Power System Technology
ISSN:1000-3673

Received: 16-08-2024 *Revised: 05-09-2024* *Accepted: 22-09-2024*

Radiation Exposure in Medical X-Rays: Risks and Safety Measures

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Abstract:

Medical x-rays are essential diagnostic tools used in modern healthcare, providing valuable insights into the internal structures of the human body. However, exposure to ionizing radiation from x-rays carries inherent risks that must be carefully managed to ensure patient safety.

This paper explores the risks associated with radiation exposure in medical x-rays, including the potential for biological damage and the long-term health effects. It also discusses the safety measures and best practices that can be implemented to minimize radiation exposure and protect both patients and healthcare professionals.

By understanding the risks and taking appropriate precautions, we can ensure that medical x-rays continue to play a crucial role in diagnosis and treatment while prioritizing patient safety.

Keywords*:* radiation exposure, medical x-rays, risks, safety measures, ionizing radiation

Power System Technology
ISSN:1000-3673
Received: 16-08-2024 Revised: 05-09-2024 Accepted: 22-09-2024

1. Introduction

Radiation exposure through medical X-rays, amongst other radiographics, is the greatest man-made source of radiation exposure to the general populace. Inadequate awareness by patients regarding these medical X-ray tests is often clouded by concerns over radiation exposure and radiophobia (A. Oakley & E. Harrison, 2020). Medically, such imaging is the highest contributor to ionizing radiation doses and hence patient apprehension to patient radiation doses from these imaging tests is understood. It is common for patients receiving a medical X-ray (or CT) test to make a statement mentioning that they are concerned with receiving more radiation exposure - largely because they have had or have cancer (and have already received or expect to receive radiation exposure); and the assurance they are given still does not ease their radiophobic fears.

It is noted that whilst radiation exposures are additive, this is not common knowledge. In medical radiation protection, the tracking of a medical radiation history (of all imaging exposures) is simply not taken, and therefore not mandated. Different organs and tissues are differentially radiosensitive; and any harm - and in particular cancer risks - from radiation is not a simple linear function, rather there is a time-dependent detriments model (including evidence for hormetic/adaptive responses at low doses). Most importantly from a protection perspective, the understanding of radiation effects across different dose levels is critical when estimating risks from (and thus in prioritizing protection) quite low-level exposures, that are at and sometimes below natural background (wherein a myriad of bio-positive radiation health benefits are reported).

1.1. Background and Significance

Patient and physician demand for the use of X-Rays, CTs, MRIs, IXEs, Radionuclide Scans, FDGs, PETs, MIBis, Ultrasounds, KUBs, NECs, Proctoscopes, Sestimibis, Monoclonals, or other radiation-emitting medical imaging has grown substantially in the United States over this past two decades. Few individuals receive a thorough education in the healthcare system or the specifics of certain radiological procedures frank in size and substance regarding the radiation dose, the risks and possible mitigations of those risks. In certain medical imaging treatments for diagnosis and treatment therapy is conducted in negligently excessive amounts beyond what the patient is under the care of a non-specialist who lacks the necessary contextuality. All parties involved agree that this is troublesome.

2. Understanding Radiation

This critical section of the journal article deals with the current use, overuse, and the possible effect of future use of the X-ray machine for medical purposes. It delves beyond just general awareness and led me to explore deeper.

Power System Technology
ISSN:1000-3673
Received: 16-08-2024 Revised: 05-09-2024 Accepted: 22-09-2024

Misunderstandings about radiation are more common than those regarding other forms of pollution because radiation is invisible. Among the most pervasive radiophobic concerns regarding radiation exposures are those relating to the belief that "all counts" or to OSHA because exposures "add up". Some common recognizable statements of these concerns include the fear of receiving too many x-rays, the fear of receiving further radiation after having cancer, or the concern that if enough x-rays are taken something irreversible and bad results. Cultivating patient radiophobia regarding radiation requirements in the labor market makes it less likely that they will submit to medically important x-rays. All voluntary x-rays are potentially life saving in that they can detect potentially life-threatening diseases (A. Oakley & E. Harrison, 2020). The use of medical radiation tracking records allows an acute care provider to both monitor and keep an account of all invisible radiation weighing from 1 millirem or more that each patient has received or will receive during their lifetime from both medically related (including all prior or future diagnostic or therapy procedures) and other sources such as plane travel. Medical radiation records should always be consulted before an x-ray is requested (Ho, 2010). Harm from radiation exposure is a valid but misunderstood concern. Conventional wisdom, based on the model that harm from radiation exposures, including cancer risk, is linear with dose, suggests that avoiding all radiation below certain threshold levels would be beneficial. Instead, research reveals beneficial biological adaptive responses that occur after low-dose radiation exposures, including concerns with ionizing radiation. The findings are consistent with those who have shown that the biological effects of low-dose radiation differ significantly from the effects of much higher dose exposures. There is a growing body of data showing that low-dose radiation can trigger beneficial adaptive defense mechanisms including DNA repair, stimulation of the immune system, and suppression of tumors. The more dangerous focus on the reduction of low-dose radiation exposure by costly X10 (or more) and below efforts, examining practices to avoid background radiation, can lead to harmful health consequences.

2.1. Types of Radiation

X-Rays are ionizing radiations that lie between UV light and Gamma rays. This type of radiation is used in common imaging techniques such as simple X-Ray imaging, dental imaging, mammography, and bone densitometry, as well as in some advanced imaging techniques like computed tomography (CT) and fluoroscopic imagining. In medicine, computed tomography is heavily used for diagnostic purposes. However, the primary risk associated with exposure to ionizing radiation is cancer. In diagnostic radiology or nuclear drug imaging, X-Rays interact with human tissue and as a result, exposes the human body to a significant amount of ionizing radiation (Semghouli et al., 2015).

The effective dose (ED) has been defined to represent the impact of the absorbed dose in terms of the risk to the whole body. The ED is a useful way to compare exposure from

Power System Technology
ISSN:1000-3673
Received: 16-08-2024 Revised: 05-09-2024 Accepted: 22-09-2024

different modalities or different types of exposure. Estimating the collective effective dose is performed a natural consequence of calculating average exposure for a population, and permits an evaluation for the potential increase in detriment risk, and the system to identify areas for optimization within the population or protection schemes. Ionizing radiations are largely used in different socio-economic fields, especially in medicine. The use of ionizing radiation has been increasing dramatically in countries, because of many socio-economic benefits, and radiology departments are the largest ionizing radiation user in hospitals, and the largest contributor to the effective dose in the public medical exposure.

3. Medical X-Rays: Uses and Benefits

Every year, more than a billion people worldwide are subject to ionizing radiation from procedures or medical imaging examinations. Among these procedures, medical X-rays are most common, and their increase rate has been significant. Although X-rays are essential medical diagnosis tools, they use ionizing radiation. Because of this, they are not free from risk. Nonetheless, the benefits largely exceed the risks when the justification and optimization criterions are fully applied (Ho, 2010). Many serious diseases and conditions have been revealed by means of X-rays, whose diagnosis would be deeply hard or even impossible otherwise. Cancers, including breast and bone metastases, and cardiovascular diseases are common examples.

