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Research Article

Ionizing Radiation Safety Perception of Hospital Radiation Exposed Workers

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Abstract:

Occupational health and safety have become essential pillars in the modern workplace, reflecting the growing emphasis on valuing employees within their work environments. As Turkey has seen a rise in occupational accidents and diseases, new legal regulations have become necessary. The goal of these regulations extends beyond merely preventing accidents and illnesses; they also aim to foster mental well-being through a safe working environment. A particular area of concern is the radiation risk in the healthcare sector. This study explores the potential hazards and risks faced by healthcare workers who are exposed to radiation by reviewing existing literature. It assesses the devices used by radiology department staff and their associated exposure levels. Furthermore, the study proposes strategies to enhance risk awareness among these workers and to mitigate potential dangers.

1. Introduction

Technological advances and scientific studies have provided significant increases in the development and diversity of production. With these developments, the importance given to occupational health and safety has also increased, and a continuous improvement process has begun. The European Union has a comprehensive and detailed legislation on occupational health and safety. Studies on this legislation are increasing and its scope is being expanded. Occupational health and safety are of great importance for employees, employers and the state. It is seen that healthcare professionals face serious difficulties both physically and psychologically due to their working conditions. The concept of health defined by the World Health Organization (WHO) is becoming even more important for healthcare professionals. In this context, studies and measures taken will contribute to the improvement of safe and comfortable working conditions. This compilation study addresses the importance of occupational health and safety and the risk factors faced by healthcare professionals. Radiation, one of the physical risk factors, is particularly emphasized, and the devices used by employees in areas where radiation is most intense and the effects of these devices on employees are explained. Informing and raising awareness of healthcare professionals working in radiated environments about radiation safety is of great importance in terms of occupational health and safety. Even if healthcare managers have taken the necessary precautions for employee safety, these precautions will be ineffective unless employees know and apply these precautions; therefore, it is of great importance to conduct awareness studies to increase the perception of safety. In this context, it is aimed to increase the awareness of healthcare personnel working with radiation about radiation exposure.

2. The Concept of Occupational Health and Safety

Occupational health and safety is a system that aims to protect and improve the health of employees, beyond work-related injuries and illnesses. It aims to improve working conditions and the environment. This system includes maximizing and maintaining

the physical and mental health and social well-being of employees in every occupation. In this context, the basic principles of the process of assessing and managing occupational hazards are based on the expectation, recognition, evaluation and control of risks that arise in or from the workplace and are detrimental to the health and well-being of employees. The potential impact on surrounding communities and the general environment should also be taken into account. The basic learning process for reducing risks and hazards is derived from the roots of more complex principles that control occupational health and safety [1].

The need to control todays growing industrialization and its demand for providing energy sources and transportation systems and complex technologies that are inherently dangerous, such as the use of nuclear energy, has led to a better development of the world [2].

A balance must be achieved between the benefits and costs of risk in all areas of human activity. However, when it comes to occupational health and safety, many factors such as the pace of scientific and technological progress, the diverse and ever-changing world of work, and the economy affect this complex balance. The application of occupational health and safety principles, which involve the mobilization of all social and scientific disciplines, is a clear measure of this complexity. Occupational health and safety is considered a major global issue because it is one of the determining factors in industrial and agricultural development in developing countries [1].

3. Factors Affecting Occupational Health and Safety

Factors affecting occupational health and safety can be classified into various categories as physical, chemical, biological, ergonomic and psychosocial risks in the workplace. Physical factors include the use of dangerous machinery, excessive noise and inadequate lighting, while chemical factors include exposure to harmful substances. Biological factors include exposure to agents such as microorganisms and pathogens. Ergonomic factors can lead to musculoskeletal disorders caused by poor working positions and repetitive movements. Psychosocial factors, on the other hand, arise from factors such as stress, workload and work-life balance. Effective management and control of these factors is vital to protect the health of employees as well as to increase productivity and safety in the workplace [3].

3.1 Physical Risk Factors

Physical risk factors refer to hazards that threaten the health of employees in the workplace and may cause physical harm. These factors include the use of dangerous machinery and equipment, ergonomic deficiencies, noise, vibration, extreme heat or cold, exposure to harmful chemicals, inadequate lighting, and physical conditions that may lead to accidents such as slipping and falling. The negative effects of physical risk factors on employees include musculoskeletal disorders, hearing loss, skin and respiratory diseases, injuries, and serious work accidents. Preventing and managing these risks is critical to ensuring that employees have a safe and healthy work environment and to increasing work efficiency [3].

