. The radiologists must have important role in the judgment on the appropriateness of X-ray examinations, and in the increasing of non-radiologist physicians' awareness about radiation hazards.

c. Increasing physicians' access to scientific journals that provide them with up-to-date research and other articles concerning radiation hazards. In addition, professionally-oriented web-sites must be available at the workplace in order to provide physicians with new radiation protection information.

3. *Palestinian Ministry of Health*

a. The establishment of a regulatory framework involves the drafting, and promulgation of radiation protection laws and regulations aimed at controlling the exposures of patients in diagnostic radiology, radiotherapy and nuclear medicine. It includes the establishment and implementation of quality assurance programmes.

b. Appointment of a Medical Physicist or Radiation Protection Officer to act as an advisor on all radiation protection issues in Palestinian hospitals. He/she will be the person permanently assigned as a radiation safety specialist to routinely manage a facility's radiation protection program.

c. The organization of conferences on the radiological protection of Patients in diagnostic radiology in co-operation with national, and international radiation protection experts and organizations (e.g. ICRP).

d. Increasing public awareness about the potential harmful effects that may caused by unnecessary radiological examinations on peoples' health. This can be achieved by disseminating information through various types of media, such as TV, newspapers and magazines.

4. Palestinian Medical association

a. The referring physician should possess a radiation protection examination before he licensed to prescribe an X-ray examination based on professional experience, judgment and common sense; give consideration to alternative, non X-ray utilizing, examinations; and should: be confident that the procedure will improve the patient diagnosis and/or treatment sufficiently in comparison with alternate, non X-ray utilizing, methods of diagnosis and/or treatment; be aware of the risks associated with X-ray procedures.

b. Increasing physicians' awareness about their responsibility to justify their requests for radiological examinations and to protect their patients from unnecessary hazards of radiation. This includes enhancing physicians' judgment regarding the appropriateness of X-ray exams and stressing the need to consider alternative, non-radiological examinations such as MRI and ultrasound.

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Appendix A

حضرة الدكتور/ه المحترم/ه

يقوم الطالب احمد حمارشه بأجراء بحث حول معرفة الأطباء بالمخاطر الناتجة عن الفحوصات الشعاعية (Radiological examinations) التي تستعمل في الحقل الطبي مثل الفحوصات الشعاعية للصدر(Chest X-ray)، الفحوصات الطبقية للبطن(Abdominal CT scan)، الفحوصات الملونة للمعدة (Barium meal)....... الخ. كمتطلب للحصول على درجة الماجستير في الصحة العامة من جامعة القدس – أبو ديس.

أرجو من حضرتك المساعدة على تعبئة هذه الاستبانة، مع التأكيد أن جميع المعلومات ستعامل بسريه كاملة ولن تستخدم إلا لغرض البحث العلمي. وان مشاركتكم في هذه الدراسة طوعيه ولا داعي لكتابة الاسم الشخصي على الاستبانة.

شاكرين لكم حسن تعاونكم

Appendix B

حضرة الأخ/ د.فاروق عبد الرحيم المحترم/ مدير مستشفى المقاصد الخيرية الإسلامية
تحيه طيبه وبعد،،،

الموضوع: تسهيل أجراء بحث

يقوم الطالب احمد حمارشه بأجراء بحث حول معرفة الأطباء بالمخاطر الناتجة عن الفحوصات الشعاعية (Radiological examinations) و التي تستعمل في الحقل الطبي مثل الفحوصات الشعاعية للصدر(Chest X-ray)، الفحوصات الطبقية للبطن(Abdominal CT scan)، الفحوصات الملونة للمعدة(Barium meal) ..... الخ. كمتطلب للحصول على درجة الماجستير في الصحة العامة، وعليه نرجو من حضرتكم التكرم باتخاذ الإجراءات المناسبة لتسهيل مهمة الطالب في جمع المعلومات ألازمه من مستشفى المقاصد الخيرية الإسلامية خاصة أن مصداقية البحث تتطلب توزيع و جمع الاستبانات في نفس اليوم.

نؤكد أن جميع المعلومات ستعامل بسريه كاملة ولن تستخدم إلا لغرض البحث العلمي.وبعد الانتهاء من الدراسة سوف نقوم بتزويد المؤسسات ألمشاركه في هذه الدراسة بالنتائج من اجل الاستفادة منها بالطريقة التي ترتئيها هذه المؤسسات.

أرجو من حضرتكم الاتصال بالدكتورة منى حميد المشرفة على هذه الدر اسه في حال وجود أي استفسار على الهاتف رقم 022779234 أو الهاتف المحمول رقم 0599992543

وتفضلوا بقبول فائق الاحترام

د.محمد شاهين
عميد كلية الصحة العامة/ جامعة القدس

Appendix C

حضرة الأخ/ د.نعيم صبره المحترم \ مدير عام المستشفيات
تحيه طيبه وبعد،،،

الموضوع: تسهيل أجراء بحث

يقوم الطالب احمد حمارشه بأجراء بحث حول معرفة الأطباء بالمخاطر الناتجة عن الفحوصات الشعاعية (Radiological examinations) و التي تستعمل في الحقل الطبي مثل الفحوصات الشعاعية للصدر(Chest X-ray)، الفحوصات الطبقية للبطن(Abdominal CT scan)، الفحوصات الملونة للمعدة(Barium meal)...... الخ. كمتطلب للحصول على درجة الماجستير في الصحة العامة، وعليه نرجو من حضرتكم التكرم باتخاذ الإجراءات المناسبة لتسهيل مهمة الطالب في جمع المعلومات ألازمه من مستشفى رام اللة الحكومي خاصة أن مصداقية البحث تتطلب توزيع و جمع الاستبانات في نفس اليوم.

