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THE EFFECT OF LONG-TERM X-RAY EXPOSURE ON BLOOD CELL TYPES IN THE HUMAN BODY

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THE EFFECT OF LONG-TERM X-RAY EXPOSURE ON BLOOD CELL TYPES IN THE HUMAN BODY

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June 2023

We certify that we have read this thesis and that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science

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Ali Mohammed Abed ALFENDI

ABSTRACT

THE EFFECT OF LONG-TERM X-RAY EXPOSURE ON BLOOD CELL TYPES IN THE HUMAN BODY

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June 2023

In this study, the results of the effect of X-rays on blood components for people working in hospitals and health centers were discussed, the data relating to the subject of this study were collected, and the data and information were taken about people working on the devices and also, the extent to which they were affected by long exposure to X-rays, and the effect of X-rays on five blood components was studied. Five different parameters were examined such as Platelets, Erythrocyte Sedimentation Rate (ESR), Hemoglobin (HB), Packed Cell Volume (PCV) and White Blood Cells (WBC). It turns out that X-rays significantly influence changing the proportion of blood components. It was found that by increasing the X-rays exposure percentage, the number of blood platelets will decrease because of the high sensitivity of blood tissues towards radiation. In addition, the Erythrocyte Sedimentation Rate (ESR) increased with the increase in the exposure time to X-rays, due to the difference in the size of the absorbed dose. It can be said that hemoglobin (HB) and Packed Cell Volume (PCV) decrease as the exposure time to X-rays increases, and there is also an increase in white blood cells (WBC).

2023, 70 pages

Keywords: Blood cells, Hemoglobin, Sedimentation rate, X-ray

ÖZET

UZUN SÜRELİ X-IŞINLARINA MARUZ KALMANIN İNSAN VÜCUDUNDAKİ KAN HÜCRE TİPLERİ ÜZERİNDEKİ ETKİSİ

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Haziran 2023

Bu çalışmada, hastanelerde ve sağlık ocaklarında çalışan kişilerde X-ışınlarının kan bileşenleri üzerine etkisinin sonuçları ele alınmış, bu çalışmanın konusu ile ilgili veriler toplanmış ve bu cihazlarda çalışan kişiler hakkında veri ve bilgiler alınmıştır ve ayrıca X-ışınlarına uzun süre maruz kalmaktan ne ölçüde etkilendikleri ve X-ışınlarının beş kan bileşeni üzerindeki etkisi çalışılmıştır. Trombositler, Eritrosit Sedimantasyon Hızı (ESR), Hemoglobin (HB), Paketlenmiş Hücre Hacmi (PCV) ve Beyaz Kan Hücreleri (WBC) gibi beş farklı parametre incelenmiştir. X-ışınlarının kan bileşenlerinin oranını değiştirmede önemli bir etkiye sahip olduğu ortaya çıkmıştır. X-ışınlarına maruz kalma yüzdesinin artmasıyla, kan dokularının radyasyona karşı yüksek duyarlılığının bir sonucu olarak kan trombositlerinin sayısının azalacağı bulunmuştur. Ayrıca, X-ışınlarına maruz kalma süresinin artmasıyla, absorbe edilen dozun boyutundaki farklılıktan dolayı Eritrosit Sedimantasyon Hızı (ESR) artış göstermiştir. X-ışınlarına maruz kalma süresinin artmasıyla beraber hemoglobinin (HB) ve Paketlenmiş Hücre Hacmi'nin (PCV) azaldığı ve ayrıca beyaz kan hücrelerinde (WBC) bir artış olduğu söylenebilir.

2023, 70 sayfa

Anahtar Kelimeler: Kan hücreleri, Hemoglobin, Sedimantasyon oranı, X-ışınları

PREFACE AND ACKNOWLEDGEMENTS

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Ali Mohammed Abed ALFENDI
Çankırı-2023

CONTENTS

LIST OF SYMBOLS

°C	Degree celsius
h	Hour
µg	Microgram
µL	Microliter
mL	Milliliter
min	Minute
%	Percentage
±	Plus, minus
R	Resistance
S	Sensitive
UV	Ultra-violate

LIST OF ABBREVIATIONS

ARS	Acute radiation syndrome
CBC	Complete blood cell counts
CAT	Computerized tomography
ESR	Erythrocytes sedimentation rate
HEH	Hawler education hospital
HB	Hemoglobin
IR	Infrared
KeV	Kilo electron volt
MRS	Medical radiographers
MW	Microwave
PCV	Packed cell volumes
PPARA	Peroxisome proliferator-activated receptor-alpha
RF	Radiofrequency
RBCS	Red blood cell cells
3D	Three-dimensional
WBCS	White blood cells
WBCA	White blood cells acidic
WBCl	White blood cells lymphocyte
WBCT	White blood cells total
WBCU	White blood cells unicellular

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1. INTRODUCTION

It is known as ionizing radiation when the radiation energy is high sufficient for the separation of the electrons from their atoms or molecules. Radiation is the energy that the waves or substances small particles release. It can have different forms, including sunlight, light rays, X-rays, and gamma rays (Spinks and Woods 1990). Alpha particles, electrons, and protons are charged particles in ionizing radiation. The term "ionizing radiation" can stand for high-energy electromagnetic waves like X-rays and gamma rays. The energy of ionizing radiation is sufficient for breaking chemical bonds in molecules or for the removal of electrons from closely bound atoms charging molecules or atoms (ions). X-rays are one of the most useful forms of energy among these ionizing radiations. X-ray radiography (Ryan 2012), computed tomography (CT) (Ward 1988), fluoroscopy (Olive 1998), mammography (Li *et al.* 2020), and angiography (Kasten *et al.* 2020), are all examples of medical procedures that employ X-rays to create pictures of bones and internal body organs. It's also utilized in cancer treatment since it kills cancer cells faster than normal cells (Arena 1971).

The safe application of ionizing and non-ionizing radiation to people is referred to as health physics, radiological health and engineering in public health, and environmental health engineering to ensure that worker radiation exposure is minimized and kept within acceptable limits at all times, the health physicist is responsible for the safety of the procedure design, tools, and facilities that employ radiation sources and the radioactive waste secure disposal. They must continuously monitor workers and the environment for ensuring the success of these designs. When there are ineffective control measures, the health physicist should evaluate the level of risk and make recommendations for corrective actions (Holmes *et al.* 2022). All of the body's cells and tissues have varying levels of radiosensitivity; some are radiosensitive, while others are radioresistant (Luo *et al.* 2022).

One of the organ systems most vulnerable to radiation is hematopoiesis. Red blood cells (RBC), a vital blood component, are in charge of carrying gases and nutrition throughout the body. These specialized cells' unique composition and structure enable them to carry out their essential functions. An important role of the erythrocyte is played in the analysis of numerous disease processes in numerous body systems. Their structure, function, physiology, preparation, microscopy, and clinical importance are all examined in this review article. The nucleated, biconcave discoid adult erythrocyte has a defined shape. A peripheral blood smear is a common test for red blood cells. The findings of a complete blood count (CBC), a review of white blood cells, and a study of the erythrocyte shape, size, color, configurations, and inclusion bodies suitable for use as a bioindicator to forecast ionizing radiation damage are routinely requested (Zhang *et al.* 2019).

More X-ray technicians will be required as ionizing radiation used in medicine increases, according to projections. During the research, we observed diagnostic technicians working with modest doses of X-rays without using radiation protective equipment. Any change in a person's blood cell count could lead one to suspect illness. Several studies tested the influence of partial or whole-body radiation on peripheral blood cell count to examine the relevance of blood cell count, with the majority of the studies concentrating on high-dose radiation received accidentally or for therapeutic purposes. Clinical radiology technicians are at risk because they lack knowledge about the radiation, particularly the potential change in fundamental hematological parameters like red blood cells (RBCs), white blood cells (WBCs), and platelet count utilized for determining the harmful effects of X-ray radiation, despite the fact that many studies are conducted on the dangers of high-dose radiation (Yang *et al.* 2019).

2. LITERATURE REVIEW

2.1 Problems and Motivation Statement

X-rays are electromagnetic waves that may pass through a variety of things, including the human body. X-rays are utilized in many aspects of our life in medicine, including radiation, which is crucial in the fight against cancer, and medical imaging, which shows images of different parts of the human body using different processes. Long-term exposure to X-rays is considered ionizing radiation, which is extremely harmful. As a result, users and operators must be aware of the issues, hazards, and harmful effects of X-rays on various types of cells in the human body, as well as be cautious and limit risks (Rose 2004).

2.2 Research Objectives

The goals a part of this initiative are to look into the negative effects of X-rays in large doses or long-term exposure on various types of cells in the human body and their functions, as well as to look into how certain blood characteristics, such as RBC shape, are affected by X-rays, ESR, biological measurement, and mechanical features of blood cells. Furthermore, to investigate the possible hazards of exposure to dangerous levels of X-ray emissions for both users and operators, as well as to compare the effects of X-rays based on radiation dosage, long-term, patient sex, and patient age (Rose 2004).

2.3 Radiation

Background radiation surrounds us constantly. The majority of it is caused by minerals. Radioactive materials are present in human bodies, the environment, soil, and water (Rose 2004). Potential background radiation sources include solar and astronomical radiation. Man-made sources include X-rays, radiation therapy for cancer treatment, and electrical power lines (Figure 2.1). It is known as ionizing radiation when the radiation energy is high enough to separate electrons from their atoms or molecules in the medium they are passing through. Radiation is energy released as waves or small substance particles with many possible forms such as sunlight, light rays, X-rays, and gamma rays (Hirota *et al.* 2011). And belong to ionizing radiation electrons, protons, and alpha particles, which are all particles with an electric charge, also belong to ionizing radiation electromagnetic waves that carry high energy, such as X-rays and gamma rays. To the medium through which it travels, radiation is non-ionizing. It contains electromagnetic waves with low energy (below 1 eV), such as radio waves and microwaves, as well as light waves. These particular rays lack the energy necessary to ionize the atoms of the medium they travel through. Energy is what radiates. It moves as either energetic waves or swift particles. Both man-made and natural radiation is possible. Non-ionizing radiation is classified into radio waves, microwaves, cell phones, infrared radiation, and visible light. Ionizing radiation can be radon, X-rays, gamma rays, and ultraviolet light (Bouchami *et al.* 2011).

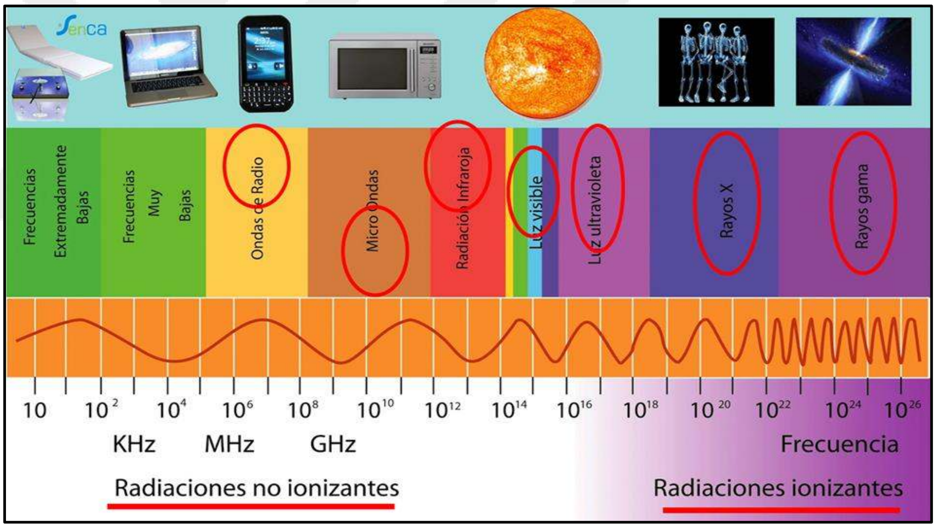

Figure 2.1 The electromagnetic radiation spectrum (Rose 2004)

2.3.1 Non-ionizing radiation

Non-ionizing radiation is electromagnetic radiation with no enough energy per quantum to ionize atoms or molecules for the total removal of an electron from an atom or molecule. It is a set of energy waves made of oscillating electric and magnetic fields moving at light speed. Non-ionizing radiation includes, but is not limited to, ultraviolet (UV), infrared (IR), radio frequency (RF), visible light, microwave (MW), and very low frequency (ELF). The UV widely uses visible, and infrared spectrums, and lasers. It encompasses both low-frequency and moderately high-frequency radiation and has just enough energy to make the atoms in a molecule vibrate or move about, but not enough to remove electrons (Belpomme *et al.* 2018).

2.3.2 Ionization of radiation

In contrast, ionization of radiation has enough energy to displace tightly bound electrons from atoms or to rupture chemical bonds in molecules, resulting in charged molecules or atoms (ions) (Ryan 2012). Ionizing radiation may harm tissue and DNA in genes, posing a health concern. This radiation, the exposure route, the radiation's energy, and the radiation absorbed total amount affect how much harm is done. Because the harm is done at the cellular level, a small or even large amount of exposure might not have any consequences. Most cellular damage might be repaired. However, some cells might not recover as quickly as others, which could lead to them being harmed or developing cancer. In order to kill cells, radiation removes electrons from atoms and molecules found in materials including air, water, and biological tissue. These materials make ionizing radiation pass without undetected as in the next diagram. Ionizing radiation, commonly referred to as gamma radiation or X-ray radiation, is a type of energy that is produced by atoms and travels as electromagnetic waves (gamma or X-rays) or particles (Morgan and Sowa 2005).