3.2 Biological Risk Factors

Biological risk factors are factors that endanger the health of employees in the workplace as a result of their exposure to biological agents such as microorganisms, bacteria, viruses, fungi, and parasites. These risks pose a significant threat, especially to workers in sectors such as healthcare, laboratories, agriculture, food processing and waste management. Biological risk factors can lead to health problems such as infectious diseases, allergic reactions and toxic effects. In order to manage these risks, it is important to identify biological agents, minimize exposure, use appropriate personal protective equipment, ensure hygiene and sanitation practices and train employees on this issue. Effective control of biological risks is critical to protect the health of employees and provide a safe environment in the workplace [4].

3.3 Chemical Risk Factors

Chemical risk factors are factors that endanger the health and safety of employees as a result of exposure to harmful chemical substances in the workplace. These risk factors can be in various forms such as respirable dusts, vapors, gases, liquids and solid chemicals. Exposure to chemical substances can cause acute and chronic health problems. In addition, serious illnesses such as respiratory diseases, skin irritations, allergic reactions, poisoning and cancer can occur. Management of chemical risks includes measures such as correct storage, use and disposal of hazardous substances, use of appropriate personal protective equipment and training of employees on this subject. Effective control of chemical risk factors is vital to protect the health of employees and ensure occupational safety [3].

3.4 Psychosocial Risk Factors

Psychosocial risk factors include social and psychological factors that can negatively affect the health and well-being of employees in the workplace. These factors include excessive

workload, unclear roles and responsibilities, inadequate job control, poor management and leadership, conflict and mobbing at work, inadequate social support, job insecurity and work-life balance problems. The negative effects of psychosocial risks on employees, such as stress, anxiety and depression, can lead to results such as job dissatisfaction, loss of motivation and increased work accidents. Effective management of these risks is vital to protect the health of employees as well as to increase productivity and satisfaction at work [5].

3.5 Ergonomic Risks

Ergonomic risks are the type of risk that occurs when the type of work, body positions and working conditions put a strain on the body of the worker. It is the application of scientific knowledge to the design of the environment, tools, work environments and job content to suit the mental and physical limitations and abilities of the worker [6].

4. Radiation Source Devices and Their Effects in Hospital Environment

4.1. X-ray

An X-ray device is a medical imaging device that allows the internal structures of the body to bevisualized using X-rays. Discovered by Wilhelm Conrad Röntgen in 1895, X-rays are widely used in medical diagnosis and treatment processes today. An X-ray device consists of a tube that produces high-energy X-rays and a detector that records the passage of these rays through body tissues. As X- rays pass through body tissues, they are absorbed at different rates by different tissues. Dense structures such as bones absorb more X-rays, while soft tissues and air-filled spaces absorb less. These different absorption rates are recorded by the detector as a grayscale image. X-rays can be obtained in X-ray devices at different times, with varying quality and quantity. The amount of X-rays to be used is adjusted according to the organ or body part to be examined. In general, X-ray devices are divided into two main groups: radiography and radioscopy. While radiography devices provide static imaging, radioscopy devices provide dynamic imaging. Digital X-ray devices were developed by integrating radiography with computer technology. In digital X-ray, X-rays passing through the patient fall on a special detector. This detector converts the image data into numerical data, and then an image is created on the screen from these numerical data [7].

4.2 Computerized Tomography

Computed tomography (CT) is a diagnostic method developed by Cormack in 1963 and based on X-ray technology. This method creates cross-sectional images of a specific area of the body using X-rays. The device takes many two-dimensional X-ray images of an object from different angles and creates a three-dimensional image of the internal structure of the object from these data. Thanks to computer software, these cross-sectional images are obtained in detail and a clear image is obtained by collecting the necessary information with the help of X-rays [8].

4.3 Magnetic Resonance (MR)

Magnetic resonance imaging (MR) is a cross-sectional imaging method, like computerized tomography (CT). However, MRI uses advanced computer programs to create images from digitally obtained signals. This method uses radiofrequency (RF) energy, also known as radio waves. Radiofrequency energy is a type of electromagnetic radiation and works with information from hydrogen nuclei found abundantly in cell fluids and fats. The behavior of these nuclei within the magnetic field allows detailed and high-resolution images to be obtained [9].