نؤكد أن جميع المعلومات ستعامل بسريه كاملة ولن تستخدم إلا لغرض البحث العلمي.وبعد الانتهاء من الدراسة سوف نقوم بتزويد المؤسسات ألمشاركه بالدر اسه بالنتائج من اجل الاستفادة منها بالطريقة التي ترتئيها هذه المؤسسات.

أرجو من حضرتكم الاتصال بالدكتورة منى حميد المشرفة على هذه الدر اسه في حال وجود أي استفسار على الهاتف رقم 022779234 أو الهاتف المحمول رقم 0599992543

وتفضلوا بقبول فائق الاحترام

د.محمد شاهين
عميد كلية الصحة العامة\ جامعة القدس

Appendix D

حضرة الأخ/ د.حسني عطاري
مدير عام مستشفى رام الله الحكومي
تحيه طيبه وبعد،،،

الموضوع: تسهيل أجراء بحث

يقوم الطالب احمد حمارشه بأجراء بحث حول معرفة الأطباء بالمخاطر الناتجة عن الفحوصات الشعاعية (Radiological examinations) و التي تستعمل في الحقل الطبي مثل الفحوصات الشعاعية للصدر(Chest X-ray)، الفحوصات الطبقية للبطن(Abdominal CT scan)، الفحوصات الملونة للمعدة(Barium meal)........ الخ. كمتطلب للحصول على درجة الماجستير في الصحة العامة، وعليه نرجو من حضرتكم التكرم باتخاذ الإجراءات المناسبة لتسهيل مهمة الطالب في جمع المعلومات ألازمه خاصة أن مصداقية البحث تتطلب توزيع و جمع الاستبانات في نفس اليوم.

نؤكد أن جميع المعلومات ستعامل بسريه كاملة ولن تستخدم إلا لغرض البحث العلمي.وبعد الانتهاء من الدراسة سوف نقوم بتزويد المؤسسات ألمشاركه بالدر اسه بالنتائج من اجل الاستفادة منها بالطريقة التي ترتئيها هذه المؤسسات.

أرجو من حضرتكم الاتصال بالدكتورة منى حميد المشرفة على هذه الدر اسه في حال وجود أي استفسار على الهاتف رقم 022779234 أو الهاتف المحمول رقم 0599992543

وتفضلوا بقبول فائق الاحترام
د.محمد شاهين
عميد كلية الصحة العامة
جامعة القدس

Appendix E

Please answer the following questions by ticking one box:

1. Do you primarily work at?

☐ Privet hospital
☐ Governmental hospital

2. Are you:

☐ Consultant
☐ Resident
☐ Other (please mention it): ______________________

Please state your main specialty: ________________

Country of your medical graduation: ______________________

3. Gender

☐ Male
☐ Female

4. Years of clinical practice

☐ < 5
☐ 5 – 10
☐ 11 – 20
☐ > 20

5. Have you ever attended a radiation protection course/training during your medical study?

☐ Yes
☐ No

6. During your work or practice have you received any specific teaching regarding radiation doses of medical imaging?

☐ Yes
☐ No

If yes, where the teaching from?

☐ Formal lecture/course/workshop
☐ Personal reading
☐ Informal discussion with senior staff
☐ Other (please mention it): ______________________

7. The radiation protection philosophy of the ICRP (International Commission on Radiological Protection) is including the ALARA principle. Do you know the ALARA principle?

☐ Yes
☐ No

If yes, which of the following explains the ALARA principle?
☐ As Low as Reasonably Achievable
☐ Allowable Administered Radiation
☐ Assurance Limits Applied to Radiation
☐ Don't know

8. What do you think is the best form of radiation protection for individuals who are usually exposed to radiation (such as radiation workers)?

☐ Film badge to measure the radiation dose
☐ Lead screen/Apron
☐ Maximizing the distance from the radiation source
☐ Minimizing time of exposure
☐ Don't know

9. How often would you request routine X-ray examinations such as chest X-ray, abdomen X-ray, extremities X-ray…….., etc for the diagnosis of patients?

☐ Never
☐ Rarely (less than 25% of time)
☐ Sometimes (25%- 75% time)
☐ Often (more than 75% of time)

10. How often would you use CT scan examinations for the diagnosis of patients?

☐ Never
☐ Rarely (less than 25% of time)
☐ Sometimes (25%- 75% of time)
☐ Often (more than 75% of time)

11. In general, prior to obtaining an X-ray examination, do you outline all risks and benefits of this X-ray examination to your patients and patients' families?