We are exposed to radiation in our evolution course. Because of this, the design of our bodies withstands the small amounts we are exposed to each day. Yet the damage to the tissues can happen by excessive radiation exposure which changes cell structure and is based on DNA. Major health problems, like cancer, could arise as a result of this. This radiation and the dosage (amount) of radiation are two factors that affect how much harm radiation exposure may result in. Here radiation accumulation happens in the body for sometime, whether by skin contact, ingestion through food or air, or through the body itself. Your body's vulnerability to radiation. Radiation's effects are most hazardous to a fetus. Negative health effects are more likely to affect vulnerable populations such as infants, children, pregnant women, the elderly and people who suffer from immune system problems than healthy individuals (Gomes *et al.* 2015). Exposure to quick and large radiation such as during a radiation emergency burns the skin. Additionally, acute radiation syndrome may result (ARS, or radiation sickness). Two ARS symptoms can cause headache and diarrhea. Usually, they start within a few hours. The person seems to be well sometimes upon the disappearance of the symptoms. However, they become ill once more. How quickly patients become unwell again, the symptoms are, and how sickness depends on the amount of received radiation. In some examples, ARS can cause death within a couple of days or weeks. There are low radiation quantities in the environment with no acute health consequences. Yet, it could modestly increase your total cancer risks. Healthcare providers should determine the amount of radiation in the body absorbed before therapy. Your symptoms will be discussed, blood tests will be performed, and a radiation detector may be used. They also make an effort to learn more about the radiation exposure, including the type of radiation utilized, source distance, and the duration of your exposure. Ionizing radiation includes gamma and X-rays, alpha, beta, and neutron particles. Stable atoms that are too energetic or massive cause a variety of problems (or both). To achieve a stable condition, they must emit radiation to discharge the extra energy or mass (Flakus 1982).

2.3.2.1 Alpha radiation

The alpha particle, simply the helium-4 atom nucleus, is released when an atom undergoes radioactive decay changing the original atom into one with an atomic number of 2 less and an atomic weight of 4 less when starting. Due to their mass and charge, alpha particles interact with matter very strongly, barely moving a few centimeters in the air. Although alpha particles can not get past the outer cover of the dead skin cells, they may damage cells seriously with the consumption of the alpha-emitting substance in food or air (Bahrassa and Datta 1983). Alexander Litvinenko is a well-known illustration of whom the alpha emitter polonium-210 poisoned by drink (Chambers *et al.* 2006) (Figure 2.2).

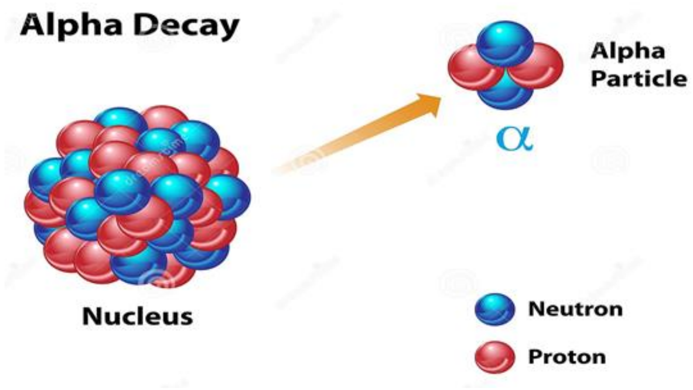

Figure 2.2 Schematic diagram of alpha radiation (Rose 2004)

2.3.2.2 Beta radiation

In an electron or a positron shape, an atom emits beta radiation (a similar size particle and mass as a positive charge electron). The lower mass may float longer in the air, up to a few meters which a thick plastic or even a paper stack stops. It could provide an external health risk by penetrating the skin a few millimeters deep. But the major risk is still internal emission from ingested particles (Chambers *et al.* 2006) (Figure 2.3).

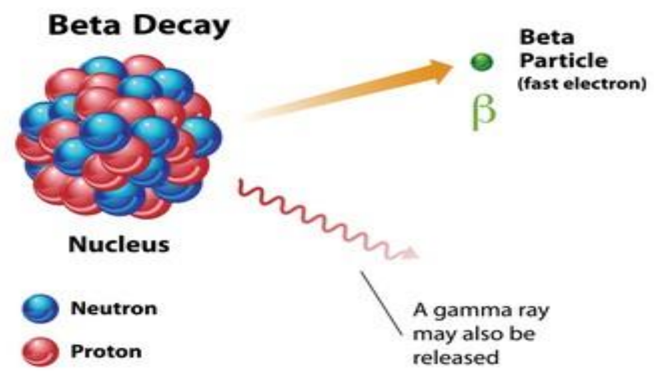

Figure 2.3 Schematic diagram of beta radiation (Rose 2004)

2.3.2.3 Radiation of gamma

Gamma, alpha, and beta radiation are different in that it consists of an energy photon produced from a non-stable nucleus than particles. Gamma radiation does not consist of mass or charge traveling through air farther than alpha or beta which loses half of its energy every 500 feet. A thick or dense enough layer of materials can block Gamma blocked, with high atomic number materials such as lead or depleted uranium as the greatest active shielding (Pound and Snider 1965) (Figure 2.4).

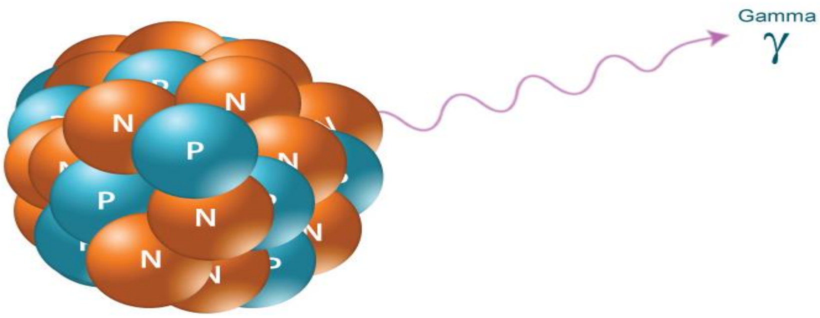

Figure 2.4 Schematic diagram of gamma radiation (Rose 2004)

2.3.2.4 Neutron radiation

Last but not least, a free neutron that is emitted because of nuclear fission, whether spontaneously or induced, makes up neutron radiation. They are able to fly hundreds or even thousands of meters in the air, yet they stop by a hydrogen-rich object like concrete or water effectively. Due to their lack of charge, neutrons cannot directly ionize an atom. Or, they usually indirectly ionize an atom by absorbing them into a stable atom making it more likely unstable and emitting another ionizing radiation. The only radiation turning other materials radioactive comes from neutrons (Snyder and Neufeld 1955) (Figure 2.5).

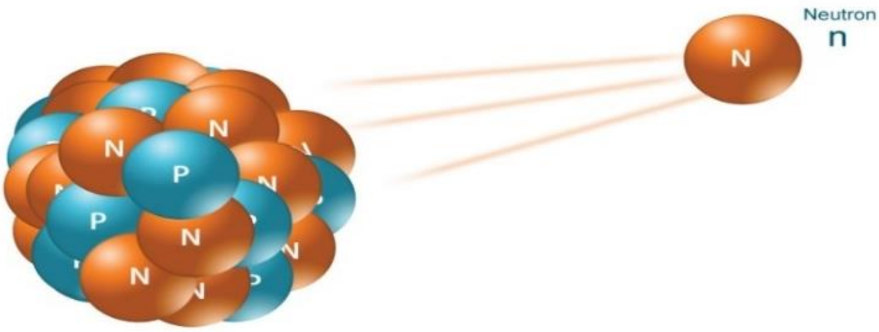

Figure 2.5 Schematic diagram of neutron radiation (Rose 2004)

2.3.2.5 X-rays

X-rays differ from gamma radiation in originating from a plasma. Usually, an electron's energy changes, including the movement from a higher to a lower energy level which releases the extra energy. Hamma radiation and (generally) less energy have a shorter wavelength than X-rays (Suryanarayana *et al.* 1998).

2.4 Biological Effects of X-Ray

Electromagnetic waves (Baird 2019), are a type of radiation that X-rays fall under. Imaging called X-ray imaging produces internal body pictures. Your bodily parts are shown in the images in different black-and-white shades because different tissues absorb radiation in various ways. Bones are white as their calcium absorbs most of the X-rays. Gray and less absorbent are fat and other soft tissues. The lungs appear black because of air absorbance of the least color. A type of piercing, high-energy electromagnetic radiation is known as an X-ray or X-radiation. The majority of the X-rays possess wavelengths between 10 picometers and 10 nanometers converted to energies between 145 eV and 124 keV and frequencies between 30 petahertz and 30 exahertz (301015 Hz to 301018 Hz). Gamma-ray wavelengths are shorter frequently, and UV wavelengths are longer than X-ray wavelengths (Wolbarst 1999).

The biological low-level radiation influences of diagnostic medical X-rays are evaluated and debated using individual risk factors and the recent population study outcomes. The recent years witnesses the clarity that every diagnostic X-ray exposure carries a certain amount of risk, inversely related to dosage, and that the procedure should only be utilized when the risk-to-benefit ratio is acceptable. X-rays are electromagnetic waves produced outside of a nucleus. Compared to -ray, it has less energy. The majority of X-rays are produced artificially, and their main application is in medicine (Lewiecki and Laster 2006). By removing one electron from their orbits, ionizing radiation can ionize atoms, producing positive-charged ions and negatively-charged free electrons. Ionizing radiation includes radiation from the natural and artificial creation of radioactive materials (Thorne 2003).

Both low and high ionizing radiation doses may harm live cells, on the basis of dosage, dose rate, sex, age, and target kind. The ionizing radiation's direct interaction with crucial targets includes DNA and the process known as direct contact. Ionizing radiation interacts with water in a cell through a mechanism known as indirect contact, which results in producing ions and free radicals (Alizadeh *et al.* 2015). The safe application of ionizing and non-ionizing radiation to reduce biological effects on people is the focus of health physics, radiological health, and radiological engineering in public health and environmental health engineering. For ensuring radiation exposure to personnel is minimized and kept within acceptable limits at all times, the health physicist is responsible for the safety of the procedure design, tools, and facilities that employ radiation sources, as well as the secure disposal of radioactive waste. They must continuously monitor people and the environment to ensure that these designs are successful. In the event that control measures are found to be ineffective or ineffective, the health physicist must establish the level of danger and offer recommendations for corrective action (Fine 1971).

2.4.1 History

Wilhelm Conrad Röntgen (Figure 2.6), a German scientist, discovered X-rays, which could be used to examine the human body, in 1895 (Grainger 1998). This finding ushered in a new age of radiation's medicinal applications, which have only grown since then. In 1901, the first Nobel Prize in Physics was awarded to Röntgen (Reed 2011). Marie Curie, Pierre Curie, and Henri Becquerel shared the 1903 Nobel Prize in Physics (Figure 2.6). Her contributions to radiation chemistry made her the first woman winner of the Nobel Prize a second time in 1911. X-rays were first employed in medical diagnostics six months after its invention in 1895 (Allisy 1996).

Röntgen (1845-1923) Marie Curie (1867-1934) Henri Becquerel (1852-1908)

Figure 2.6 Photographs of Röntgen, Marie Curie, and Henri Becquerel (Rose 2004)

Röntgen was a professor at the University of Wuerzburg in Germany. During his work in his laboratory, Röntgen noticed a crystal bright light on a table near his cathode-ray tube. Röentgen's tube was made from a glass bulb containing positive and negative electrodes. The deceivably of the high voltage to a tube with vacuumed air lightens the fluorescent. Röntgen covered the tube with thick black paper and noticed a green fluorescent light emanating from somewhere just a few feet away. He deduced that the tube was releasing a novel kind of beam. He showed his colleagues the radiographed box of weights. The radiation passed through the thick paper covering and activates the phosphorescent materials for industrial (not medical) usage. The discovery made by Röntgen was a scientific "bombshell" that sparked interest in both scientists and the general public. Scientists all over the world reproduced his experiment as the cathode tube was well-recognized at the time. Many experts turned away from other lines of research to look into the mysterious beams.

Over the course of its 25-year existence, CT has substantially improved in resolution, speed, and patient comfort. It has increased many, and more anatomy is possibly scanned in less time. Quicker scanning decreases artifacts brought on by patient motion, including peristalsis, or breathing. CT scans are now faster and more pleasing than ever for the patient. Extensive studies have been done to provide acceptable diagnostic confidence picture quality at the lowest practical X-ray dosage. In the history of X-ray computed tomography, the Radon transform mathematical theory may be traced back to at least 1917. “A patent for a radiant energy system for probing specific areas of interior objects obscured by thick material" was issued to William H. Olden Dorf in October 1963. Godfrey Hounsfield created the first commercially feasible CT scanner in 1972 (Balter 2019).

Wilhelm Röntgen's invention of X-rays in 1895 may be credited with the invention of mammography as an ionizing radiation-based medical procedure (Figure 2.7). German surgeon Albert Salomon performed 3.000 mastectomies in 1913 as part of a mammography study, when X-rays of the breasts are compared to the removed actual tissue and looked for microcalcifications. He was able to do this because it allowed him to tell apart between cancerous and non-cancerous tumors in the breast that was apparent on an X-ray image. Salomon's mammography provided a wealth of information regarding the boundaries and spread of malignancies. In his 1930 study, "A Roentgenologic Study of the Breast" American physician and radiologist Stafford L. Warren employed stereoscopic X-rays to monitor changes in breast tissue brought on by mastitis and pregnancy. In 119 women who had surgery thereafter, he properly diagnosed breast cancer in 54 of 58 instances (Hu 1999).

Figure 2.7 Röntgen reported the discovery of X-rays in December 1895

2.4.2 Properties of X-ray

One kind of electromagnetic radiation is X-rays. They, like light, may be made out of energy called photons. IR, visible light, UV, radio, radar, TV signal, y-ray, and X-ray are all examples of electromagnetic waves. X-ray has a variety of qualities, including:

- The frequency of X-rays, an electromagnetic radiation, is 10^{18} Hz, and the wavelength of 10^{-10} m (high frequency and very short wavelength).
- X-ray has the ability to pass through liquids, solids, gases and many materials.
- X-ray is traveling in a straight line.
- X-ray is invisible to the eye.
- Long-term X-ray radiation may be hazardous to living organisms, but short-term X-ray exposure is not.
- Because of their high frequency and intensity, X-rays may be an extremely harmful form of radiation.
- When X-rays strike a substance, its electrons are expelled from the atom, leaving a positive charge behind. As a result, X-ray radiation is sometimes referred to as ionizing radiation.