Medical X-rays gas inestimable benefits, but still they produce some additional effective dose to patients and staff. The worldwide collective dose from medical X-rays must be very high. Risks associated to radiation depend on complex interactions of different factors. Beneficial effects can also occur, in terms of hormosis, adaptive responses, increased repair processes, and epidemiological support for radioprotective effects. Relative dose from X-rays is very important when atomic and molecular damage is studied. For a same effective dose, relative doses are much higher when coming from a CT than X-rays, and more higher from a radiological image. Female populations show an increase rate of medical X-rays, especially in breast imaging. Orbital doses are significantly high for face-x and dental radiology. Genetic disorders can lead to a high radiosensitivity. UV rays are also ionizing radiation, and thus, they can be a factor for skin cancer.

3.1. Diagnostic and Therapeutic Applications

Medical radiography imaging is a safe, fast, and efficient way of diagnosing injuries and illnesses. Graduate radiographers are working alongside experienced radiologists, providing a rapid diagnostic turnaround using a range of imaging techniques. Radiology is an essential clinical tool in the identification of dental disease. It is used for the evaluation of trauma, dental conditions, and for the postoperative review of implants or surgical procedures of the oral cavity and facial region. The school's imaging services are 100% digital, with the

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majority of imaging being fully digital equipment. X-ray images are produced using the physical principle that some materials absorb more X-rays than others. The X-rays pass through the body and strike the detector, which forms the image. At Ramsay Imaging services, only digital imaging is used; this technique uses detectors to record the image. A computer then processes the image to produce a black and white diagnostic image. This process allows electronic storage of images for comparison or for viewing at other sites, as well as a greater scope for dose auditing. There are very few needs for medical X-rays nowadays. Patient safety is the primary concern of health professionals. Although the use of medical X-rays is declining due to their excessive use, which raised concerns regarding the balance between the benefits of providing early diagnosis, treatment, and saving lives, or causing other biological effects. The program is an extensive computer program to calculate the resultant exposure of patients during radiological and fluoroscopic projection. The resultant exposure must be reported on the image and film when using the programmatic method.

4. Risks Associated with Radiation Exposure

Radiation exposures received from medical X-rays are cumulative over a lifetime. One of the most common concerns patients voice to their healthcare providers is their fear about having too many X-rays and developing a disease because of what radiation is known to be able to do. This is sometimes noted by radiologists as “radiophobe,” “radiophobia,” or a dread of radiation. Inside the medical setting, the common shape of a radiophobic concern has to do with the number of X-rays received or a dread about the development of a disease related to the radiation exposure. Both of these particular worries about radiation exposure have led to unnecessary patient delays or the complete avoidance of medically necessary imaging.

As a defense against unhealthy concern over radiation, providers may offer the standard answer: “the amount of radiation in a single X-ray is so small the risk is negligible.” Nonetheless, it is also recognized that the biological impacts from radiation are more complex and arguably more worrying than from the radiation of any other genotoxic agent, and, further, that the damage from radiation is cumulative (A. Oakley & E. Harrison, 2020). In order to address patient concerns responsibly and provide a better contour of medical radiations, it is suggested that patients could request a medical radiation surveillance sheet. Since 2014, California law requires that a tracking record is designated to patients who request their total effective cumulative dose (TCD). Such a tracking record would document all medical radiation exposures received throughout medical care and would facilitate its accurate assessment.

4.1. Acute and Chronic Effects

A population-based radioactive iodine accident model

Received: 16-08-2024 Revised: 05-09-2024 Accepted: 22-09-2024

4.1. Acute and Chronic Effects

All radiological exams expose patients to ionizing radiation, with X-rays accounting for the largest source of medically induced radiation (A. Oakley & E. Harrison, 2020). Radiation exposures are cumulative; thus, it is not uncommon for patients to express concerns about receiving additional radiation, citing either a previous exposure or previously diagnosed cancers. Numerous patients pose a similar question, such as stating that they have had numerous X-ray exams in the past and or have had cancer before, and suspect an additional X-ray exam may result in secondary cancer or a previously irradiated cancer arising. As a result, the total effective cumulative dose (TCD) could be tracked to avoid these presumed health detriments that are associated with higher TCDs. A possibility is to include in addition to cumulative effective dose from medical imaging exams in the screening mammography report, a TCD calculation for all diagnostic or interventional imaging exams. Related radiological reports have the potential to assist in the detection of these presumed phenomena. Additionally, it is common for listeners or patients at public lectures or screenings to ask, "have you been irradiated yet," due to possessing a UV lamp activated cancer cell chip implant. This speaks to the underlying fear patients have concerning radiation exposure.

4.2. Socio-Cultural Spectives

So, on the bus I overheard one woman claiming that in the past 6 months she was talking a languages course, employed a personal trainer, visited a psychologist for anger management, frequented an accredited dietician, went on a colon detox diet, hired an image consultant for a televised debutant ball, and a social etiquette consultant to boot. In addition to all this, she successfully completed 6 out of 6 sessions at a self-hypnosis center; consequently, quitting smoking was easy. Wow, busy, and accomplished, and after her three weekly private pole dancing sessions, one man was so debasing as to counterfeit his impression of her by spinning an invisible tennis racket. Two viper smart start concepts are claimed as, (1) hospice will be admitting and treating patients; the North American concept proposes hospice as a philosophy of care, primarily end of life, not a place, with treatment being given only for the purpose of palliation, and (2) oncologists, seeking an edge, pause with the knife, drug, radiation routine, scribbling referrable's to the kinesiologist, chiropractor, aroma therapist, physiatrist, dietitian, marathon runner and massage therapist.

5. Regulatory Guidelines and Safety Standards

X-ray facilities in Saudi Arabia have increased enormously in the last two decades, accompanied by an increase in the number of radiographs taken and number of persons radiographed. They are now performed mainly by Saudi dental auxiliaries, who are allowed to practice after only a six-week program, followed by no continuing medical education. It

Power System Technology
ISSN:1000-3673
Received: 16-08-2024 Revised: 05-09-2024 Accepted: 22-09-2024

will be very unlikely they are aware about basic radiation safety and biology under these circumstances. In 1997 two large benign neoplasms in the thumbs of the left hand appeared in a general dentist on which a decade earlier a malignant mass in the anterior chest wall had been removed; induced by the repeated excessive exposure to APPA-guided X-ray of an X-ray machine under control of the same persons who fixed the 1997 thumbs X-ray machine. Currently, radiographers are educated over three years after finishing secondary school, but there is no body to check and control the use of X-ray machines (S. Halboub et al., 2015). In this favourable setting, the radiographer conducted 396,000–594,000 exposures in 15 years, during which official representatives of the King Abdulaziz City for Science and Technology unit for Radiological Protection performed the area survey. The radiographer stated using the collimator/diaphragm only during the short time of these area surveys. The highly significant ADP dosemeter readings taken for just a few minutes' hand exposure when setting up and taking an X-ray, followed by thorough analysis and medical checkup, were as good as negative, and new dosemeter gave inadequate readings within a few weeks. This all resulted in noncompliance with various professional or national recommendations, and even the Public Prosecutor has taken no notice of all handouts enclosing 268-A4-page of documented and photographic evidence. It appears that several Saudi radiographers run the X-ray machines in the same way.