☐ Yes
☐ No

12. In general, how often do patients and patients' families ask you about radiation doses and risks?

☐ I can't remember the last time I was asked.
☐ Rarely - approximately 1 in 100 patients.
☐ Sometimes - approximately 1 in 10.
☐ Frequently - more than 1 in 10.
☐ Non

13. In the last years many articles were published in the main scientific journals concerning the radiation doses associated with CT scan examinations especially in children. These articles focus on cancer risk from CT scan. Are you aware of this?

☐ Yes
☐ No

14. If there is a proven increase in lifetime risk of cancer from any X-ray examination such as abdomen X-ray, skull X-ray, lumbar spine X-ray…., etc, would this knowledge makes you less likely to order X-ray examinations?

☐ Yes
☐ No

15. If there is a proven increase in lifetime risk of cancer from any fluoroscopic examination such as barium enema, barium meal, urethrogram…., etc, would this knowledge makes you less likely to order fluoroscopic examinations?

☐ No
☐ Yes

16. If there is a proven increase in lifetime risk of cancer from any CT scan examination, would this knowledge makes you less likely to order CT scan examinations?

☐ Yes
☐ No

17. According to the ICRP recommendations, which of the following statements do you think is describing the real responsibility of protecting patient from unnecessary radiation doses?

☐ Authorizes any ionizing exam according to the freedom of prescription
☐ States responsibility of the prescriber, not of the practitioner
☐ States responsibility of the practitioner, not the prescriber
☐ Forbids unjustified exposure and states responsibility of both the prescriber and the practitioner
☐ Don't know

18. The Food and Drug Administration (FDA) in the USA has listed medical X-rays as a known carcinogen. Are you aware of this?

- ☐ No
- ☐ Yes

19. If you believe that the radiation dose from one abdominal and pelvic CT scan for a child may *increase his lifetime risk* for the development of cancer, by what value do you think the risk of cancer is increased:

- ☐ None (i.e. No one will develop cancer as a result of this exposure)
- ☐ 1:1000 (i.e. 1 out of 1000 people receiving this CT scan will develop cancer as a result of this exposure)
- ☐ 1:50,000
- ☐ 1:100,000
- ☐ 1:500,000
- ☐ Don't know

20. The new 'multislice' CT technology allows faster scanning compared to previous single-slice helical scanners. The radiation dose to the patient in the multislice CT is:

- ☐ Similar
- ☐ Higher
- ☐ Lower
- ☐ Don't know

21. The ionizing radiation exposure to the general public comes from various sources (natural sources such as soil and man made sources such as medical radiation). Which is of the following percentages do you think is due to 'medical radiation'?

- ☐ 1% -10%
- ☐ 15%- 30%
- ☐ 35%-45
- ☐ 60%- 75
- ☐ 80%- 95
- ☐ Don't know

22. According to radiation protection regulations, the maximal dose limit for radiation workers is 20 msv per year .What do you think is the whole body dose limit for patient that was determined by radiation protection regulations?

☐ 150 msv
☐ 100 msv
☐ 50 msv
☐ 20 msv
☐ 5 msv
☐ 0.5 msv
☐ No limit
☐ Don't know

23. Body organs differ regarding sensitivity to ionizing radiation. Based on your knowledge, please arrange the following organs according to radiation sensitivity in the table below from 1 to 4. Indicate the most sensitive organ with number (1) and the least sensitive organ with number (4).

4 = least radiosensitive
1 = most radiosensitive

lungs	
bladder	
gonads	
kidneys	
stomach	

☐ Don't know

24. The effective dose is one of the radiation concepts. The amount of effective dose differs according to the type of X-ray examination, for example, the effective dose from one skull X-ray is equivalent to effective dose of four frontal (PA) chest X-rays. What do you think that the effective dose from each of the following X-ray examinations is, if we compare it with the effective dose in one frontal (PA) chest X-ray?

a) The effective dose in one Lumbar spine is equivalent to:

☐ Less than1 chest X-ray
☐ 10 chest X-rays
☐ 65 chest X-rays
☐ 120 chest X-rays
☐ 250 chest X-rays
☐ Greater than 250 chest X-rays
☐ Don't know

b) The effective dose in one Barium enema is equivalent to:

- ☐ Less than1 chest X-ray
- ☐ 10 chest X-rays
- ☐ 65 chest X-rays
- ☐ 120 chest X-rays
- ☐ 250 chest X-rays
- ☐ Greater than 250 chest X-rays
- ☐ Don't know

C) The effective dose in one abdominal CTscan is equivalent to:

- ☐ Less than1 chest X-ray
- ☐ 10 chest X-rays
- ☐ 65 chest X-rays
- ☐ 120 chest X-rays
- ☐ 250 chest X-rays
- ☐ Greater than 250 chest X-rays
- ☐ Don't know

25. The radiation protection officer has an important role in controlling radiation hazards from X-ray examinations. Do you think that there is a need for radiation protection officers at our Palestinian hospitals?

- ☐ No
- ☐ Yes