2.4.3 X-ray tube (Generator)

The energy conversion of electrons into photons creates X-rays. This energy conversion happens inside the X-ray tube. The radiation produced quantity (exposure) and quality (spectrum) of the x- can be changed by the adjustment of the electrical amounts (KV, MA), as well as the exposure duration (S), applied to the tube. An electrical device that produces X-rays, the X-ray tube is made up of numerous parts, including a (i) glass tube, (ii) cathode, and (iii) anode. The flow of electrical current through a tube from cathode to anode causes energy loss in the electrons producing x-radiation. An X-ray tube is an energy converter. It transforms electrical energy into heat and other energy: X-rays.

2.4.3.1 Glass tube

- Glass envelope makes the evacuated X-ray tube house an anode and a cathode (Figure 2.8)
- Oil is encased by the glass enclosure to aid with electrical insulation and heat absorption.

- A tiny window near the X-ray tube anode allows X-rays to exit the tube in the desired direction.

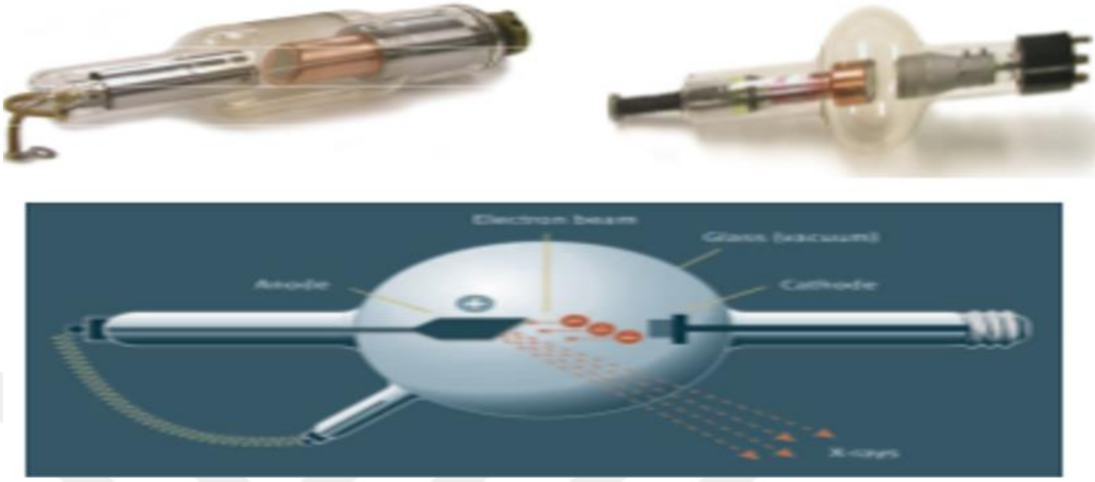

Figure 2.8 The X-ray tubes (Rose 2004)

2.4.3.2 Cathode

- The X-ray tube cathode contains a filament of tungsten wire (as found in the lamp). When the current passes through the tungsten wire, the temperature rises until it reaches a certain temperature enabling the electrons of the tungsten wire to emit from its surface.
- Tungsten is utilized because it emits a lot of heat with a high melting point (3410°C).
- Thermionic emission emits the electrons from the filament's surface (tungsten wire) and is propelled towards the anode.
- The cathode and anode's high voltage helped accelerate the electrons' forceful release in the direction of the anode.

2.4.3.3 Anode

- The tungsten makes anode commonly, although molybdenum or rhodium may be used in particular applications that need a low-energy X-ray beam.

- The electrons slow down and halt when they come into contact with the anode of the X-ray tube. Most energy taken by the anode from electrons manifests as heat and X-ray.
- An electric field accelerates electrons released from the cathode through the vacuum inside the tube, causing them to collide with the anode (also called the target).

2.4.3.4 Production of X-ray beams

X-ray photons may be produced by two separate atomic processes. Bremsstrahlung, a German word that means "braking radiation," is one of them. The other kind of emission is known as K-shell emission. They can both be found in tungsten's heavy atoms. X-rays are photons of electromagnetic radiation created when electrons moving at high speeds strike a heavy metal target (tungsten is often used as the target or anode of an X-ray tube). Because it's difficult to accelerate electrons in the air, the procedure must be carried out in a vacuum. Only around 1% of electrons become X-ray photons; the remainder is lost during the heating of the target. Bremsstrahlung, which translates to "braking radiation" in German, and characteristic X-ray, which is the removal of an inner electron, are the two methods by which X-rays are produced. Photons are released as the electrons change from one energy level to another and take the place of the inner electron. High-speed electron strikes an atom with an X-ray photon (Seibert 2004).

2.4.3.5 Bremsstrahlung X-ray (Braking Radiation)

A fast-moving electron collides with a nucleus and emits braking radiation as a result. According to Maxwell's theory, when an electron approaches the nucleus, Coulomb forces cause it to veer off course and lose the energy of Bremsstrahlung X-ray. The general theory of electromagnetic rays, which posits that energy is transported across a vacuum by electromagnetic rays, foresaw this phenomenon. When the electron, together with its electromagnetic field, approaches the nucleus' field, it experiences an abrupt negative acceleration and deviation, as a consequence of which some or all of its energy is dissolved and distributed in the vacuum as electromagnetic rays (Behling 2017). The process of producing these rays is illustrated in Figure 2.9.

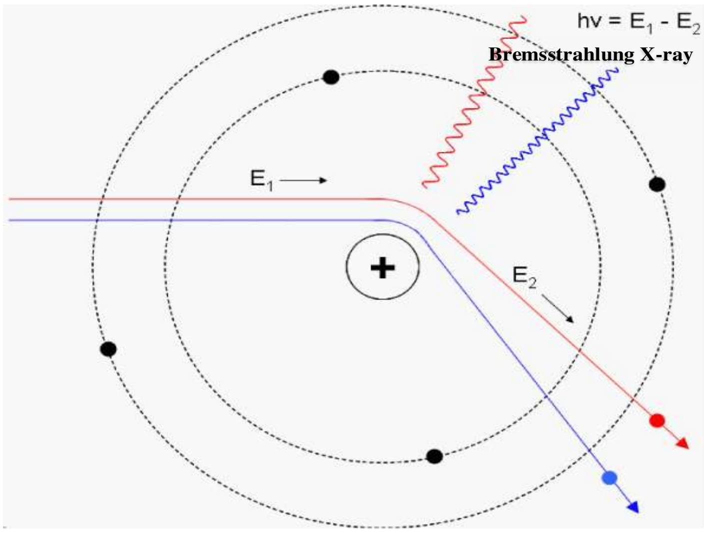

Figure 2.9 Diagram of the generation process of Bremsstrahlung X-ray (braking)

The Bremsstrahlung X-ray emission direction depends on the energy of the incident electrons because of an electron interaction with matter one or more times for producing rays, and one interaction may cause a partial or complete loss of the electron's energy. As a result, the produced photon will have energy reaching the electron's original energy. When electron energy is less than 100 keV, X-rays are almost equally distributed in all directions. As the electrons' kinetic energy increases, the X-ray emission will move ahead. The possibility of producing rays and their efficiency are proportional to the target material's atomic number and the potential difference supplied to the X-ray tube as the energy lost for each atom by falling electrons is in proportion to the square of the target material's atomic numbers (Berair 2017).

2.4.3.6 Characteristic X-ray

Additionally, falling electrons on a target can produce distinctive X-rays. The following (Figure 2.10) illustrates how these rays are created:

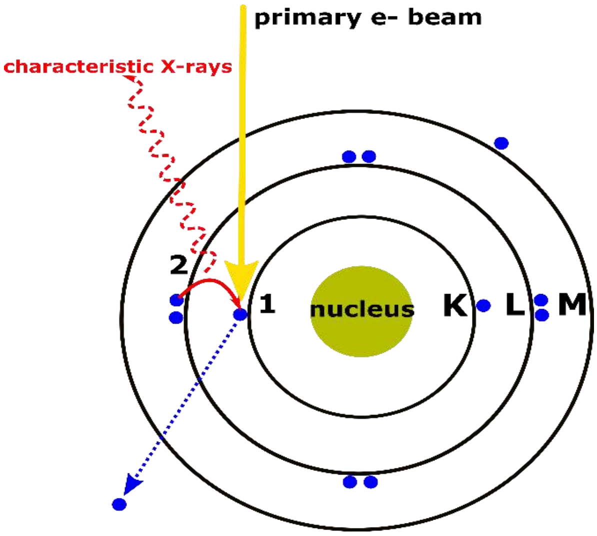

Figure 2.10 Diagram showing the generation process of characteristic X-ray

The incident electron, carrying kinetic energy interacting with the atoms of the target material through the spell of an electron from the K, L, or M orbitals, leaves the atom ionized. This expelled electron carries an energy that is its binding energy in its orbit from which it exited. An electron falls from an outer orbit to fill an empty space in the orbital when there is one. Electromagnetic rays will be released as a result of this procedure. These rays are known as characteristic X-rays because the orbits in which the electron transfer took place and the target atoms to which they were directed are both typical of them. The distinctive beams emitted at high atomic quantity of the target materials and electron transitions between internal K, L, M, or N orbitals will carry significant energy that merits consideration in the research of X-ray spectroscopy (Kiss *et al.* 2011).

2.4.4 X-ray radiography

It is known as ionizing radiation when the radiation energy is high enough to separate electrons from their atoms or molecules. Radiation is the energy produced as waves or substance small particles.

2.4.4.1 Radiography (Plain X-rays)

- Plain X-rays are the simplest medical images made using X-radiation; they give rapid, high-resolution images at a cheap cost, and the most frequent plain X-rays are chest and arm, leg, or spine images in patients with bone, joint, or back disorders. When an electron beam released by a cathode is fired at a target material called an anode, it produces an X-ray spectrum with varying energies in a vacuum tube composed of glass. The X-ray spectrum is limited by the anode material and the electron beam's accelerating energy. The following are some of the components found in most conventional X-ray systems:
- An X-ray tube is an electrical device used for the generation of X-rays, which is constant from a glass tube, cathode, and anode.
- X-ray detector (receptor): are devices to measure the X-rays flow, locative distribution, and spectrum.
- Collimators: a device for producing a parallel beam of X-rays or radiation.
- Anti-scatter grid: a device between the patient and the image receptor that transmits the majority of the primary radiation while rejecting the majority of the scatter radiation.
- Couch with bucky tray which represents the holds the X-ray cassette (Silver halide film).
- Silver halide film: X-ray film displays the radiographic image using silver halide (silver bromide ($AgBr$) mostly). Its exposure to light produces a silver ion (Ag^+) and an electron.
- An X-ray tube, a high-voltage power supply, and a control unit are essential components of an X-ray system. You should be aware that X-ray creation necessitates the use of electricity.
- All of these components work together and are common in standard systems (Figure 2.11) (Figure 2.12).

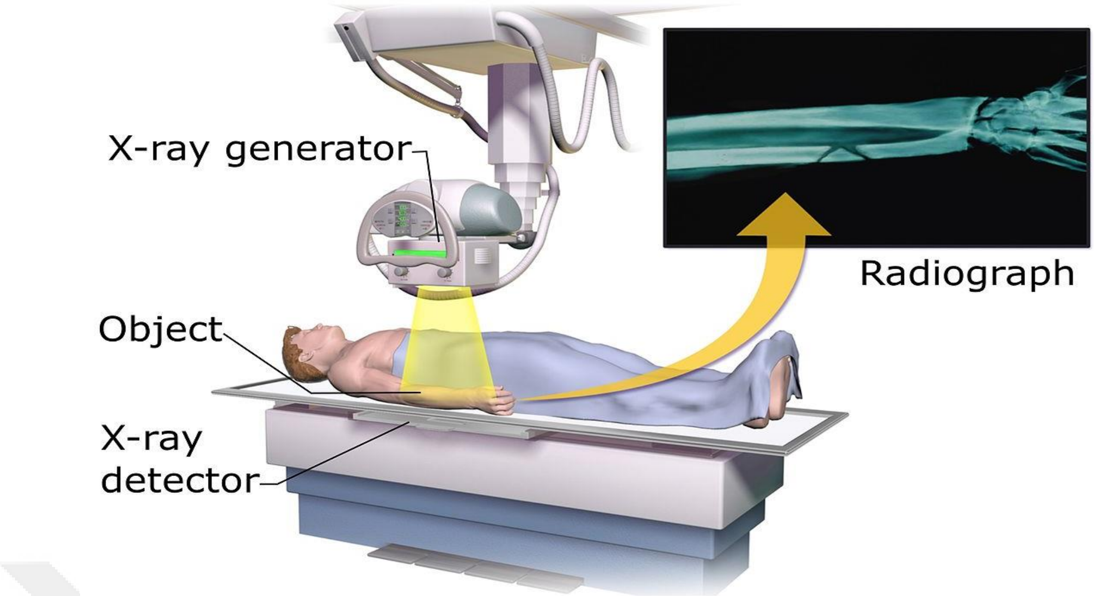

Figure 2.11 The components of a typical X-ray imaging system

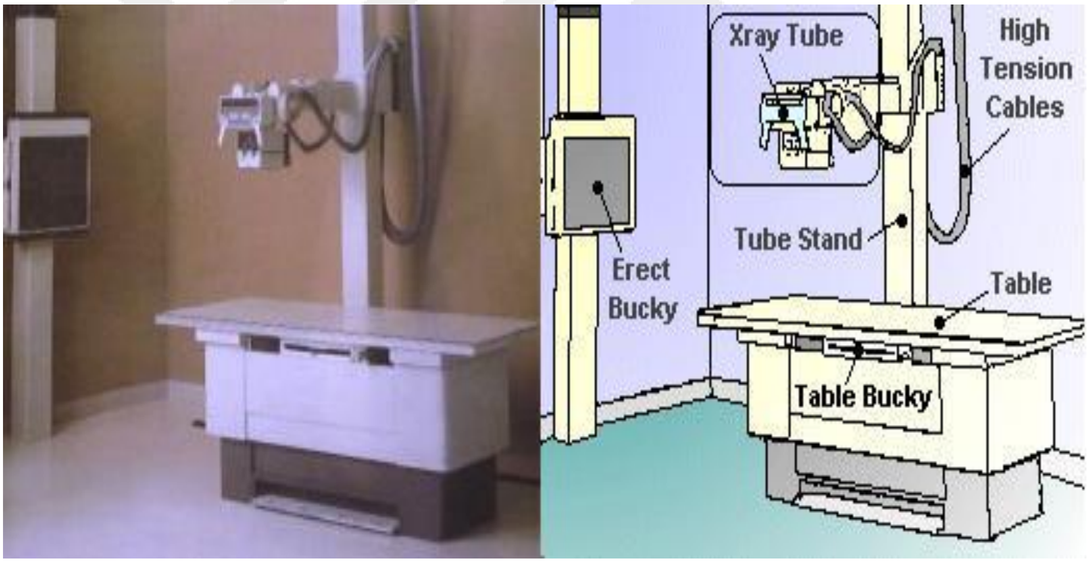

Figure 2.12 The X-ray room

The radiographic image produced by the interaction of X-ray photons has a photon detector and is passed through the patient before being captured by the detector. One of two types of photons could be present:

Initial photons, carry information and have passed through the patient without interacting.