4.4 Ultrasonography (US)

Ultrasonography is a method that uses high-frequency sound waves to image the internal structures of the body. In this method, crystals in the ultrasonography probe convert high-frequency alternating current into sound waves. Sound waves are reflected back from the tissue and these reflections are processed by the computer and converted into real-time images. The frequency of the sound waves used in ultrasonography is well above the frequencies that the human ear can hear (over 20,000 Hz). This method can be safely applied to sensitive groups such as infants and pregnant women because it does not use ionizing radiation. One of the most important advantages of ultrasonography is that it can detect fluid accumulations with high accuracy. In addition, the fact that it does not contain radiation, is portable and easy to apply allows ultrasonography to be used in a wide range of areas, including emergencies and intensive care, as a practical tool [7]. Ultrasound is generally used to image organs such as the liver, spleen, bile ducts and bladder, pancreas, kidneys, breast, bladder, testicles, uterus, ovaries, prostate gland, thyroid and salivary glands. In addition, thanks to the Doppler feature, it is possible to evaluate the flow direction and speed of the vessels in real time [8].

4.5 Angiography Device

One of the basic tools of interventional radiology is angiography units. Angiography is mostly used for interventional procedures today and stands out in

treatment and intervention processes rather than a method used for diagnosis. Modern angiography units are fully equipped with digital systems, have the capacity to perform subtraction, and are advanced technology devices that can take images in one or two planes [9].

4.6 Mammography

Mammography is a technique used in imaging breast tissue and is of great importance especially in the early diagnosis of breast cancer. In this method, fat, glandular and muscle tissues with similar atomic numbers and densities are examined. Unlike traditional X-ray methods, mammography operates in the lower voltage range used in imaging soft tissues (25 to 50 kV). This makes mammography an effective method in the early diagnosis of breast cancer [7].

4.7 Bone Density Measurement Device (Dual X-Ray Absorptiometry (DXA))

The bone density measurement device was introduced in 1987 and is a widely used technique in the diagnosis and evaluation of osteoporosis. DXA measures bone mineral density to predict fracture risk. It is the most effective method for diagnosing osteoporosis and monitoring changes in bone density, especially by evaluating bone density in the spine, hip and forearm regions. This device plays a critical role in the management and treatment of osteoporosis [10].

5. Diseases and Effects That May Be Seen in Radiology Workers

The use of ionizing radiation in medicine was initiated by Wilhelm Conrad Roentgen in 1898. X-rays, which are of great importance especially for physicians, nurses, X-ray technicians and other healthcare professionals, can pose serious health risks for procedures performed with natural radioactive substances and radioactive isotopes such as radium, uranium and thorium [11].

These radioactive substances can damage cells, cause mutations and chromosomal disorders, have negative effects on the skin, thyroid and bone marrow, and increase the risk of cataracts and cancer [12]. Radiology workers constitute the highest risk group for thyroid diseases [13].

The incidence of cancer as a result of X-ray applications varies in various countries; it was determined as 2.9% in Japan, 1.3% in Germany, 0.09% in the USA and 0.6% in the UK. However, there is no comprehensive data on this subject in Turkey. X-ray technicians are the group with the highest prevalence of thyroid diseases among healthcare professionals [14]. Continuous radiation exposure, even at low doses, can accumulate in the body and pose great risks, especially during pregnancy. Studies conducted on Australian orthopedists have emphasized the importance of radiation safety in operating rooms [11]. Both patients and staff are exposed to different levels of radiation during radiological examinations. The quality of ionizing radiation, the thickness of the protective lead, the distance between the radiation source and the patient, and the position of the operator are the main factors affecting the radiation dose received by the whole body. The International Commission on Radiological Protection (ICRP) has determined the annual maximum radiation dose for the whole body as 5000 mrem. The Turkish Atomic Energy Agency has similarly reported that the annual dose should be 5000 mrem and the average of five consecutive years should be 2000 mrem. Among the radiation protection measures, staying away from the radiation source, using dosimeters and using personal protective equipment (glasses, aprons, etc.) are at the forefront [15].

A study conducted by Dökmeci and Aksan in 2019 examined the effects of electromagnetic fields on healthcare personnel and found a significant relationship between symptoms such as irritability, headache, fatigue and electromagnetic field exposure [16]. In Türkkan and Kayıhans's study, the effects of very low frequency electromagnetic radiation on health were examined, especially in terms of cancer, reproductive health, nervous tissue disorders and heart diseases [17].