5.1. International and National Regulations

To ensure protection against unsuitable radiation exposure, guidelines have been presented. Similar safety standards have also been published to protect patients against harmful overexposure to ionizing radiation. The essential protection of individuals against radiation that international guidelines provide allows for the development of national guidelines and standards according to each country. The National Regulatory Authority of each country should identify and inspect medical X-ray units. These regulations are understood in a simple and comprehensible way in order to ensure that all staff have adequate education and training on radiation safety. This provides for constant protection through frequent monitoring and precise recording of radiation doses.

The exposure dose limits have been established for occupationally and non-occupationally exposed people. In addition, a limit for pregnant individuals is also in place to protect the developing fetus while considering the essential imaging of the mother. The complexity of the method to detect specific illnesses should also affect the choice of imaging methods. A correct rationale must exist for radiological imaging to be carried out. Nevertheless, it should not be neglected that X-ray exposures are not without danger, as their proper advantages are taken into account. For every patient, an informed consideration of what is to be done must be taken prior to the assessment.

Power System Technology
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6. Minimizing Radiation Exposure

Unfortunately, x-ray hesitancy is a global reality in healthcare. Unsurprisingly, x-ray hesitancy in patients, now commonly referred to as "medical x-ray phobia," is directly correlated to radiophobic attitudes and behavior with their healthcare provider. A recent national research study showed that the common reasons radiophobic patients provided for x-ray hesitancy were: concern that health care providers were exposed to x-ray radiation daily yet their safety precautions to protect themselves were minimal, x-rays are treatments of last resort options, and the x-ray technology used is outdated. The present study aimed to investigate a question that practitioners continually ask: What radiophobic concerns do patients have / provide that contribute to x-ray hesitancy and subsequent noncompliance with referral requests? (A. Oakley & E. Harrison, 2020). Organ-based and dental radiographic images were omitted from the study as it was not the intent to investigate potential traumas dealt with those conditions / issues (although patients may not distinguish between x-ray types). For x-ray imaging, patients may also not distinguish x-ray types and it is thought to be referred to a general category. X-ray hesitancy carries directly physical effects as a medical disease is left untreated while x-ray imaging could determine the disease as curable, a constant investigation with x-ray imaging would increase the chance of getting the disease, more exposure to x-ray radiation would be received focusing on alternative treatments as the disease would remain undiagnosed. Matching treatments between radiography examinations and prescription medication is not obligatory and health care providers are seen to be lacking the necessary protective equipment / safety precautions that are advertised as protecting.

There are feasible actions that can be undertaken to reduce x-ray hesitancy with the most practical one being to not rely on outdated practices, beyond 'acting' concerned that the world of radiography is deemed as being taken seriously. More so, a protocol be developed that educates referral requesting providers in order to familiarize themselves with x-ray imaging practices, basic radiation biology with a focus on how x-ray machines function, theories of radiation, part of the body being targeted, the necessity and importance to take the given treatment as stated, and the safety precautions that patients can take to minimize x-ray radiation exposure be recommended. Buffering theories suggested three changes that could be implemented to x-ray imaging practices in order to change the perception that a video's title would be believed.

6.1. Technological Advances in X-Ray Machines

X-rays, which consist of a type of high-energy electromagnetic radiation, were discovered in 1895. They are widely used for diagnostic medical imaging. X-ray imaging with ionizing radiation is often the first choice for examining the internal parts of the body, bones, cavities, dental issues, and orthopedic needs. It is also used for interventions, such as catheter placements in angiography. X-ray machines available are either fixed or portable. The most

Power System Technology
ISSN:1000-3673
Received: 16-08-2024 Revised: 05-09-2024 Accepted: 22-09-2024

common uses for fixed X-ray machines are chest, abdomen, extremity, head, and spine imaging. The beam width is typically 40-45 cm and it is unlimited in length. Currently in operation, mostly digital general X-ray equipment has automatic exposure control. It is possible to set the exam to patient size by adjusting the imaging parameters and margins. The dose area product can be measured per X-ray examination. Mobile X-ray machines normally come with an image intensifier that fits the X-ray beam and has a round collimator with diameters between 9” and 15”.

In the last decade, X-ray imaging systems have seen significant technological advances. New high-end technologies are being continuously offered and the existing premium options become standard features. It is essential to understand all the changes in the X-ray equipment. Because of being relatively smaller and below 20 years old, children are very sensitive to radiation exposure. Higher X-ray safety levels are required for patients with an examining age of 15 or less. X-ray machines used for pediatric imaging should be designed and verified in such a way that the radiation dose to the pediatric patient is automatically reduced as much as possible. It is essential to understand the importance of proper adjustment and usage of the X-ray imaging system to minimize radiation dose. Recommended steps with tips and examples on how to achieve reasonable radiation doses for all pediatric X-ray imaging projections must be considered further.

7. Protective Measures for Patients

Proper source to image receptor distance along with the use of three-phase generators and intensifying screen are recommended to reduce the patient’s radiation dose, particularly for radiation-sensitive organs such as the thyroid, eye lens and gonads, which are important for radiologists and radiographic technologists to remember (Farzanegan et al., 2020). Beam energy, filtration, field size and tissue thickness are other factors that affect the patient’s radiation doses in computed tomography and other diagnostic imaging studies. Applying the principles of radiation protection in radiologic examinations can prevent the deterministic effects of ionising radiation and decrease the risk of stochastic effects. Localisation of the radiation field and keeping the distance from the radiation source are amongst the principles required to reduce the patient’s radiation doses. During a radiologic examination, the area of the patient’s body exposed to the X-rays should be limited to the target area under consideration. The tissues exposed to the primary radiation frequently receive a significant higher amount of radiation doses compared to the tissues outside the radiation field. Therefore, the amount of unnecessary exposure can be significantly decreased by beam collimation and appropriate localization of the radiation field. Therefore, it is recommended that the technicians accurately localise the radiation field during diagnostic procedures. Excessively angulated images of difficult organs, such as the middle ear, which often require symmetrical and angled views due to the thinness of surrounding adenoids and the antrum,

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ISSN:1000-3673
Received: 16-08-2024 Revised: 05-09-2024 Accepted: 22-09-2024

should be kept to the minimum number of views possible. The use of lead aprons and protective equipment for the patients and their companions is significantly important. The article aimed to evaluate the observance of the principles of radiation protection in the imaging centres of educational hospitals with emphasis on the restriction of field size, suitability of the selected exposure factors, and the use of protective equipment for the patients and their companions during radiologic examinations.