Secondary photons, are the outcome of patient contact. No valuable information is carried by secondary photons (Henke *et al.* 1981).

Sending X-rays through the body and onto photographic film is the traditional method of using X-rays to form images of the internal regions of our bodies. If X-rays strike the film, it will react by darkening. If the X-rays are absorbed by the body, they are unable to reach the film, which causes the film to appear white in those areas (Henke *et al.* 1981).

The patient is exposed to the photons emitted by the X-ray tube by being between the X-ray tube and the silver halide film. X-rays that travel through a body are absorbed or directly transferred to the tissue. X-rays penetrate a body and deposit darkened silver halide film; the more X-rays that penetrate, the darker the area inscribed on the film. Inscribed region on film is "lighter" or "more white" because bones and metal absorb or reflect X-rays. The written region on the film is "darker" because soft tissues allow more X-rays to penetrate (Henke *et al.* 1981).

Previously, medical X-ray images were exposed on photographic film, which needed to be developed before viewing and took up a lot of room in clinics and hospitals. Digital X-rays, which address these problems, have therefore become more and more common in radiography. An electronic detector similar to that of a digital camera is employed in place of film (Henke *et al.* 1981) (Figure 2.13).

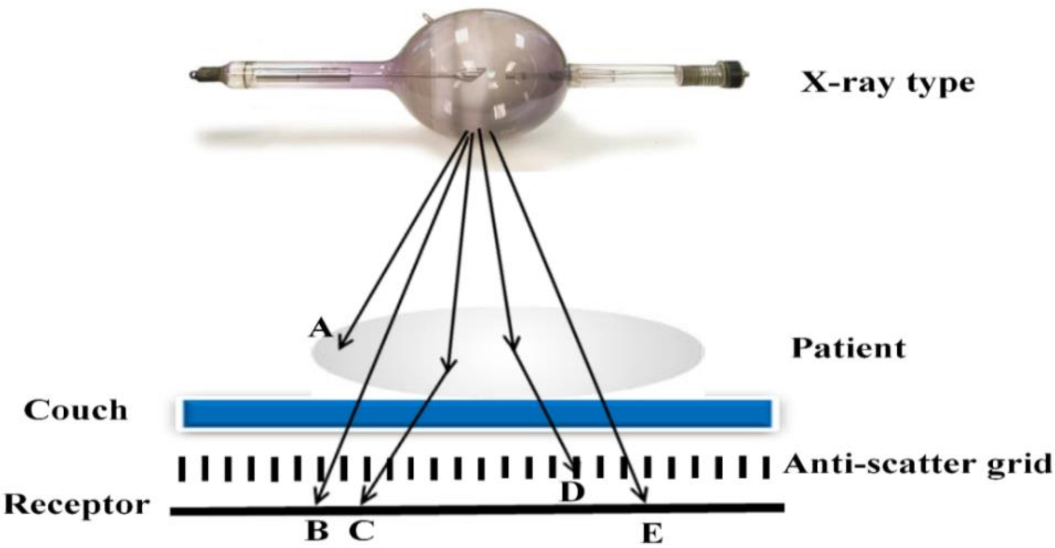

Figure 2.13 The components of an X-ray imaging system and how a radiographic picture is created. B and E are photons that have traveled through the patient without interfering with each other. Photons C and D are dispersed. An anti-scatter grid has slowed D down. Photon A has been absorbed by the body (Bushberg and Boone 2011)

2.4.5 Computed tomography

A computer and an advanced X-ray are used by medical imaging machines called CT scans for producing three-dimensional (3D) internal body images. CT is a type of computerized tomography also known as "computerized tomography" or "computed axial tomography" (CAT). The first clinical application of CT (Computerized Tomography) was in 1971. It has developed into a flexible 3D whole-body imaging technique with uses in oncology, cardiovascular radiology, traumatology, and interventional radiology, among other fields. In this innovative method, CT creates a cross-sectional body image in a virtual pile of X-ray photos. The image in the cross-section is a tomographic image. Greek terms tomos, which means to slice, and graphein, which means to write are the source of the English word "tomography." Tomography is defined as "writing slices" in English. Previously difficult-to-distinguish structures and lesions are now quite clear to see. A small, collimated X-ray beam passes through the body during a CT scan and is then picked up by a detector. The collimator creates a thin, straight X-ray beam by using a grid of lead plate small holes or a series of narrow lead tubes. Numerous measurements are made when the source and detector move through the body side by side. The X-ray generator is then slightly rotated around the body axis before being scanned once more. For instance, this is performed 180 times at 1° intervals. A computer receives the transmitted beam's intensity and reconstructs the slice's image for all of the scan's various locations and angles. The image is displayed on a computer screen (Duclos *et al.* 2003).

The imaging slice and the body's long axis are vertically aligned. Although CT is commonly referred to as computed axial tomography, the acronym CAT, as in CAT scan, is taken to mean computer-assisted tomography (CAT). The system can now produce multiple slices at once due to the greater image dimension. In CT, photo-detector arrays include about 1000 detectors along the semi-circular detector arch in the long dimension, while 16 or more detectors are tangential to the bracket in the shorter dimensions. The potential visual slice quantity depends on the density of detectors in the short dimensions. The description of the CT scan system can be summed up as follows (Duclos *et al.* 2003).

- CT images of the body by the use of complex X-rays and computers.
- The intensity of the transmitted beam is given to a computer, which reconstructs the picture of the slice for each of the scan's numerous points and angles.
- CT imaging systems create cross-sectional images of the internal body (images of a slice through the body) from a virtual image.
- CT scans could work on any part of the body for many reasons (e.g., diagnostic, treatment, intervention, or screening).
- Each cross-sectional image shows a slice (section) of the body being photographed, similar to the slices in a loaf of bread.
- The image is presented on a computer monitor.

In order to make a CT scan, the patient must first be exposed to a fan-shaped X-ray beam. A digital X-ray detector is then used to detect the projected image on a semi-circular. The X-ray beam and detector rotate in a fan-like pattern on a semi-circular. To gather the plurality of X-ray projections, the X-ray beam and detector revolve in opposing directions inside a semi-circular at the same time (dropping). The X-ray generator is rotated slightly between 1° to 180°, as shown in (Figure 2.14). The patient is put between the source and the detector. Each image in CT represents one of the X-ray projections (dropping) for a slice of the body. Finally, images are collected and stored.

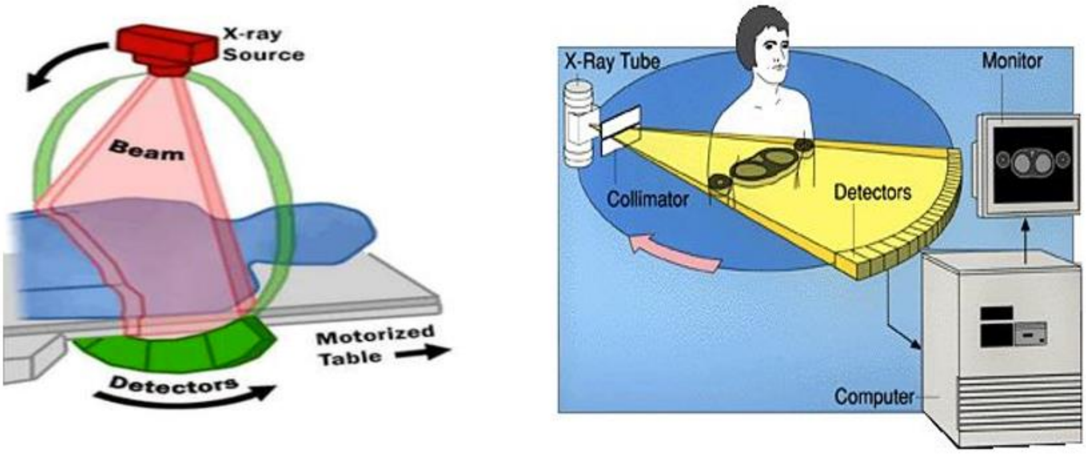

Figure 2.14 Schematic of computed tomography scan system

Loss of depth information is one of the problems. A front-to-back chest scan, for example, might show a small lung cancer (Figure 2.15). In the forward-backward direction, the radiologist is unable to pinpoint the specific site of this tumour. A side picture (a side view) might be taken, but the malignancy could be hidden behind a rib. In this instance, a cross-sectional picture (Figure 2.16) (Fukuda *et al.* 2012), is required.

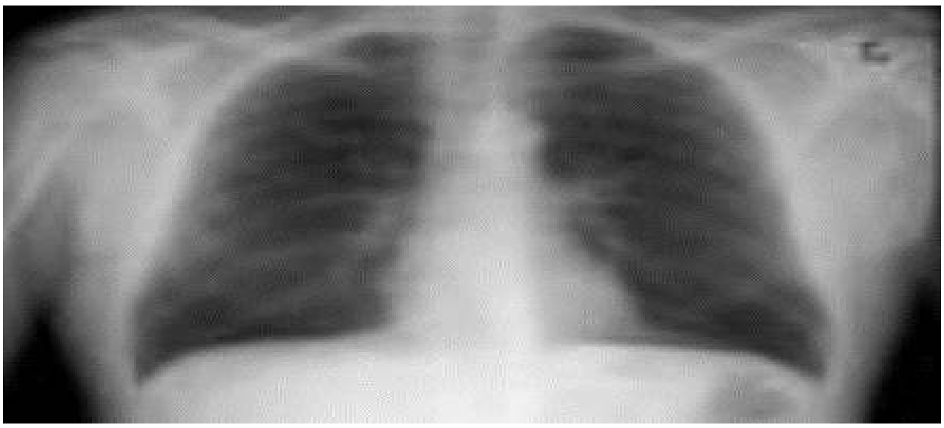

Figure 2.15 A typical AP (anterior-posterioruor front-to-back) X-ray of the chest

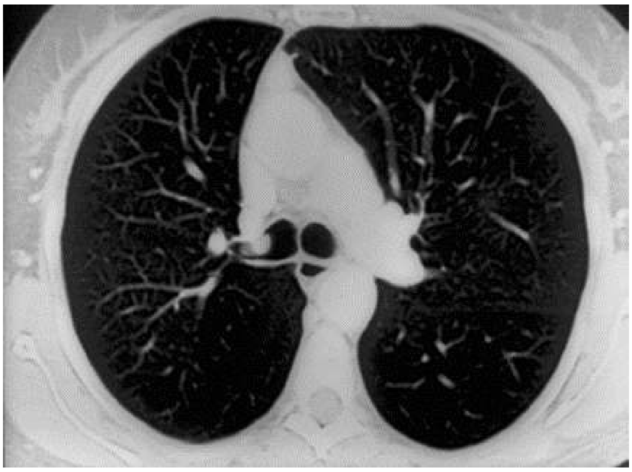

Figure 2.16 Transversal CT slice of the chest

2.4.6 Fluoroscopy

A continuous X-ray image, like an X-ray movie, is put on a monitor in fluoroscopy, medical imaging. The body is traversed by an X-ray beam in fluoroscopy. The image is transmitted to a monitor to show in great detail how a body part, instrument, or contrast agent X-ray dye moves through the body. Fluoroscopic imaging is used to diagnose and treat patients in a set of tests and procedures. Here are a few illustrations: Barium X-rays and enemas (to see the gastrointestinal tract) catheter insertion and manipulation for directing the catheter movement in the blood vessels, bile ducts, or the urinary system). Stents and other tools are inserted into the body (for opening narrowed or blocked blood vessels). Angiograms include angiograms (for visualizing blood vessels and other parts) A type of surgery known as orthopedic surgery involves the removal (for guiding joint replacements and treating fractures) (Mahesh 2001).

Like other X-ray methods, fluoroscopy may be dangerous. Depending on the procedure, the patient receives a different amount of radiation. Performing complex interventional procedures (such as implanting stents or tools in the body) needs fluoroscopy for a prolonged period of time, fluoroscopy can expose patients to considerable doses of radiation. The radiation-related risks associated with fluoroscopy include burns developing rapidly upon exposure to radiation, as well as radiation-induced cancers that may develop later. According to statistics, there is very little probability that someone will experience these side effects as a result of a fluoroscopic procedure. Therefore, if the procedure is medically required, the benefits to the patient outweigh the hazards of radiation. The risk from radiation is typically much smaller than risks from anesthesia, drowsiness, or issues with the procedure itself. For minimizing the danger of radiation, fluoroscopy is recommended by the lowest permissible dose for the shortest time. The Medical X-ray Imaging homepage has further details on the advantages and disadvantages of X-ray imaging, like fluoroscopy (Mahesh 2001).