The study conducted by Saygın and his colleagues in 2011 revealed that depression and anxiety symptoms increased with increasing age and tenure of radiology workers [14]. In addition, in Yaman's 2011 thesis study, measurements of electromagnetic fields in the hospital environment were made and the effects of some medical devices were determined [18]. In 2013, Gürsu and his team evaluated the effectiveness of gonadal protectors in pediatric patients and determined that the effect of ionizing radiation was greater in this age group and emphasized the importance of gonadal protectors [19]. In a study conducted by Zeyrek (2013), general concepts regarding the safety and protection of ionizing radiation were discussed and information was provided about the practices in Turkey. In this study, referring to past studies, it was stated that 0.9% of healthcare workers exceeded the 5 mSv effective dose, but there was no worker who exceeded the annual dose limit of 50 mSv [20]. Manavgat and Mandıracı (2012) investigated the perception of occupational ionizing radiation hazard and the factors affecting it among healthcare workers using personal dosimeters in a medical faculty hospital. According to the results of the study,

healthcare workers generally had a high risk perception, but physicians had a lower risk perception. The study recommends that radiation protection training be provided regularly, health checks be performed periodically, and radiation awareness of employees be increased [21].

Uzuntarla and Doğan (2019) examined the ionizing radiation risk perceptions and knowledge levels of healthcare workers using dosimeters in a training and research hospital. In the study, it was determined that 67.8% of the employees had a very high, 20.4% had a high, and 11.8% had a moderate risk perception. There were no personnel with a low risk perception, and it was observed that risk perception increased compared to previous years. It was stated that this increase was related to the increase in work intensity and the number of procedures, as well as improvements in the education and awareness levels of employees [22]. The use of radiation protection equipment is critical for healthcare workers. The study by Miller et al. showed that the thyroid and hands were the areas most affected by radiation. In the study on the radiation protection effect of lead shirts, it was found that the radiation dose outside the lead shirt was 17-245 mrem and under the shirt was 0-5 mrem. Effective use of personal protective equipment and implementation of safety standards play an important role in radiation protection [23].

Balsak (2014) evaluated the knowledge, attitudes and practices of radiology personnel in hospitals in Diyarbakır regarding ionizing radiation. As a result of the research, it was determined that hair loss and eye diseases were among the most common complaints, and one-third of the participants had eye problems [24]. Guden et al. (2012) examined the knowledge, attitudes and behaviors regarding radiation safety in public hospitals in Kayseri. Employees stated that radiation safety programs were in place and lead vests were used. It was stated that most employees used dosimeters [25].

Yuce (2016) investigated the genetic effects of low dose ionizing radiation on healthcare personnel working in radiology, radiation oncology and nuclear medicine departments in various hospitals in Aydin province. The study showed that micronucleus and other nuclear anomalies were seen at the highest rate in the Radiology Department of Aydın State Hospital, followed by other departments [26]. Vural et al. (2012) evaluated the knowledge, attitudes and behaviors of healthcare personnel working in the operating rooms of Gölcük State Hospital regarding radiation safety. The results emphasized the importance of in-service training, auditing of practices and the certification and awareness of personnel using scopes [27].

Many studies have been conducted on the effects of radiation on human health, and these studies are ongoing. The effects of radiation on health vary depending on the dosage; while effects can be seen even at low doses, high doses can cause serious illnesses and even death. When the damage caused by radiation to DNA occurs in reproductive cells, these changes can be passed on to future generations. Exposure to high levels of radioactivity causes serious damage to tissues, which can manifest itself with symptoms such as nausea, vomiting, diarrhea, hair loss, deep tissue burns, fatigue, mouth and throat sores, inflammations, and loss of energy. These effects usually occur within hours, days, or weeks. Such effects become apparent when a certain threshold value is exceeded, and these effects are called deterministic effects; in most cases, death can occur within a few days or weeks. Late effects, on the other hand, can occur years later; for example, secondary cancers that develop after treatments such as radiotherapy and chemotherapy are examples of this situation. The risk of harm to healthcare personnel working with ionizing radiation is related not only to the radiation dose, but also to the duration of exposure. Therefore, reducing the duration of radiation exposure is of great importance for the protection of the health of healthcare workers. Radiation dose limits should be determined in accordance with international standards “in a way that does not harm health” in accordance with Article 10 of the Radiation Safety Regulation. In addition, the duration of exposure is an important factor in addition to the radiation dose. In order to protect the health of employees, arrangements regarding working hours should be made as soon as possible [28].