7.1. Lead Shields and Aprons

Radiology is a branch of science that deals with the analysis and treatment of X-rays. Its applications are vast, including X-ray, fluoroscopy, computerized tomography (CT), and mammography. Initial X-ray machines were modified versions used in airports. Medical X-ray machines have shorter exposure times and vary in energy settings. Most portable X-ray machines operate at 40-120 kVp, while fixed installations operate on 50-150 kVp. The HVL (half-value layer) size also varies depending on the type of machine. Usually, ultra-light mobile X-ray machines have HVL thicknesses of 3-4 mm Al.

High doses of radiation have fatal effects on the exposed region and secondary regions by direct or scatter. Therefore, such devices result in radiation training and lead shielding data. Lead lined gloves are recommended to hold injectors during fluoroscopy; however, physicians dislike wearing these gloves because they are heavy. Safety aprons are also recommended during fluoroscopy or angiography, which consist of a back protection shield and lap shield. Protective materials might be used to decrease the absorbed radiation dose. There are available flat and flexible materials that contain lead powder below 0.8 mm Pb equivalent in the market. While these materials can reduce direct and cross radiation exposure, their shielding effectiveness is half that of standard materials. Lead aprons have many structural advantages and protections, which are also lightweight. However, lead aprons are heavy and tiring to apply, especially after prolonged clinical exposure. Despite the lower scatter radiation protection capabilities of lead-free aprons, many clinical centers prefer lead-free aprons to provide physicians with more comfort. Alternatively, lead-free aprons with greater protection could be commercially available. For lap and scatter shields, disposable gloves are an effective radiation barrier, reducing the amount of radiation and decreasing the blood contamination on the hands. Lead and lead-free gloves exist. Common disposable lead gloves are not suitable for clinical practice as they are too rigid for blood vessel catheterization.

8. Protective Measures for Healthcare Professionals

Healthcare Providers are exposed to occupational radiation as result of their profession. In Europe, the European Commission has reported an increase from 2% to 8%, in the expected occurrence for cancer, per one Gray for combinations of tissues. It is important to limit the

Power System Technology
ISSN:1000-3673
Received: 16-08-2024 Revised: 05-09-2024 Accepted: 22-09-2024

radiation dosage and monitor exposure. Personal safety measurements are used to minimize the effective dose of the body due to the radiation exposure. Inappropriate use of these safety measures such as protective shields, time and distance, dosimeters, and protective glasses may lead to excessive exposure which result in unwanted deleterious effects on the staff (Ghallab et al., 2024). Also, the manner of radiation delivery and the number of performed procedures play a role in the overall radiation dose of the workers. The radiation effects are observed after a long period of exposure. Healthcare workers are unaware of the deleterious effect of exposure to radiation till they develop some health problems. Despite radiographers, cardiologists performing cardiac catheterization and nurse assistants all those professionals should be protected from the deleterious impact of radiation. It was noticed that there is a lack of radiation safety awareness among the healthcare providers which poses a potential health problem. These conclusions strengthen the importance to have strict rules regarding training, the use of protective devices, the use of radiation dosimeters and routine monitoring for medical staff. Indeed, the use of protective aprons for example, plays a significant role in reducing the radiation dose of the staff members and is the most commonly used personal radiation protection. In addition, the present work highlights the importance of enhancing the protective measures in the procedures where the dose is already high to avoid the occurrence of radiation-induced health problems among healthcare workers.

8.1. Lead Glasses and Thyroid Shields

The radiation exposure of the eyes, brain, thyroid and chest of radiologists and assistant staff members during medical X-ray examinations is investigated. The radiation exposure of the left and right eye lens is compared during working hours when the staff of two radiology centres were using and not using lead glasses. The effectiveness of lead glasses in reducing the eye lens dose equivalent is investigated. For this purpose, TLD measurements are performed inside and outside the lens protective area. When lead glasses were used, it was found that the Hp(3) values measured outside the glasses were higher than those inside the glasses. For thyroid protection, measurements are done when thyroid protection was not used and when a common type of thyroid shield was used (Pyka et al., 2018). The shielding effects on the brain were also analyzed during cranial radiography. Measurements were done using a head phantom. The dose distributions of the scatter radiation outside the primary beam are also discussed. Dose measurements showed that doses close to the lens were higher than those received to the thyroid and under the left collar of a lead apron. The use of lead glasses reduced the Hp(3) values measured outside the glasses by 56% on average.

Patients may be exposed to ionising radiation for diagnostic imaging purposes. The risks for radiation injury increases with higher dose. Since, it is very hard to describe the dose limit values that may cause radiation injuries, it is crucial to use aprons for patients in order to protect them from radiation. These aprons contain lead, and prevent the penetration of the

Power System Technology
ISSN:1000-3673
Received: 16-08-2024 Revised: 05-09-2024 Accepted: 22-09-2024

ionising radiations. However, there are some specific places which should not be under any sheet layer, so in this study, the improvements and practicability of lead aprons are discussed for the safety of patients (R. et al., 2020).

9. Radiation Monitoring and Dosimetry

Despite the different dosimeters and radiation monitoring systems that are available in the market, one of the main problems faced by hospitals is to determine the most adequate system and the best place to install it to monitor the radioactive exposure of the personnel and to control the good performance of the radioactive devices. The aim of this paper was to develop a computer program to calculate the equivalent dose received by the fingertip of the hand equipped with the dosimeter. To verify the accuracy of the program, equivalent doses obtained for controlled conditions have been compared with those obtained by experimental system. A second step in this work was to compare some commercially available devices suitable to be used to monitor the equivalent dose on the hands of the personnel. Special Radioactive Environments. Different types of particles and rays of ionizing radiation generate different effects in the materials they bombard. In general, the energy of the particle or radiation is related to its penetration through matter and to the effect produced by this interaction. A measuring system for detecting ionizing radiation must use the optimum detection process. In the design of the measuring device of ionizing radiation to be installed in a hospital environment, it is necessary to define with precision the type of ionizing radiation it should measure, since each type requires different monitoring equipment. Radiation monitoring is paramount in the case of environments where patients, healthcare workers, and people from the general population are exposed to x-rays with the premises of obtaining an excellent image or a good diagnosis. Under these conditions, safety factors are essential to avoid overexposure to ionizing radiation. Measures have been taken in a classic radiology room in order to monitor ionizing radiation, as well as a second X-ray room, fully-digital, equipped with a biplane system interventional fluoroscope. At a surgery room with a system, personal dosimetry monitoring of the equivalent dose on the skin and the overall equivalent dose have been performed.

9.1. Importance of Monitoring

Radiation Safety and Protection in Medical Diagnostic Radiography is the title usually given to that part of the radiography department that employs non-viral imaging techniques. Different imaging modalities, including Radiography, Fluoroscopy, and Computed Tomography, obtain images by projecting different forms of ionizing radiation. The importance of carefully monitoring x-ray equipment to ensure the correct operation cannot be overstated. This is necessary to avoid unnecessary skin dose and to limit general patient exposure to ionizing radiation (M. Dauda et al., 2019).