For further details regarding Patients Fluoroscopy is used by doctors to help diagnose patients and guide them through particular a treatment. Some fluoroscopy can be carried out as awake outpatient operations, such as an upper gastrointestinal series for examining the esophagus, small intestine, and stomach, or a barium enema to assess the colon. Under general anesthesia, other fluoroscopy procedures, such as assisting in aligning and mending broken bones, may be carried out during surgery. A medically approved X-ray imaging test has a minimal radiation risk, but the therapeutic advantage outweighs it. The FDA suggests that patients and parents of young children discuss the advantages and disadvantages of fluoroscopy with their doctor (see the Medical X-ray Imaging webpage for info on questions for asking health care providers) (Mahesh 2001) (Figure 2.17).

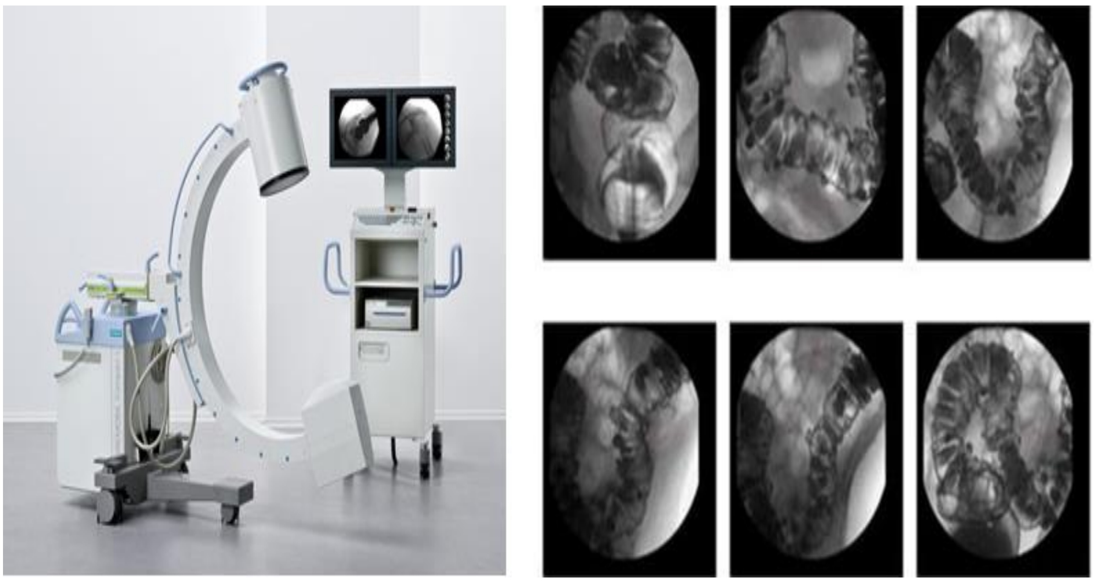

Figure 2.17 Photograph of fluoroscopy imaging and system

2.4.7 Mammography

Mammography is a type of X-ray imaging frequently used in breast cancer screening to provide fine-grained images of the breast. A breast imaging called screening mammography utilizes low-dose X-rays to detect cancer at an early stage, prior to symptoms while most treatable (Kerlikowske *et al.* 1995) (Figure 2.18).

Figure 2.18 Photograph of mammography imaging and system

2.4.8 Angiography

A contrast agent is injected into circulation during angiography, a type of X-ray technique, to make blood vessels and organs, particularly the heart, more visible on the X-ray image. A special dye needs to be put into your blood beforehand since blood vessels are challenging to view on a regular X-ray.

Your blood vessels are highlighted, which makes it simpler for your doctor to spot any anomalies. The X-ray images produced during angiography are called angiograms (Lu *et al.* 2009) (Figure 2.19).

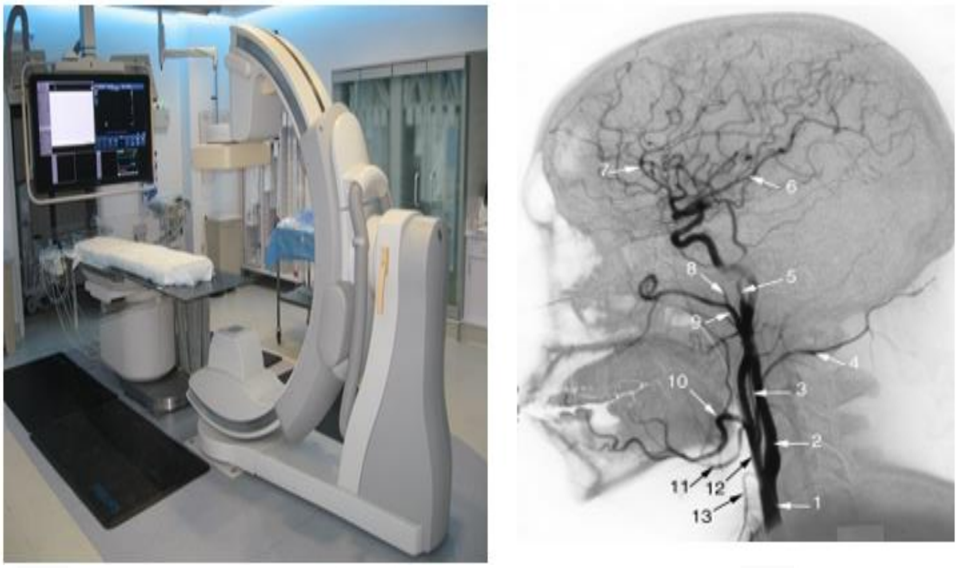

Figure 2.19 Photograph of angiography imaging and system

2.5 Biological Effects of X-ray

Biological impacts will occur regardless of whether the source of radiation is natural or man-made, whether the dosage is modest or big and it may influence all regions of the human body(Figure 2.20).

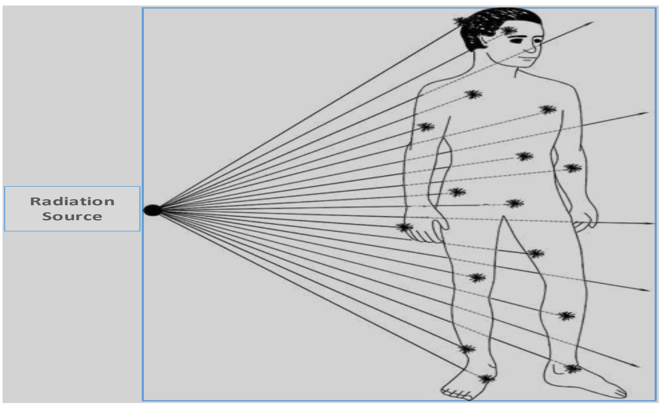

Figure 2.20 The spread of radiation to all parts of the human body

Radiation workers who are exposed to ionizing radiation at work must take the appropriate safety precautions because X-rays are frequently utilized in medicine for diagnosis and therapy. If all safety procedures are not taken, ionizing radiation poses a serious risk to human health. Ionizing radiation exposure for nuclear medicine employees is low at work. Effective doses for people who are exposed at work range from 6 to 20 mSv (Joudoh *et al.* 2018). Ionizing radiation can damage cells directly or indirectly through the generation of free radicals and induction of inflammation. On the basis of the kind and radiation absorbed whose dose, the given dose rate, and the exposed tissue's relative sensitivity, deterministic consequences, such as acute radiation sickness and cutaneous burns, develop after exposure and are foreseeable (Deas *et al.* 2017). Ionizing radiation is mutagenic and carcinogenic in animals, including humans, at low and high doses. Radiation exposure may be too high for medical staff who use it for therapeutic and diagnostic purposes. Fortunately, the adoption of radiological protective principles has reduced exposing medical staff to ionizing radiation. Also, it is now typically below the limit of 20 mSv/year. Yet, many works have demonstrated that exposed workers to low doses of ionizing radiation have a higher prevalence of micronuclei, chromosomal abnormalities, and DNA strand breaks (Dobrzyn´ska *et al.* 2014).

Cells and plasma are the two elements of blood. The cellular component is made up of white and red blood cells (W.B.Cs). After developing in the bone marrow, red blood cells have a disc-like shape and rapidly lose their nuclear structure. These cells are 71% made of water and 28% of hemoglobin (Hb). The bone marrow yields many kinds of white blood cells (acid, base, and neutral). All of the body's cells receive oxygen and nutrients through hemoglobin. The responsibility for protecting the body from disease falls on the lymphocytes (Kadhim 2013). High or low blood cell counts suggest a disease because blood-generating cells are very sensitive as indicators to detect the influence of ionizing radiation and intensity, even in people who appear to be healthy (Nureddin and Alatta 2016). Blood cell count is, in fact, a popular bio dosimeter for occupational exposure (Shafiee *et al.* 2016). Radiation doses to radiosensitive organs including the thyroid, ovaries, and testicles can harm DNA and increase the risk of cancer, among other things (Zarghani and Bahreyni Toossi 2015), The effects of X-rays on various parts of the human body have been the subject of several studies. X-rays may permeate live tissues and result in cell death, chromosomal abnormalities, and carcinogenic effects, claims (Adhikari 2012). When these ionizing radiations penetrate living tissues, they may damage live cells, result in chromosomal abnormalities, and have a carcinogenic effect. Ionizing radiation randomly harms every part of the cell and has a variety of negative consequences on DNA. As a result, X-rays are frequently used in protective and well-preventive circumstances. A mouse model employed by Venkata Ramesh (Yentrapalli 2013) claims that exposed persons to higher radiation have a higher risk of contracting deadly diseases like cancer. Preventive interventions that are insufficient or flawed are what cause the stochastic effect. Skin discomfort, joint pain, hair loss, and high blood pressure are all common among technicians. By employing protective measures such as a lead apron TLD, it was found that the majority of the technicians in this experiment were under the safe exposure level. Due to not wearing lead glasses, one of the technicians is having vision issues. Additionally, it was discovered in this study that X-rays have stochastic effects and can be harmful if exposed for an extended length of time. Consequences like hair loss and skin burn are foreseeable when a person is regularly subjected to increasing doses of X-rays. No cancer in the technician was found since the study was so small. The technicians are afflicted with problems like hair loss and bad vision since they are not aware of the most recent protective measurement tools and safety precautions. As a consequence of X-rays, no cancer was found in this particular group of technicians because the study only included a small number of patients. According to low-dose soft X-ray radiation (Truong *et al.* 2018).

The hematopoietic system, radiosensitive in the body, could be damaged by ionizing radiation (X-rays) (Taqi *et al.* 2019). The majority of radiographers are at risk of CT scans and X-ray radiation, and the levels are higher than the recommended regulations. Therefore, it is vital that the technicians, attendants, and maintenance employees who work in the X-ray and CT-scan departments take radiation protection precautions (Farman *et al.* 2021) discovered alterations in a number of blood variables in X-ray exposed individuals as compared to a control group, the exposure duration of influence on these blood variables. Samples were provided by radiation-exposed patients and those in the radiography industry. Platelet, HB, ESR, RBC, monocyte, eosinophil, basophil, neutrophil, lymphocyte, and WBS blood variables were examined. Depending on how long they had been exposed, the volunteers who had been exposed to radiation were divided into 20 technicians, and 10 mL of blood was drawn through a venipuncture and put into a bottle containing EDTA. The hospital's process was utilized to calculate several variables, including RBC, WBC, and ESR. The studies show that X-rays affect human blood cells, yet some blood constituents, such as RBC, are significantly similar in the patient and control groups. Although WBS, platelets, and hemoglobin varied significantly, there is an apostive correlation between how long the radiation exposure was and the impact on blood components. According to this research, no significant difference in RBC between the patient and control groups was found, but WBS, platelets HB were different, and WBC and ESR, Lymphocytes, and Monocytes are directly linked. The yearly average effective dosage of radiation workers, according to Banik *et al.* (2021).

3. MATERIALS AND METHODS

Radiation that enters the body from outside interacting with us is called external exposure. Machinery that emits radiation, like an X-ray, or radioactive materials in a container can generate radiation. The distance from the source, the energy of the radiation emitted, the general amount of radioactive material or the machine setting, and the exposure period influence the amount of external radiation. Radiation workers are capable of using time, distance, and shielding for managing and reducing their exposure to radiation of penetrating.

Reducing time

The worker's dose is in a direct inverse proportional to the amount of time of exposure to radiation. The dose received is directly influenced by time; spending as little time to exposure reduces the dose. For instance, if at all possible, speak with a nuclear medicine patient prior to giving them medication.

Increasing distance

The distance between the person and the radiation is necessary (sealed source, X-ray tube). The square inverse of the distance determines the radiation exposure rate from a source. So, difficulty in a fluoroscopy operation necessitates possibly standing on the C-image arm's intensifier side, moving away from the patient while not providing assistance.

Using shielding

The third exposure control method relies on suitable radiation shielding, automatic interlocks, and on-site radiation monitoring devices. This sort of control is typically integrated into the specific facility, such as concrete walls next to radiation oncology accelerators, lead or lead equivalent aprons, temporary or portable shields, and protective curtains. Follow the vendor's directions while using portable X-ray devices.

Generally, alpha, beta, gamma, and X-ray radiation are stopped by:

- Minimizing the exposure duration.
- Keeping a safe distance from the origin.
- If necessary, erect a barrier between you and the source.
- Employing appropriate protective clothing to shield yourself from radioactive pollution.

3.1 Materials

In the subject of our study, at first a visit to:

- The Radiology and Nuclear Medicine Hospital in Baghdad.
- Oncology and Nuclear Medicine Hospital in Mosul.
- Some institutions that deal with open radioisotopes (Figure 3.1).

Figure 3.1 A group of hospitals that specialize in X-rays in Iraq

The workers in these hospitals during the two years in the field of X-rays conducted examinations were diagnosed five variables (Platelets, ESR, HB, PCV, WBC) as shown in APPENDIX 1.

Approvals were taken to collect information and data because it is confidential and especially for those working on the devices and taking all the data and information related to our study by identifying the devices used, the way they work, and the workers on the device.

The data of the workers in the radiation centers were taken and the extent to which they were affected by the radiation was measured and the period of time for the periodic inspections of the workers on the devices.