6. Radiation Safety Awareness in Healthcare Workers Using Dosimeters

Many important studies have been conducted in the world showing the importance given to the radiation factor. These studies aim to evaluate the awareness levels of those working with radiation. For example, Tüzüner and Özarslan (2011) examined the perceptions of safety climate in hospitals and determined that doctors and attendants have a higher perception of safety than nurses [29]. Söylemez et al. (2013) conducted a study evaluating the knowledge and attitudes of urology residents in Europe regarding ionizing radiation; the results showed that urology residents have insufficient knowledge about radiation safety and most of them are not aware that radiation can carry a fatal cancer risk [30].

Koçyiğit et al. (2014) evaluated the knowledge levels of hospital personnel about radiation during radiologic imaging and found that many healthcare workers lack information about the actual radiation doses of some imaging methods [31]. Devebakan

and Paşalı (2015) evaluated the safety conditions of healthcare professionals working in four hospitals in İzmir and determined that the safety perception of radiology workers was lower than that of other healthcare professionals [32]. Tüfek et al. (2015) investigated the attitudes of anesthesiologists across Turkey towards radiation exposure and found that most anesthesiologists did not regularly use the necessary protective equipment [33].

Kahraman et al. (2016) found that the safety awareness levels of healthcare personnel working in state and private hospitals in Ankara were low [34]. In a study conducted by Abuelhia (2016), it was observed that the perception of radiation risk was low and the participation rate in radiation training was low among medical students and young doctors at Dammam University [35].

These studies emphasize the importance of presenting scientific data in an accessible and understandable manner to ensure the protection of healthcare professionals and patients. In Turkey, the licensing of radiology departments is carried out by the Turkish Atomic Energy Authority (TAEK) and is carried out in accordance with international standards. According to Article 2/4 of the European Social Charter, it is stated that the risks of those working in hazardous jobs should be reduced or additional leave should be given to those working in these jobs [36].

In line with the integration efforts with the European Union, a new article was added to the Law No.3153 on "Radiology, Radiography and Electrical Treatment and Other Physiotherapy Institutions" in accordance with Article 9 of the Law No. 5947 on "Full-Time Work of University and Health Personnel and Amendments to Certain Matters". This article states that the weekly working hours of personnel involved in diagnosis, treatment or research with ionizing radiation and those involved in these procedures are 35 hours. It is emphasized that the radiation dose limits determined by the Ministry of Health must be observed during this period, and the necessary measures and permits to prevent dose limits from being exceeded will be regulated in the regulation to be issued by the Ministry of Health. With this regulation, the weekly working hours of those working with radiation were increased from 25 hours to 35 hours. However, while daily workload is restricted to certain limits in some European countries, it is observed that this regulation does not have the same effect in Turkey. In European and OECD countries, radiology technicians perform an average of 20-25 patients and 50-60 exposures per day, while in Turkey these increase to 75-80 patients and 250 exposures. It is important that regulations to protect the health of healthcare personnel are in compliance with the European Convention on Human Rights and the articles of the constitution [35].

7. Conclusions

Occupational health and safety is a critical issue for all employees, and employee safety should come first. In this study, general information about the occupational health and safety perception of healthcare personnel working in the radiology department is presented. In particular, how radiology department employees are affected by radiation related risks is examined. In various countries, the diseases and awareness of healthcare workers exposed to radiation have been statistically investigated. Studies have shown that awareness of radiation exposure among physicians, medical school students, nurses and technicians working with radiation is high in some countries and low in others. It has been observed that healthcare professionals have a high rate of participation in radiation safety training across Europe (53% across Europe, 82.6% in Poland). In Turkey, a similar study on the use of personal protective equipment found that very few healthcare professionals regularly use lead aprons (30.11%) and thyroid shields (11.3%) [30]. X-ray technicians working in radiology departments see and perform imaging 3-4 times more patients in Turkey compared to European countries. With the regulations made within the framework of European Union harmonization, the daily working hours of radiology department employees in Turkey have been increased to 7 hours. However, when the amount of work done per unit time is taken into account, technicians who see an average of 25 patients in European and OECD countries encounter approximately 80 patients in Turkey. In light of this information, awareness of radiation exposure and occupational health and safety needs to be further increased in Turkey [37]. Even many different works were done in this fields [38-54].

The purpose of this review is to draw attention to the risks faced by those working with radiation by making them aware of them. The study is a preliminary study for a more comprehensive investigation of the perception of occupational health and safety in our country. This review, which emphasizes that the awareness of radiology department employees in particular should be increased on this issue, can form the basis of further studies.

Author Statements:

- **Ethical approval:** The conducted research is not related to either human or animal use.

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