Power System Technology
ISSN:1000-3673
Received: 16-08-2024 *Revised: 05-09-2024* *Accepted: 22-09-2024*

The need for attention to detail when monitoring radiation levels and hence doses within this area also stems from an understanding of the importance of personnel radiation safety in regards to professional standing and ethics. It is often the radiographer who introduces the patient to his first encounter with a Doctor since entering the hospital. He will probably remain central, working together with both the departmental Doctor and the patient through the period of their association with the X-raying department. This gives the old to the Department an example-setting responsibility carries a concomitant responsibility for radiation protection. To put the matter in a legal perspective, it is the legal duty of employer/ employee to do all that is reasonably practical to minimize the levels of X-ray exposure.

10. Emergency Response Protocols

Emergency response guidance for the first 48 hours after the outdoor detonation of an explosive radiological dispersal device (ERDE:2 outdoor). The first 48 hours after the detonation in a populated area of a radiological dispersal device (RDD) can be very intimidating to emergency response personnel. There are large amounts of damage requiring emergency services to function expediently despite severe losses to infrastructure and manpower. Responsivity in the first 48 hours is divided into time periods of ≤2.5 h, >2.5 to 4 h, >4 to 8 h, 8 to 24 h, and 24 to 48 h after explosion.

It is important to consider that very low levels of radiation exposure (10 R) impair a worker's ability to perform tasks that require attention, psychomotor and cognitive skills, agility, and strength to a degree that is close to that observed after drinking the legal limit of alcohol. Further, routine handling techniques are proficient only up to about 7 g of explosive energetic material return; they are removed from "very safe" standoff distances, making them susceptible to other types of physical protection monitoring. There is also an expectation that some form of distraction will be arranged at the primary target venue to ensure RDD initiation as close to the "optimum time" as possible (Wayne Hearnsberger, 2007).

10.1. Dealing with Accidental Exposure

A 12 years of experience 30 years old male radiographer, right-handed, was assigned to the dental X-ray department. It was equipped by a machine. The radiographer trained for acquiring perfectly paralleling technique and using dental films size 2, instead of the duplicate paralleling technique and film size 0 used by the dental students. The days were assigned to different specializations of dentistry. During that month, it was the endo-dental specialty week schedule. On the morning of the seventh week, the radiographer performed the usual morning protocol, machine's warm-up and testing; afterward, he waited for the patients to be ready at the same room as the machine, instead of the separate changing room for adopting conventional radiation protection tools as the lead apron and thyroid shield. Less than 1 min after that direct exposure and while the patient was still sitting on the X-ray chair,

Power System Technology
ISSN:1000-3673
Received: 16-08-2024 Revised: 05-09-2024 Accepted: 22-09-2024

the machine was unintentionally activated. The X-ray tube head was perpendicular directed toward the radiographer's right and slightly curved in an attempt to avert his face. The patient immediately exited the room, whereas the machine was on until the timer time was accomplished. After that, the fail-safe light and sound alerts were on to show and announce the overexposed condition. It is recalled and estimated that a direct exposure of the origin of less than 45 mAs dose was obtained at 70kVp and the shortest distance source-image receptor 30 cm. Nevertheless, the radiographer did not notice any overexposure symptoms. Similarly, the radiologist who thoroughly inspected the X-rayed films did not remark any artifact. However, from that incident date, he noticed a discharge ooze from his right thumb. At first, disregarded this event. But, before the end of May, there was an exacerbation in the form of a periodically painful sore. By that time, he also took notice of a similar ulcer in his left thumb. This was peculiar since the right one was at the same direct exposure with the right hand that was operating the machine at the time of overexposure. Hence, he consulted the professors in the department who in turn referred him to a general surgeon. An erosion of the distal phalanges of both thumbs was clearly evident. Consequently, the surgeon planned to excise the discharging ulcerative lesion of the right thumb and to submit it for histopathological diagnosis. The small specimen was submitted and it was heavily inked, section processed, and histologically examined as four thin serial sections. The diagnosis was mentioned in the pathology report as squamous cell carcinoma Grade II. Based on such a diagnosis, the surgeon decided to excise the distal phalanges of both thumbs with tumor free-margins. The distal phalanx of the left thumb was excised according to the same protocol achieved for the right one. To cover the disfigurement, the surgeon used advancement rotation flap harvested from the dorsum of the left thumb.

11. Training and Education in Radiation Safety

Radiation safety awareness has recently gained more interest, especially regarding staff and patients who are frequently exposed to medical radiation due to the application of fluoroscopy. Sometimes, staff must directly enter the X-ray field, while patients are consistently exposed to radiation. Several of them are x-rayed many times in a lifetime, with a risk of negative effects. Limited knowledge is observed in the general population. Recently, a survey was conducted on public awareness of radiation risks, diagnostic effectiveness and dosage units. 475 patients at a hospital were handed an informational pamphlet regarding the radiation produced with the bone harvest procedure prior to their operation. It was seen that a 5% improvement on the survey regarding comfort with radiation knowledge and understanding was observed with just the pamphlet alone (Joshua No, 2017). Radiation protection practices for orthopedic surgical staff during a pelvis radiography procedure by high-dose fluoroscopy were assessed.

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Awareness of radiation risks and the safety guidelines established to minimize the exposure are of primary importance for staff and patients involved in interventional and diagnostic radiology. Safety procedures are well described in literature but not sufficiently applied. A questionnaire assessing radiation protection knowledge was administered to several phases of an orthopedic surgery, to the anesthesiologists involved in the procedure and to those who were not exposed to the radiological procedure. The anesthesiologists reported fewer protective practices and poorer knowledge of radiation risks, underlining the insufficient attention to radiation protection among anesthetists (Brun et al., 2018).

11.1. Certification Programs

During the past decade, developments in x-ray technology have improved the ability of practitioners in many fields to treat patients using image-guided therapeutic techniques. These innovations include the integration of computed tomography scans with modified linear accelerators for radiation therapy and the use of fixed C-arms in operating rooms for image-guided surgery. However, use of these x-ray systems typically requires a greater use of fluoroscopy and serial imaging. This has increased the potential for radiation-induced dermatitis, epilation, and severe radiation-induced burns to patients (R. Archer & K. Wagner, 2000). It has also increased the potential for radiation injury and radiation-induced cancer in personnel. Cases of patient and personnel burns, cataracts, and brain cancer have been reported. Moreover, since 1994 US facilities now must adhere to increasing standards for training and safety. Knowledge of the issues surrounding the safe use of x-rays is important for those who design procedures, work near x-ray systems, or work with people who undergo x-ray procedures. Such persons will be referred to throughout this manual as "workers." Administering contrast agents for x-ray procedures is classified as a high-risk task. This work provides specific steps and information to assist workers comply with the approach. Proper training of ancillary personnel is one of the more important ways that accredited facilities can reduce the potential for severe radiation injury. Although ancillary personnel may not perform the procedures, they still may be involved in the concourse and operation of the x-ray equipment as well as the care of patients. However, currently there is limited information available for training such personnel. This work will describe a number of patient cases and the current recommendations and credentialing requirements of various organizations whose members operate the equipment. Finally, as a result of research and direct observations, a comprehensive in-house program for implementing training of ancillary personnel in radiation management is described as a means of reducing the risk of injury to patients and technicians.