20 full blood images were taken as shown in Figure 3.2 for 20 X-ray workers in the centers mentioned above, and we made tables for all parameters of blood groups, which include platelets, erythrocyte sedimentation rate (ESR), hemoglobin (HB), packed cell volumes (PCV), white blood cells total (WBCt), WBC neutrophils (WBCn), white blood cells lymphocyte (WBCl), white-blood cells unicellular (WBCu), white blood cells acidic (WBCa), white-blood cells neutral (WBCn) and white blood cells basal (WBCb) are shown in the results chapter. Each person has a special form in which the date of the examination and the next examination is fixed, as well as the collection of examination results, and a periodic update is made of it. In the event of an increase in the rates, the employee is notified to review and examine the results of the tests (Figure 3.3) (Figure 3.4).

Figure 3.2 A group of workers in the field of X-rays inside hospitals

Figure 3.3 A group of devices used in X-rays inside hospitals

Figure 3.4 Analysis of a person working in X-rays

In our research, the (Mindray BC-10) device is used (Figure 3.5), which analyzes blood diseases, as it warns in the event of abnormal cell results, where he checks each of the Platelets, HB, ESR, PCV, and WBC.

This gives confidence in the results. This device is used in more than 190 countries in the world and gives you less downtime and gives you more time to work.

Smart and intuitive software increases productivity. The 10.4-inch TFT touchscreen facilitates operations and maximizes productivity. The incredible 400.000 storage capacity makes a worry-free solution to managing previous patients' data. The smart software detects and removes operational errors and runs automatic maintenance with one click.

Technology

- CBC+3-DIFF, 20 parameters+3Histograms
- Amount of work: About 30 samples every hour
- 8.4 inch TFT touchscreen
- Three reagents required
- Open vial sampling
- Big storage: about 50.000 samples
- Original QC, calibrators, and reagents

The way it works:

2 mL blood was collected and placed in an EDTA K3 tube and mixed for 5-10 minutes After that, a label is made for the patient’s name, and it is inserted into the examination device, and within two minutes, the results of the blood analysis appear

Figure 3.5 Mindray BC-10 device

4. RESULTS AND DISCUSSION

4.1 Platelets

Platelets are the smallest blood cells, as megakaryocyte cytoplasm fragments which are critical in normal hemostasis and contribute to thrombotic disorders. Understanding the role of platelets in hemostasis and disorders which abnormal platelet function causes can make significant new thrombotic disease therapies (George 2000).

The blood platelets and dose rate of X-ray exposure for 20 technicians are explained in Table 4.1. The blood platelets were reduced with higher dosage rate exposure, as can be seen in Table 4.1. Because stem cells are the precursors to every blood cell line and a decrease in mature cells might be seen, the drop in blood platelets may be caused by this (Shahid *et al.* 2015). At degree (1124 mrem), the highest rate of radiation exposure was observed (125×10^9/L) The main causes of these decreases could be attributed to the hematopoietic tissue's high sensitivity to ionizing radiation and the spleen's declining stem cell viability (Chew and Park 2004). It is clear from Figure 4.1 which explains that decrease in blood platelets with an increasing dose rate. The usual platelet quantity in the blood ranges from 150.000 to 400.000 per microliter (µcL) or 150 to 400×10^9/L, so the high X-ray exposure affects the blood platelets. This result agreed with the previous studies (Faraj and Mohammed 2018).

Table 4.1 The value of platelets with the exposed dose rate for 20 technicians

SAMPLE NUMBER	DOSE RATE (GY)	PLATELETS
1	0 mrem	268×10^9/L
2	0 mrem	260×10^9/L
3	0 mrem	250×10^9/L
4	301 mrem	251×10^9/L
5	303 mrem	248×10^9/L
6	318 mrem	240×10^9/L
7	349 mrem	235×10^9/L
8	365 mrem	233×10^9/L
9	381 mrem	230×10^9/L
10	381 mrem	228×10^9/L
11	396 mrem	210×10^9/L
12	401 mrem	207×10^9/L

Table 4.1 The value of platelets with the exposed dose rate for 20 technicians (Continued)

SAMPLE NUMBER	DOSE RATE (GY)	PLATELETS
13	443 mrem	200×10^9/L
14	459 mrem	190×10^9/L
15	713 mrem	150×10^9/L
16	801 mrem	147×10^9/L
17	830 mrem	144×10^9/L
18	897 mrem	150×10^9/L
19	1129 mrem	138×10^9/L
20	1422 mrem	125×10^9/L

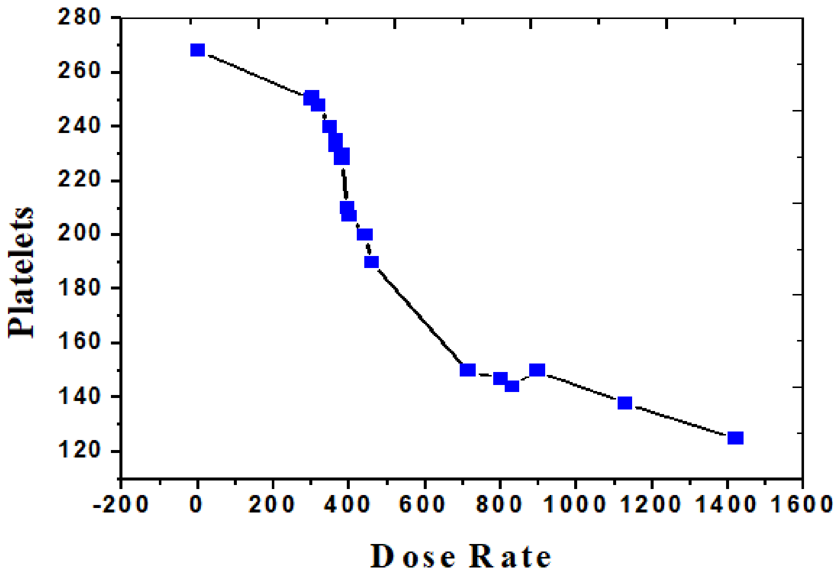

Figure 4.1 The variation of blood platelets with the dose rate

4.2 Erythrocyte Sedimentation Rate (ESR)

The erythrocyte sedimentation rate (ESR) is the RBC sediment used usually as a nonspecific measure to monitor disease activity and assist in diagnosing many inflammatory disorders (Vennapusa *et al.* 2011).

Erythrocytes Sedimentation Rate (ESR) for 20 technicians with exposure dosage rate (Table 4.2). From Table 4.2, it can be seen that the ESR first grew a little bit as the exposure dose increased before raging. This outcome might be brought on by the various radiation kinds and dose sizes. Figure 4.2 shows that the ESR increased gradually as the exposed dose rate increased, but rapidly increased up to 60 when the exposed dose rate increased (1422 mrem). This outcome is based on research (Ibrahim 2006). At degree (1422 mrem), the highest rate of radiation exposure was observed (60 mm/h). The usual number of ESR in the blood is 0-15 mm/h, therefore the exposure to high X-ray effect the ESR.

Table 4.2 The value of ESR with the exposed dose rate for 20 technicians

SAMPLE NUMBER	DOSE RATE (GY)	ESR
1	0 mrem	3 mm/h
2	0 mrem	4 mm/h
3	0 mrem	4 mm/h
4	301 mrem	5 mm/h
5	303 mrem	5 mm/h
6	318 mrem	6 mm/h
7	349 mrem	6 mm/h
8	365 mrem	6 mm/h
9	381 mrem	7 mm/h
10	381 mrem	8 mm/h
11	396 mrem	8 mm/h
12	401 mrem	10 mm/h
13	443 mrem	10 mm/h
14	459 mrem	15 mm/h
15	713 mrem	20 mm/h
16	801 mrem	22 mm/h
17	830 mrem	23 mm/h
18	897 mrem	28 mm/h
19	1129 mrem	55 mm/h
20	1422 mrem	60 mm/h

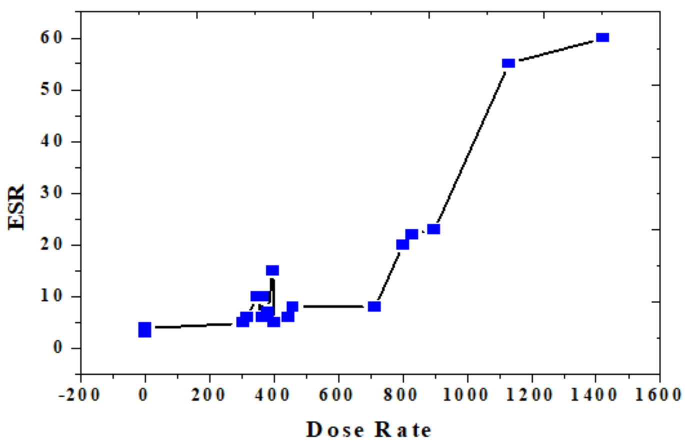

Figure 4.2 The variation of ESR with the dose rate

4.3 Hemoglobin (HB)

Hemoglobin (HB) is a metalloprotein in red blood cells transporting Oxygen in the body. The red blood cells of vertebrates except fish use hemoglobin to carry oxygen. Hemoglobin is 96% of the dry weight of the red blood cell with iron. All human bodies have hemoglobin (Panawala 2017).

Hemoglobin (HB) with a dose rate of exposed X-ray for 20 technicians are shown in Table 4.3. From Table 4.3, it is observed that the HB increased slowly with the increasing dose rate exposed and then decreased, still falling within the typical clinical range. Other researchers also found that exposure to X-rays and low radiation doses had the same impact (Abdullah *et al.* 2019). The results showed relatively minimal plasma HB rise, which was mostly caused by transfusion-related problems rather than ionizing radiation (Figure 4.3) explaining the variation of HB with the exposed dose rate. Where the highest rate of exposure to radiation was recorded a degree (381 mrem) it is (15 g/dL) It is clear that the HB increased slowly with the increasing dose rate exposed and then decreased. The ordinary HB in the blood is 13.8–17.2 g/dL, therefore the exposure of high X-ray effect the HB. This result is agreed with the researcher (Rabeya Yousuf 2015).

The values of working person No. 5 and 6 are different, as they are high compared to the values of other people because:

- They were found to be smokers (from 2 to 2 and a half packets)
- Pregnant women.
- A working person who lives in high areas due to an increase in blood levels, where oxygen is low.

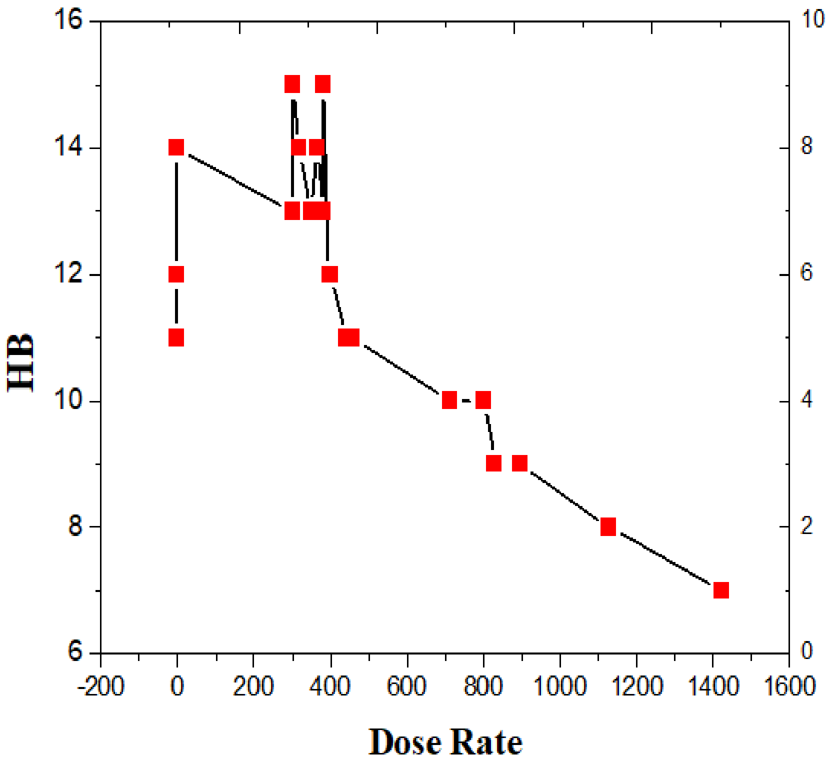

Figure 4.3 The variation of HB with the dose rate

Table 4.3 The value of HB with the exposed dose rate for 20 technicians

SAMPLE NUMBER	DOSE RATE	HB
1	0 mrem	11 g/dL
2	0 mrem	12 g/dL
3	0 mrem	14 g/dL
4	301 mrem	13 g/dL
5	303 mrem	15 g/dL
6	318 mrem	15 g/dL
7	349 mrem	13 g/dL
8	365 mrem	14 g/dL
9	381 mrem	13 g/dL
10	381 mrem	12 g/dL
11	396 mrem	12 g/dL
12	401 mrem	12 g/dL
13	443 mrem	11 g/dL
14	459 mrem	11 g/dL
15	713 mrem	10 g/dL
16	801 mrem	10 g/dL
17	830 mrem	9 g/dL
18	897 mrem	9 g/dL
19	1129 mrem	8 g/dL
20	1422 mrem	7 g/dL

4.4 Packed Cell Volume (PCV)

The packed cell volume (PCV) measures the ratio of the volume of the red cells to the whole blood in some capillary, venous, or arterial blood. The ratio is measured upon proper centrifugation expressed in decimal fractions (Obeta *et al.* 2022).

Table 4.4 tabulated the packed cell volume (PCV) with the dose rate of exposed X-ray for 20 technicians. It is obtained that the PCV increased slowly with increasing dose rate exposed and then decreased, but still within the normal clinical range. This outcome functions as the length of radiation exposure. Where the highest rate of exposure to radiation was recorded at degree (381 mrem) it is (49%). It is clear from Figure 4.4 explain that PCV increased and then decreased with the exposed dose rate. The normal number of PCV is 38.3% to 48.6%, therefore the exposure of high X-ray effect the PCV. This result is agreed with researchers (Luntsi *et al.* 2019).