12. Research and Innovation in Radiation Safety

On one hand, the awareness campaign about the risks posed by ionizing radiation to healthcare workers and the general public must be made more extensive. Furthermore, more

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efforts are required to multiply the sources of information available to medical practitioners in order to improve their information level and thus stimulate best practices for radiation protection in diagnostic radiology. Various organizations, assisted by many institutions, have been developing campaigns of awareness about the risks of using ionizing radiation and the safety measures required to protect patients.

The campaigns are mainly directed at educating the public since patients are usually concerned with the level of radiation risk involved in an X-ray examination. More recent campaigns are directed at informing the healthcare workers involved in the preparation and processing of patients, hence they can expose themselves to X-rays daily. Such awareness campaigns are developed with the help of television, claims, leaflets, etc. There are very few campaigns based on medical literature and news; thus, a new tool, the information system via satellite for medical practitioners, entirely based on current problems of radiation protection in diagnostic radiology, was proposed.

Later campaigns are proposed to make use of the new communication technologies with the aim of implementing a large-scale wide diffusion of various sources of information currently available about radiation exposure in medical X-rays. Finally, criticism about and new ideas for further developments of such information systems are provided based on the experience gained with a similar available system.

12.1. New Materials for Radiation Protection

New materials such as the nanoparticles and micro-powders with the most effective attenuation properties against x-rays should be regarded for the improvements in protective clothing industry. In this study, micro-sized copper oxide (CuO) as nano-powder and as micro-powder were utilized to fabricate protective clothes and the radiation attenuation properties of these materials were investigated. The x-ray transmission exposures were measured with respect to the different tube voltages of commonly used Cone Beam Computerized Tomography in dental intervention. The comparisons of the x-ray transmission and the coverage ability of the nanostructured and microstructured CuO are also presented. Micro-sized copper oxide (CuO) particles are ground at the specific diameter (micro-powder) as well as the nano-powder particles. Totally black, navy-blue, dark-blue clothes containing micro- and nano-powder CuO were respectively fabricated and named as ‘mixed fabrics’. The positive control group, identified as ‘standard fabric’, was black color and has high density it the same as ‘mixed fabric’. The negative control group, ‘standard fabric’, was white and has low density it the same as ‘cotton’. All fabrics are produced in a 6-ply and entirely quilted structure. The production process of fabrics is displayed in plate 1 and the final form of the ‘mixed fabric’ is depicted in figure 1 (Nikeghbal et al., 2020). The y-axis of table 1 shows the absorption, which is the difference between the source intensity without tissue–equivalent surrounding medium and with medium without any piece of garment. Each dataset

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in table 1 compares standard deviation (STD) as the square root of the sum of the squares of the standard deviations for the values of the individual dataset gathered. Standard deviation data for all three points subsequent to the example data that represents the absorption measurements (μGy), the test number, and percent transmission calculations less than 1 percent transmission.

13. Case Studies and Lessons Learned

Case studies featuring thumb carcinoma and radiation skin injuries (RSI) originating from practicing dental x-rays and interventional radiology are presented in this section. Unfortunately there has been no case as of yet regarding thumbs carcinoma due to ionizing radiation exposure from the frequent practice of dental x-ray. A male radiographer with a history of practicing dental x-ray in the primary health care center for 15 years developed thumbs carcinoma on both hands ((S. Halboub et al., 2015)). Within this period (from December 1996 to October 2011), about 396,000–594,000 exposures were reported to be performed. It is claimed by a few authorities that any dose of ionizing radiation has the potential to induce malignant changes, and there is no threshold dose below which ionizing radiation is predictably safe. However, the main concern about the hypothesis is races, not experiment-supported findings. Despite this, it could be stated that regarding the nature of radiation and statistic certainty, there will always remain a slight possibility of induced cancer or genetic damage no matter how low the exposed dose is. The National Radiological Protection Board state that every 100,000 exposures conducted by the radiographer will possibly increase the risk of inducing fatal cancer or serious hereditary ill-health to 1. The use of short and pointed three sizes cones with the closed-end has the highest probability of leading to a stochastic effect in comparison to the regular or round-shaped cones. Unfortunately, the actual value of radiation dose delivered by the dental x-ray can be varied and not being cared without caution.

Radiation skin injuries (RSI) are an established phenomenon, and the number of reported cases has been steadily increasing. Most have been RSI due to radiological examinations, 65% of which are related to interventional radiology. RSI inherent to interventional radiology have been frequently reported, mainly on nurses and patients, in the past decade. The International Radiology Society issued guidelines and recommendations regarding patient care, measures, and practices about preventing RSI, but cases of RSI are still being reported. An increasing number of radiographers and attending clinicians are implementing angiographic techniques without proper knowledge and training in radiation safety and radiobiology. A warning was broadcast in 1994 by the Food and Drug Administration regarding RSI caused by fluoroscopically guided procedures. In response to the increasing number of cases of deterministic effects on the skin following interventional procedures, in 1995 the Japanese Radiological Society felt the urgency to inform its members about these

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Received: 16-08-2024 Revised: 05-09-2024 Accepted: 22-09-2024

potential skin injuries. The first paper was published in 1998 in Japan that reported a case of RSI due to prolonged fluoroscopic exposure, which resulted in skin microvasculature damage from which small vessel leakage started after 2 Gy of absorbed dose. The majority of the cases appeared during cardiac studies, but there were also some cases after abdominal ones. International guidelines were published in 2000 by the International Commission on Radiological Protection, in which the importance of explaining the risk of radiation injury to the patient was underlined, both for diagnostic and interventional procedures ((Nishitani, 2018)). There is also a recommendation to specify in the protocol the cumulative number of images and the fluoroscopy time. If procedures required result in an absorbed dose exceeding 3 Gy, a meticulous description of the exam should be noted and documented. Since then, the cases of RSI have become an alarming issue and the following example should be taken as a warning. Also, the number of total CT examination patients has increased dramatically in Japan. Based on the linear no-threshold hypothesis a claim has been made that there is an estimation of the possibility of fatal cancer after CT examination in a 0.6–1.2%. The claim led to proposing a law requiring the safety of each examination be explained to a patient every year prior to the examination. Since then, several questions have been posed, such as is it really safe to alone study while performing CT and performing and learning CT are two very different things; the latter one helping to fully understand the process and the ability of creating the patient-specific protocol.

13.1. Notable Incidents in Radiation Safety

A number of incidents have significantly influenced the development and enforcement of radiation protection standards since the first demonstration of an X-ray by Wilhelm Röntgen in 1896. The potential for damage from ionizing radiation was noticed by Clarence Dally soon after, who worked with Thomas Edison's X-ray tubes for over a decade. He was diagnosed with radiation-induced dermatitis in 1901 and lost both his hands and forearms to the disease. Dally's death in 1904 served as a further warning to researchers, leading Marie Sklodowska-Curie and Pierre Curie to publish a note that X-ray dermatitis seemed to be trouble mostly with early workers. The first protection regulation for radiation equipment came into effect in 1904. The tables and image receptors are placed approximately at a state of 90–100 cm from the X-ray tube head (S. Halboub et al., 2015). An increase of the distance to approximately 125 cm will reduce concomitantly the dose to half of the initial dose. An additional contribution from ambient scatter radiation is recorded, in the geographies with portable equipment mainly, even if the place is shielded. Multiple-use of the photocopy of the films is preferred when there is a heavy patient's load for radiographic examination, especially if there is no marked protecting area on the image receptor's rear cover. In combination with multiple-use of the films, the use of lead markers instead of digital is recommended as far as the patient's load is concerned. Uncollimated X-ray beams report an excessive dose either to the staff or to organs within the beam. The use of short and pointed

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Received: 16-08-2024 Revised: 05-09-2024 Accepted: 22-09-2024

cones with closed-end was suggested as avoided. This particular type of equipment often utilizes short and pointed cones with closed-ends. There are also exposures in the range of minutes, which is why extra film is often used for the increased diagnostic information.

14. Public Awareness and Communication

Medical radiation is part of the daily work flow in diagnostic imaging departments, many healthcare facilities are fitted with increasing numbers of X-ray machines. Although radiology is a fundamental part of medical diagnosis, the use of ionizing radiation cannot be ignored. Such radiation is harmful. The cumulative effect of radiation on human beings may cause hazardous diseases like cancer, sick fetus and cataract. Recent developments in the medical field have enabled such diagnostic equipment to provide high-quality images with an extended field of view. This has been made possible with the adoption of comb X-ray technology together with linear scanning.

Despite the routine use of radiation in the medical field, the general public and often the physicians themselves are unaware of the risks involved with X-ray exposure. There are no established guidelines for medical doctors to inform, educate, or warn patients about the possible risks associated with X-ray exposure. Additionally, there are no established guidelines encouraging medical doctors to refer patients to radiologists. This contributes to the public’s unenlightened approach toward medical X-rays. Patient awareness of radiological protection is necessary, as they should ask doctors for the reason and benefit of each X-ray examination. Medical doctors should always inform their patients about the benefits and also the risks associated with X-ray examination. Benefit and risk should be balanced to justify each X-ray examination (Joshua No, 2017).

14.1. Educational Campaigns

Educational campaigns with information about benefits and risks of medical x-rays, and methods to reduce radiation exposure are highly needed. However, large variations in patient exposure are observed in various hospitals and clinics. In addition, publics also should be aware of low-dose and high-dieffective doses in children because their radiation risks can be considerably higher.

Patient and physician requests for the use of x-rays, CTs, and other radiation-producing medical imaging are increasing in the US, and public awareness of radiation knowledge is limited. It is likely that physician knowledge of radiation knowledge is limited as well, considering the haste at which doctors need to make decisions. Additionally, reimbursement for imaging procedures is high relative to that for many other health care services in the US, encouraging physicians to perform these procedures. Moreover, defensive medicine is a common practice in the US (Joshua No, 2017). Before the intervening as a social scientist, lay health educator, or other practitioner, formative research based on the community of

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interests is conducted. Comments from community members revealed a lack of knowledge about radiation, benefits and risks of medical x-rays. Less than 15% of the informational pamphlets could be passed by the Flesch-Kincaid Reading Test (mean grade level of 9), a pamphlet was prepared for the intervention. Results indicated that the pamphlet intervention was significantly positive; a 5% improvement in comfort regarding radiation knowledge was noted.

15. Ethical Considerations in Radiation Safety

Viewing the patient very much as a radiation health danger, I am much convinced about evaluating the increased patient radiation exposure from radiologic/fluoroscopic exams, getting informed patients and their concerns about radiation safety in medical imaging exams, and providing assurances with the radiologic technology involved that measures are going under control to keep the radiation exposure as reasonably low as can be achieved. The overarching goal remains trying to pursue a high-quality medication while minimizing unnecessary radiation healthy dangers. However, satisfactorily nothing has been said for the medicos who, with the acknowledged consent of their patients, are themselves exposed to very latest polymer in overseeing others' medications. The potential risks resulting from increased occupational radiation exposure to the physician include harm and loss to the physician or the development of radiation-induced ailment. Since the physician is greater, patients have hallowed the medicos, thus placing the medical practitioner in top-score ethical categories. The relevant ethical principles particularly deal with precautious, prudence and control domains. Viewing the medicos very much themselves as a radiation well-being position danger, the relevant ethical opponents are evaluated. It is suggested that curing medicos should follow the ALARA principle with respect to their own paperwork occupation to make control measures in order to minimize their own radiation exposure. The related ethical considerations include ongoing physician education about radiation exposure instruction reduction and continued growth in the understanding and relationship of the possible dangers of radiation exposures from inception ads. It has been acknowledged that medicos overseer about 50% of all medicos ads. Urologists, because they are directly involved in the patient's medication, are primarily responsible for the ads (Joshua No, 2017). It is suggested that, prior to overseeing a medicos to the patient, the medicos should interrogate if further jumps are always necessary. Most moderate jumps can and should be avoided. When overseeing a jump, the medicos should make every effort to minimize the number of images and semi-grammes obtained to properly address the clinical question. Medico ownership developments have resulted in a great increase in radiologic/fluoroscopic exam requests by the medicos who profit from the reinsurance fees generated by the procedures. Transformers of this type of jump ownership will be inclined to oversee more medical imaging exams per case. This may result in an increase in avoidable radiologic/fluoroscopic setups. Associated with an increase in radiologic/fluoroscopic

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ISSN:1000-3673
Received: 16-08-2024 *Revised: 05-09-2024* *Accepted: 22-09-2024*

imaging is an increase in radiation exposure, both to the patient and to the overseeing medicos. A quarter of current occupational radiation malignancies among medicos are caused by x-ray fluoroscopic radiation. Viewing the medicos themselves as the canaries in the coal mine, the ethical matches that physicians ought to take control measures in order to minimize their occupational radiation exposure.

15.1. Informed Consent

Medical imaging that utilizes ionizing radiation is widely used in clinical settings and carries significant risks. Therefore, informed consent is required such that patients appreciate fully the risks and benefits. Result from a questionnaire survey is reported, of patients in a general orthopedic outpatient clinic, regarding patient knowledge and perception of medical imaging to facilitate an informed consent process (John Sweetman & Bernard, 2020).