Table 4.4 The value of PCV with the exposed dose rate for 20 technicians

SAMPLE NUMBER	DOSE RATE	PCV
1	0 mrem	34%
2	0 mrem	38%
3	0 mrem	44%
4	301 mrem	41%
5	303 mrem	46%
6	318 mrem	45%
7	349 mrem	38%
8	365 mrem	45%
9	381 mrem	45%
10	381 mrem	39%
11	396 mrem	48%
12	401 mrem	35%
13	443 mrem	32%
14	459 mrem	32%
15	713 mrem	31%
16	801 mrem	30%
17	830 mrem	27%
18	897 mrem	27%
19	1129 mrem	24%
20	1422 mrem	21%

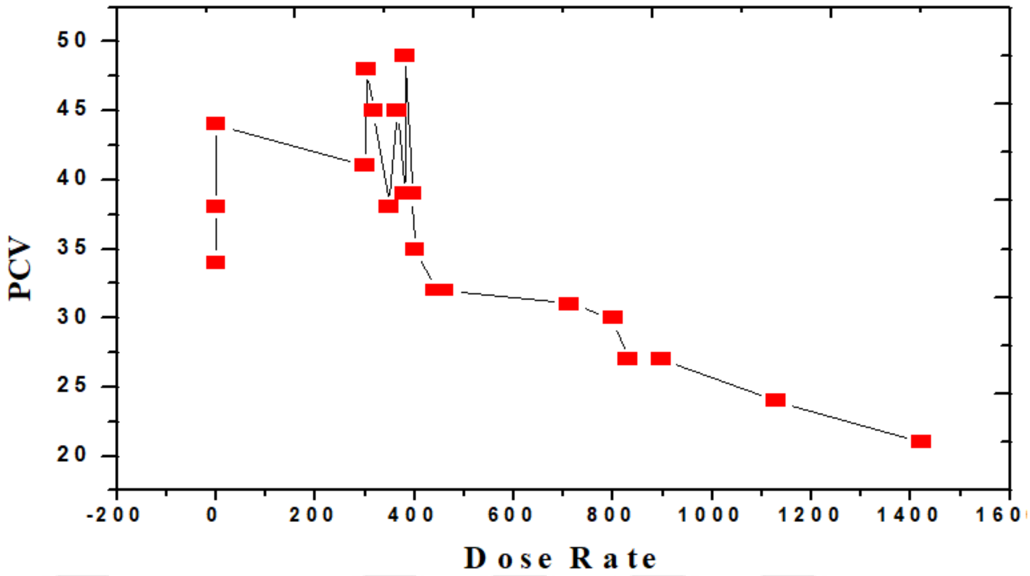

Figure 4.4 The variation of PCV with the dose rate

We note in Table 4.4 and Figure 4.4, the values of working person No. 5 and 6 are different, as they are high compared to the values of other people because:

- They were found to be smokers (from 1 to 2 and a half packets).
- Pregnant women.
- A working person who lives in high areas due to an increase in blood levels, where oxygen is low.
- Some of them were found to have rheumatoid arthritis.

4.5 White Blood Cells Total (WBCt)

White blood cells (WBC) are significant in the immune system by preventing the body from infectious diseases and invaders. so, automatically identifying WBC from microscopic images is essential for helping the hematologist in diagnosing diseases, like leukemia, AIDS, and some blood cancer kinds. Analysing WBC structure from microscopic pictures and dividing cells into types and sub-types are a challenge due to the differences in the maturation stage, and intra-class variations of the cell shape and because of the acquisition and staining (Al-Dulaimi *et al.* 2018).

The values of white blood cells total (WBCt) with exposed dose rate for 20 technicians are shown in Table 4.5. From Table 4.5, it is observed that WBCt increased with rising exposed dose rate. This result is attributed to the long time span of radiation exposure. Where the highest rate of exposure to radiation was recorded at a degree (1422 mrem) it is (35×10^9/L). It is noted from Figure 4.5 that WBCt increased with increasing exposed dose rate. The normal number of WBCt is 4.5×10^9/L to 11.0×10^9/L, therefore the exposure to high X-ray effect the WBCt. This result agrees with the researches (Liu *et al.* 2020).

Table 4.5 The value of WBCt with the exposed dose rate for 20 technicians

SAMPLE NUMBER	DOSE RATE	WHITE BLOOD CELLS TOTAL
1	0 mrem	4×10^9/L
2	0 mrem	5×10^9/L
3	0 mrem	7×10^9/L
4	301 mrem	7×10^9/L
5	303 mrem	7×10^9/L
6	318 mrem	8×10^9/L
7	349 mrem	9×10^9/L
8	365 mrem	8×10^9/L
9	381 mrem	8×10^9/L
10	381 mrem	9×10^9/L
11	396 mrem	9×10^9/L
12	401 mrem	10×10^9/L
13	443 mrem	11×10^9/L
14	459 mrem	12×10^9/L
15	713 mrem	18×10^9/L
16	801 mrem	22×10^9/L
17	830 mrem	24×10^9/L
18	897 mrem	27×10^9/L
19	1129 mrem	30×10^9/L
20	1422 mrem	35×10^9/L

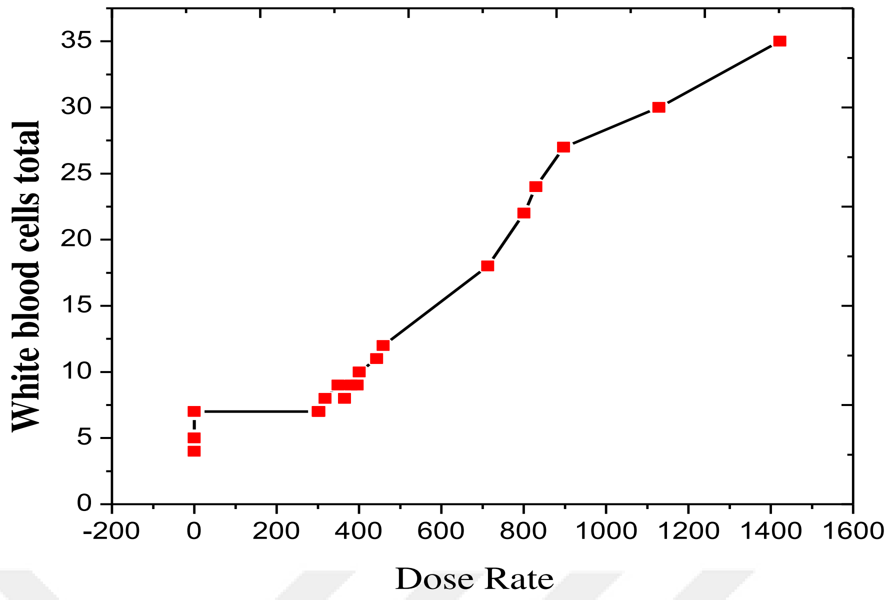

Figure 4.5 The variation of WBCt with the dose rate

4.6 White Blood Cells Neutrophile (WBCn)

White blood cells neutrophile (WBCn) are an innate immune system element and critical against bacteria. The nucleus is like a "U" in shape or a curled rod before segmentation. They are called "band neutrophils". The diameter is often between 10–18µ. There is a moderate to abundant cytoplasm with a few no definite granules. Neutrophils are about 1%–3% of the peripheral WBCs. The segmented neutrophil cell diameter range is 9–16 µ with a multi-lobed nucleus (three or four lobes usually), and the lobes overlap or twist (Standring 2021). They rise in number based on the cell age. For instance, there are seven lobes in a hypersegmented neutrophil cell in mature stages. The intra-cellular granules can be seen in the cytoplasm (Giemsa-stained, high magnification).

The values of white blood cells neutrophile (WBCn) with exposed dose rate for 20 technicians are shown in Table 4.6. From Table 4.6, it is observed that WBCn decreased with increasing exposed dose rate. The neutrophil counts were decreased which can be attributed to the cytotoxic activity of X-rays exposure.it is clear from Figure 4.6 that WBCn decreased with increasing exposed dose rate. The decrease in neutrophil counts also indicates the high radio-sensitivity of hematopoietic tissue. Where the highest rate of exposure to radiation was recorded at the degree (301 mrem) it is (65×10^9/L) Studies have indicated that the response to radiation exposure depends upon various factors such as the sensitivity of the organ and the type of radiation so, we kept our experiments under steady conditions. Our endings suggest that oxidant-antioxidant balance has an essential role in regulating cellular against free radical onslaught resulting from radiation exposure. The normal number of WBCn is 14.5×10^9/L to 75×10^9/L, therefore the exposure of high X-ray effect the WBCn. This finding supports the researcher (Sharma *et al.* 2019).

Table 4.6 The value of WBCn with the exposed dose rate for 20 technicians

SAMPLE NUMBER	DOSE RATE	WHITE BLOOD CELLS NEUTROPHILE
1	0 mrem	70×10^9/L
2	0 mrem	60×10^9/L
3	0 mrem	70×10^9/L
4	301 mrem	65×10^9/L
5	303 mrem	60×10^9/L
6	318 mrem	60×10^9/L
7	349 mrem	59×10^9/L
8	365 mrem	58×10^9/L
9	381 mrem	56×10^9/L
10	381 mrem	55×10^9/L
11	396 mrem	54×10^9/L
12	401 mrem	31×10^9/L
13	443 mrem	33×10^9/L
14	459 mrem	30×10^9/L
15	713 mrem	28×10^9/L
16	801 mrem	25×10^9/L
17	830 mrem	22×10^9/L
18	897 mrem	20×10^9/L
19	1129 mrem	15×10^9/L
20	1422 mrem	12×10^9/L

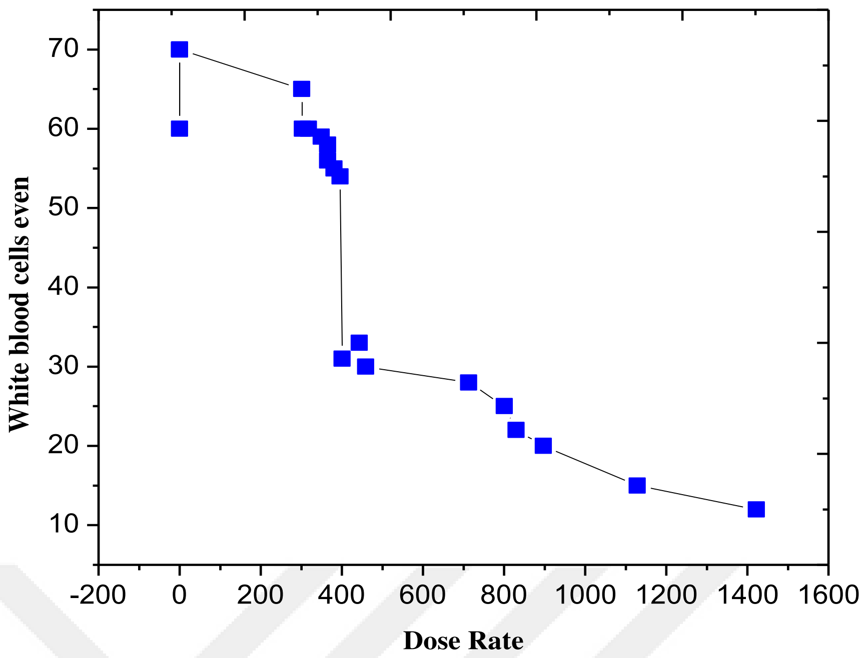

Figure 4.6 The variation of WBCn with the dose rate

4.7 White Blood Cells Lymphatic (WBCl), Unicellular (WBCu) and Acidity (WBCa)

White blood cells lymphatic (WBCl) a WBC helps in the fight infection by surrounding and killing foreign cells or micro-organisms that remove dead cells and stimulate other immune system cells. Macrophages develop from monocytes that have moved from the blood into tissues (Swartz 2001).

White blood cell unicellular (WBCu) is another type of white blood cell stimulating osteoclasts cells to dissolve bones. They are the biggest WBCs. Their diameter range is from 10-30μ and are usually known as scavenger cells or phagocytes. They have a rarely or barely lobed nucleus. The nucleus in monocytes is usually bend-shaped (horseshoe) or kidney-shaped (reniform). Two cell kinds can be made from monocyte cells: macrophages and dendritic (Van Brussel *et al.* 2013).

White blood cell acidity (WBCa) is another white blood cell for releasing toxins from its granules to kill pathogens, like parasites and worms. They are visible in stained smears by through their big granules. Nuclear material band connects two lobes in the eosinophil nucleus. The diameter range is often for between 9–15 μ accounting between 1%–4% of the peripheral WBCs (Al-Dulaimi *et al.* 2018).

The values of white blood cells lymphatic (WBCl), unicellular (WBCu), and acidity (WBCa) with a dose rate of exposed X-ray for 20 technicians are tabulated in Table 4.7, Table 4.8, and Table 4.9, respectively. It is obtained that the WBCl, WBCu, and WBCa increased with increasing exposure dose rate, which that proven by Figure 4.7, Figure 4.8, and Figure 4.9 indicating that the immune system is important to combat the radiation-induced adverse effects in blood. Where big radiation exposure was recorded at WBCI degree 1422 mrem it is 73×10^9/L and the greatest radiation exposure was recorded at WBCu degree 1422 mrem it is 14×10^9/L and where greatest radiation exposure was recorded at WBCa degree 401 mrem it is 4×10^9/L. The immune response may be found whenever the body is under stress (Hekim *et al.* 2015). The normal number of WBCl, unicellular, WBCu, and WBCa are 1-48×10^9/L, 0.2–$0.8\text{x}10^9$/L, and 0–$0.5\text{x}10^9$/L respectively, therefore the high X-ray exposure affects the WBCl, WBCu and WBCa. This result agrees with the researches (Sharma *et al.* 2019).

Table 4.7 The value of WBCl with the exposed dose rate for 20 technicians

SAMPLE NUMBER	DOSE RATE	WHITE BLOOD CELLS LYMPHATIC
1	0 mrem	18×10^9/L
2	0 mrem	20×10^9/L
3	0 mrem	30×10^9/L
4	301 mrem	25×10^9/L
5	303 mrem	25×10^9/L
6	318 mrem	24×10^9/L
7	349 mrem	26×10^9/L
8	365 mrem	28×10^9/L
9	381 mrem	29×10^9/L
10	381 mrem	30×10^9/L
11	396 mrem	35×10^9/L
12	401 mrem	42×10^9/L
13	443 mrem	49×10^9/L
14	459 mrem	51×10^9/L
15	713 mrem	55×10^9/L
16	801 mrem	60×10^9/L
17	830 mrem	62×10^9/L
18	897 mrem	64×10^9/L
19	1129 mrem	70×10^9/L
20	1422 mrem	73×10^9/L

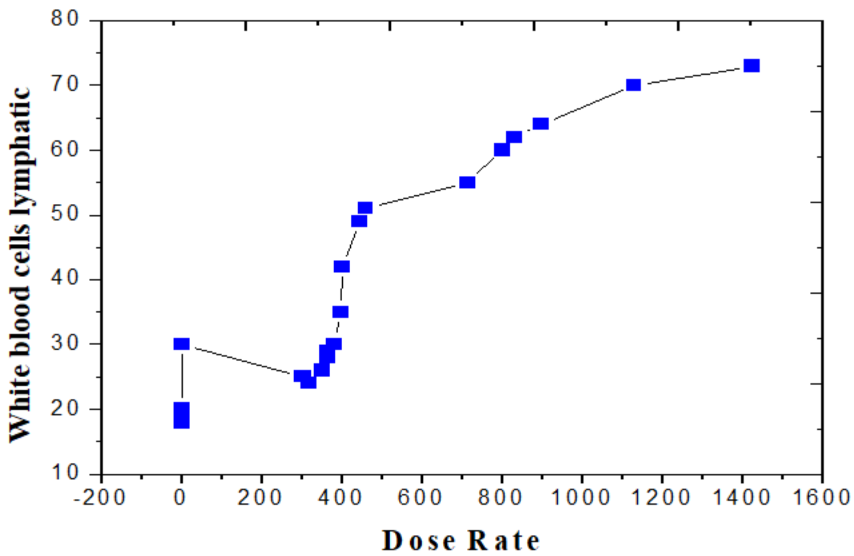

Figure 4.7 The variation of WBCl with the dose rate

Table 4.8 The value of WBCu with the exposed dose rate for 20 technicians

SAMPLE NUMBER	DOSE RATE	WHITE BLOOD CELLS UNICELLULAR
1	0 mrem	1×10^9/L
2	0 mrem	1×10^9/L
3	0 mrem	2×10^9/L
4	301 mrem	1×10^9/L
5	303 mrem	1×10^9/L
6	318 mrem	1×10^9/L
7	349 mrem	2×10^9/L
8	365 mrem	1×10^9/L
9	381 mrem	0×10^9/L
10	381 mrem	1×10^9/L
11	396 mrem	1×10^9/L
12	401 mrem	6×10^9/L
13	443 mrem	3×10^9/L
14	459 mrem	5×10^9/L
15	713 mrem	6×10^9/L
16	801 mrem	7×10^9/L
17	830 mrem	7×10^9/L
18	897 mrem	11×10^9/L
19	1129 mrem	12×10^9/L
20	1422 mrem	14×10^9/L

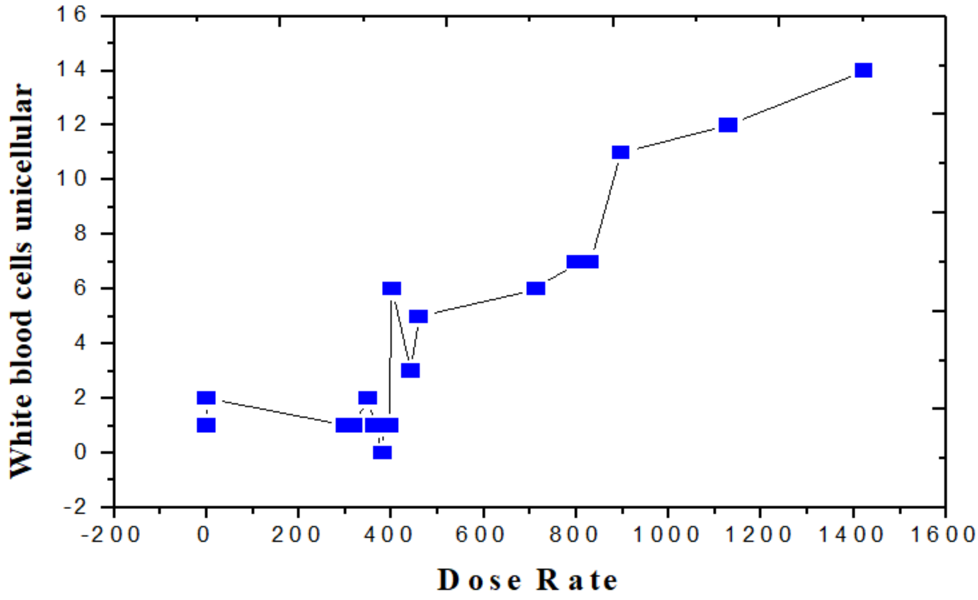

Figure 4.8 The variation of WBCu with the dose rate

Table 4.9 The value of WBCa with the exposed dose rate for 20 technicians

SAMPLE NUMBER	DOSE RATE	WHITE BLOOD CELLS ACIDITY
1	0 mrem	1×10^9/L
2	0 mrem	1×10^9/L
3	0 mrem	1×10^9/L
4	301 mrem	1×10^9/L
5	303 mrem	1×10^9/L
6	318 mrem	1×10^9/L
7	349 mrem	1×10^9/L
8	365 mrem	1×10^9/L
9	381 mrem	1×10^9/L
10	381 mrem	0×10^9/L
11	396 mrem	1×10^9/L
12	401 mrem	4×10^9/L
13	443 mrem	2×10^9/L
14	459 mrem	2×10^9/L
15	713 mrem	1×10^9/L
16	801 mrem	2×10^9/L
17	830 mrem	2×10^9/L
18	897 mrem	3×10^9/L
19	1129 mrem	0×10^9/L
20	1422 mrem	1×10^9/L

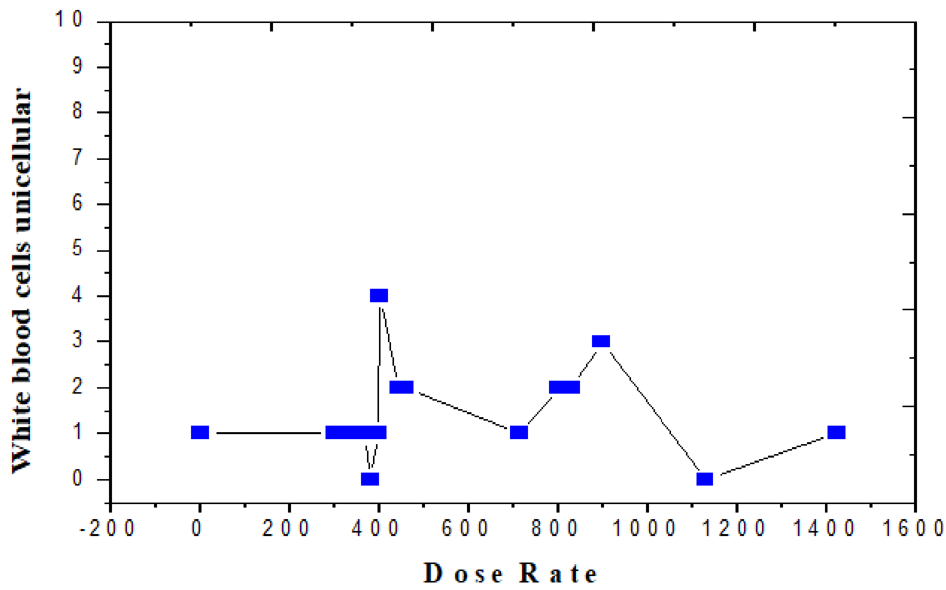

Figure 4.9 The variation of WBCa with the dose rate

4.8 White Blood Cells Basal (WBCb)

White blood cells basal (WBCb) secrete anticoagulant substances and antibodies to protect from hypersensitivity reactions in the bloodstreams. They are the smallest granulocytes that circulate. This cell has large and diverse basal granules, so they often protect the nucleus. The nucleus usually has two lobes or is unsegmented hardly divided into three or four lobes. The diameter tange is 10–15 µ (Al-Dulaimi *et al.* 2018).

Table 4.10 tabulated the white blood cells basal (WBCb) with the dose rate of exposed X-ray for 20 technicians. It is obtained that the WBCb with low dose exposure up to 349 mrem is equal to zero, there is not seen and then increased to 1 at 1422 mrem White blood cells basal that is seen in Figure 4.10. Where the highest rate of exposure to radiation was recorded at degree 459 mrem it is 2×10^9/L. This may be due to the fact that basophils are typically not present among the granulocytes in peripheral blood, so their lack is usual (El-Shanshoury *et al.* 2016). The normal number of WBCb is 0 to 0.20×10^9/L, therefore the exposure of high X-ray effect the WBCb. Similar results have been observed in earlier investigations (Rozgaj *et al.* 1999).

Table 4.10 The value of WBCb with the exposed dose rate for 20 technicians

SAMPLE NUMBER	DOSE RATE	WHITE BLOOD CELLS BASAL
1	0 mrem	0×10^9/L
2	0 mrem	0×10^9/L
3	0 mrem	0×10^9/L
4	301 mrem	0×10^9/L
5	303 mrem	0×10^9/L
6	318 mrem	0×10^9/L
7	349 mrem	0×10^9/L
8	365 mrem	1×10^9/L
9	381 mrem	1×10^9/L
10	381 mrem	0×10^9/L
11	396 mrem	1×10^9/L
12	401 mrem	2×10^9/L
13	443 mrem	2×10^9/L
14	459 mrem	2×10^9/L
15	713 mrem	1×10^9/L
16	801 mrem	0×10^9/L
17	830 mrem	0×10^9/L
18	897 mrem	0×10^9/L
19	1129 mrem	1×10^9/L
20	1422 mrem	1×10^9/L

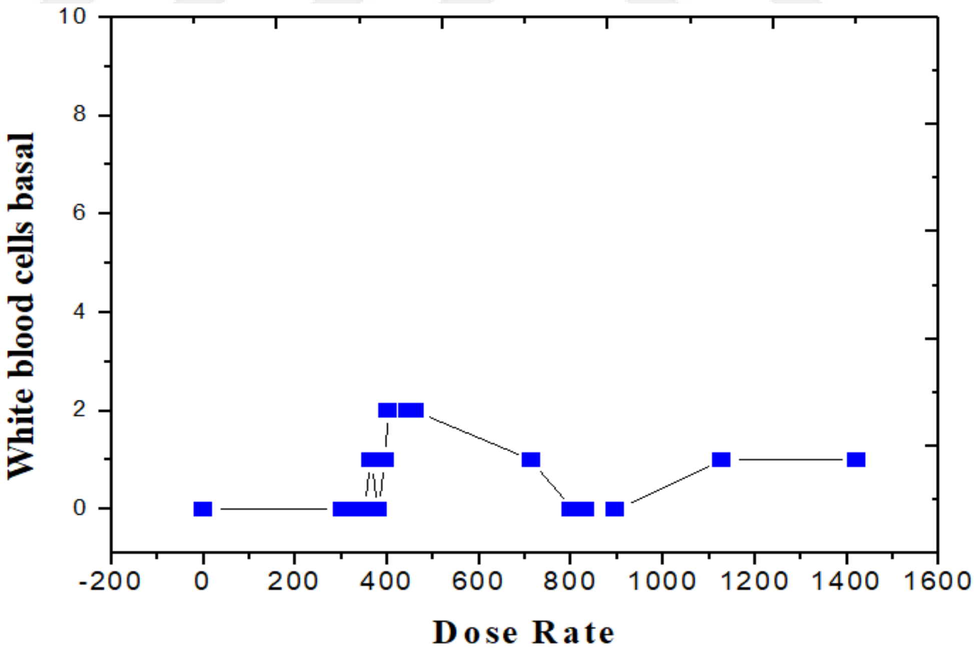

Figure 4.10 The variation of WBCb with the dose rate

5. CONCLUSIONS AND RECOMMENDATION

5.1 Conclusion

The long-term effects of ionizing radiation exposure are particularly sensitive to hematological characteristics. The study described how various hematological parameters in the blood of X-ray technicians were affected by long-term dosages of X-rays (chronic exposure).

The X-ray has an impact on human cells, tissues, and organs, and according to the exposure length, the radiation dose, and other variables, it may be lethal. Radiation-affected blood cells:

- The platelets, HB, PCV, and WBCn were decreased with increasing exposed dose rate that was due to the hematopoietic tissue's high sensitivity to ionizing radiation and the spleen's declining stem cell viability.
- ESR, WBCt, WBCl, WBCa, and WBCu were increased with increasing exposure dose rate that was because of the long time span of radiation exposure.
- WBCb not be affected by the X-ray exposure. This may be due to the fact that basophils are typically not present among the granulocytes in peripheral blood, so their absence is usual.

5.2 Recommendation

- Long-term X-ray impact of exposure on the rheumatoid factor c-reactive protein.
- The impact of X-ray radiation on certain blood variables in humans when compared to controls.
- The medical staff in this field must be changed continuously.
- Always use anti-X-ray clothing in the field.
- Increase the distance between the working person and the device to decrease the influence of X-rays.

- Reducing the exposure time of the person working with the device as the absorbed dose is reduced.
- Do a continuous blood test to measure the severity of the effect.

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APPENDICES

APPENDIX 1. Five variables (Platelet, ESR, HB, PCV, WBC) of those who worked in hospitals in the field of X-rays for two years

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