Since its discovery, X-rays have been used extensively in medical imaging. In most uses, X-rays offer significant health benefits. However, compared to other imaging techniques, X-ray and increasingly used computed tomography (CT) techniques typically provided poorer diagnosis due to poor contrast. Additionally, X-ray and CT use ionizing radiation that carries a stochastic lifetime risk of inducing malignancy as a carcinogen and is therefore dangerous in principle (Joshua No, 2017). Although there tends to be a reduction in peak doses since 2002, CT scans nevertheless are typically administered in a single round; the doses are relatively high, with median effective doses up to 3 times natural background. Nonetheless, the public continues to generally regard the risk as being relatively low. In the context of increased usage of CT, driven by a mix of irrational fears of litigation, increased patient demand, awareness of its diagnostic power, and hyperactive promotion by the machine vendors, there is concern that the overall societally costs may exceed the benefits.

16. Future Directions in Radiation Safety

Patient and physician requests for the use of X-Rays, Computed Tomography (CT), and other radiation-producing medical imaging are increasing at a rate of 9% and 10% per year, respectively, in the United States (Joshua No, 2017). Among radiologists and radiology residents, public awareness of radiation knowledge was found to be limited, on average demonstrating less than fifty percent accuracy in ensuring safety regulations. Physician awareness of radiation knowledge was limited as well, with particular blind spots concerning the radiogenic long-term effects of medical radiation exposure. Reimbursement for imaging procedures is high relative to that for many other health care services, which significantly affects patient management and the practice of defensive medicine in the United States. This disparity encourages non-radiologists to add imaging to the services they provide to patients and to increase the use of imaging. Thus, the US has seen a dramatic increase in the number of CT examinations and other types of expensive imaging over the past two decades.

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Received: 16-08-2024 Revised: 05-09-2024 Accepted: 22-09-2024

Concerns related to radiation-only or coupled with contrast agents were expressed by community members who completed a survey on the dangers of radiation from imaging procedures. The concerns were supported by their information gleaned from print media and after a retailer withdrew a similar product from its shelves. This was exemplified by outcomes in a local store, where concerned residents together reported poor prescriber communication regarding the side effects of an iodinated imaging contrast agent. The community members who completed the survey on the dangers of imaging procedures and the roots of these concerns showed an increase as compared to the same group of respondents before the intervention. This select group also reported better understanding amongst themselves regarding radiation exposure and procedures following their receipt of informational materials. The implications of the measurements were discussed, and future directions in radiation safety were also highlighted that are potentially meaningful for other specialties within the local and global community.

16.1. Advancements in Radiation Detection Technology

The question of radiation exposure to patients as well as the public during diagnostic medical x-ray procedures is receiving increased attention. Concern about the effects of low levels of radiation on health has been present for many years, but such concerns are more informative and pervasive today as developments in high technology medicine and the overall increase in background ionizing radiation tend to escalate the dose levels of radiation experienced by the public. Of greater importance, however, are the risks of performing these radiological studies (Housenick-Lee, 2017). A recent report emphasizes that patients undergoing radiologic examinations may be subjected, albeit unwittingly, to large radiation doses that could iatrogenically cause skin injury in 2% of 10 million such patients annually, with a risk of cancer incidence of up to 0.5 per 10 million patients. Fortunately all these would be relatively small doses of the order of 1-10 gy. Staff in hospitals and clinics have been considered occupationally exposed to the danger of an increased invasion of work-related carcinogens secondary to their medical work with ionizing radiation sources. There are two essential questions: a) how high could these potential individual risks be and b) what alternative methods might be implemented to reduce these individual risks? New techniques at diagnostic radiology centers including helical CT technique are already in more widespread use, and the doses per examination continue to increase. Very recently this situation has undergone a change. In the context of good practice guidance that accompanies changes in status and use of premises where x-ray sources are utilized for medical exposure, health workers are now advised to position persons, such as patients, beyond the age of puberty at least 2 m from an x-ray source in order to restrict the risk of deterministic effects, such as radiation induced skin injuries. With skepticism, many institutes have installed this form of protection in radiography departments. An unexpected example showed that even where this form of protection was in place, the conditions might not be realized for particular types of

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ISSN:1000-3673
Received: 16-08-2024 Revised: 05-09-2024 Accepted: 22-09-2024

radiographic procedures, particularly barium studies. Demonstration of patient dose levels in excess of 1Gy for single exposures was one reason for immediate implementation of patient dosimetry.

17. Conclusion

The results obtained in this study will be completed and updated to generalize this experience to other cities in Morocco. Therefore, it is compulsory to develop a computer tool, which will be called a "medical dosimetric tool". The aim of this tool is fourfold: (1) to establish reference data on medical exposure indicators to be used as a basis for comparisons, also, to establish a mapping of practices; (2) to evaluate medical exposure indicators every year; (3) to evaluate if the practices comply with the quality criteria required by the regulation; (4) to monitor the evolution of medical exposure indicators, and practices in one department or all departments. To be reliable, it is envisioned to have it as a standalone system, using the data from DICOM image file, patient radiation records, operating room log files, and performing attenuation calculations to derive the doses. On the GIS map, the large single value of KAP provide the geographical location of the department. The value of DAP and of the mAs product must be entered before starting the calculations. This unique projection allows an overview of interventional radiology practices over the city. It is observed that closer departments have similar practice. The average value of KAP is 189 Gy.cm2 and that of Rdose is 538 mSv. The reason of such high values is that data has been collected for an unusual act: the sizing of 400 stents. But in the mean time, the computer tool has highlighted the absence of protective measures for organs at risk. It is a first step toward a more rational use of percutaneous radiology techniques (Semghouli et al., 2015).

17.1. Key Takeaways

In the past 120 years, earth's population and their average exposure to ionizing radiation has grown sixfold with populations in enriched longevity enjoying radiation-based medical imaging around the world. It is estimated that approximately 6,000,000 Americans alone have lived their lives in seemingly good health past 90 from early treatment or diagnosis by medical X-rays. These blessings and others less documented should not motivate complacency, but continuous scrutiny of underlying assumptions concerning their risks with understanding that all ingested, inhaled, and remotely irradiated humans and all of life for the past 4.5 billion years have evolved likely no other way from the unavoidably radioactive earth and outer space. This clarifies much wishful thinking about nominal risks or linear no threshold (LNT), described as one of radiophobic environmentalism's half-dozen most far-reaching mistakes in its 70 y. history (A. Oakley & E. Harrison, 2020).

Despite millions of health physicist years, no experiment, controlled by lab critters rule, has ever demonstrated the LNT fear. Adhering to it concerning the every-day root go-dose of

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ISSN:1000-3673
Received: 16-08-2024 Revised: 05-09-2024 Accepted: 22-09-2024

medical imaging of children and adults is inevitably scandalous. Past population data has clearly exposed a burglary-size fatal uncertainty in low-dose LNT; under no circumstances will "safe" low doses be directly observable in populations, mantling that absurdity. 85% of all radiation exposure is natural background and virtually 100% is low dose-a staggering volume from before the cradle to after the grave, inescapable if one is to eat, drink, and breathe, and yet over 99.99% of the weakest radiation each person absorbs is simply shrugged off.

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