Volume 1, Issue 1, 2024

Intuitions & Insights

An Interdisciplinary Research Journal

X-Ray: A boon to medical diagnosis

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Abstract: X-ray is a variant of electromagnetic wave. Owing to its high frequency, it possesses high energy enabling it to penetrate through metals, body tissues etc. Almost since its discovery, X-rays had been used in imaging of bone structure in photographic film (X-ray plate) which later have been processed digitally. Use of artificial intelligence has made it possible to construct 3-D radiographic image from a series of 2-D images. Computed Tomography or CT Scan combines X-rays and computer to create cross-sectional picture of different body parts from different angles and different positions. Greater image resolution in CT has paved the way of development of new investigations like CT angiography, virtual colonography etc. Dose of X-rays is scaled down now-a-days to minimize its hazardous effects caused by over exposure to X-rays in CT scanning. For its huge usefulness in medical diagnosis , 8th November (day of discovery of X-rays) is celebrated as 'World Radiography Day' worldwide.

Keywords: X-ray, Radiography, Computed Tomography, Medical Diagnosis.

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Received: 07.09.2023; **Accepted**: 29.01.2024; **Published**: 03.04.2024

1. Introduction

X-ray, the discovery of which marks a milestone in the history of Physics, has completed its 125th anniversary very recently. On 8th November, 1895, X-ray was discovered accidentally by German Physicist Wilhelm Conrad Roentgen, Professor of Physics in Wurzburg, Bavaria while experimenting with cathode rays in his laboratory. This momentous event left an immediate, revolutionary impact in the fields of physics and medicine. Roentgen was awarded the first Nobel Prize in Physics in 1901 for

this discovery.

Fig1. Roentgen with first human X-ray image ofwife's hand*Fig2. Roentgen Memorial—Place of Discovery of X-ray*

Physics of X-ray: X-ray is a kind of electromagnetic radiation of higher frequency range from about 10^{16} Hz to 10^{20} Hz i.e. covering shorter wavelength range from about 10^{-8} m to 10^{-12} m[1]. Like any other electromagnetic wave, X-ray travels with the same speed as that of visible light and is not deflected by electric or magnetic fields. It has ionization ability and undergoes reflection, refraction, diffraction and polarization. One common way of producing X-ray is to bombard a metal target (of high atomic number) by high energy electron beam. Transition of electrons from higher energy shells to lower energy shells, governed by some selection rules, results in emission of X-ray[2].

Energy of an electromagnetic radiation is directly proportional to its frequency. Due to high frequency, X-ray possesses high energy and can pass through most objects including metal and animate entities. Depending upon the medium, it penetrates differently through different objects. This penetrating capability of X-ray has made it a potential candidate to use it as a tool for medical investigations since its discovery [3]. The ability to "see" things, that human eyes cannot see normally, is quite amazing. Fortunately, what the human eyes cannot do, diagnostic imaging tests can--- enable the doctors to see inside the body without opening it up through surgery.

Evolution in Medical imaging: In the initial days, X—ray had been used for medical imaging of bone structure which brought a revolution in medical diagnosis system at that time. This prompted to evolve a new branch called Medical Radiography which has become more and more advanced day by day[4,5]. In a nutshell, in medical radiography, X-rays are converged and projected to a photographic film passing through the part of the body of the patient to be examined. Along its way, the X-ray is absorbed in the body tissues differently depending upon the constituency and density of

the respective parts. The X-rays that emerge out of the target body part fall on the photographic film. After chemical processing of the film, translucent photograph of the part is obtained. This is commonly known as X-ray plate. Now-a-days the photographic film is replaced by a digital receiver and the image is processed digitally instead of chemical development process. It is known as Digital X-ray [6].

Advancements: In present days, in addition to 2-dimensional X-ray plates, 3-dimensional X-ray photography has become possible with the advancement of techniques. Application of artificial intelligence has made Medical Radiography more powerful and versatile. Digital geometry processing can generate a 3-dimensional image of an object inside the body from a series of 2-dimensional radiographic images. This 3-dimensional image has come out to be very effective for diagnostic purposes in several situations. Conventional 2-dimensional X-ray photography and Computed Tomography (CT scanning) are the most common investigations that medical practitioners need for diagnosis before starting the proper treatment [7].

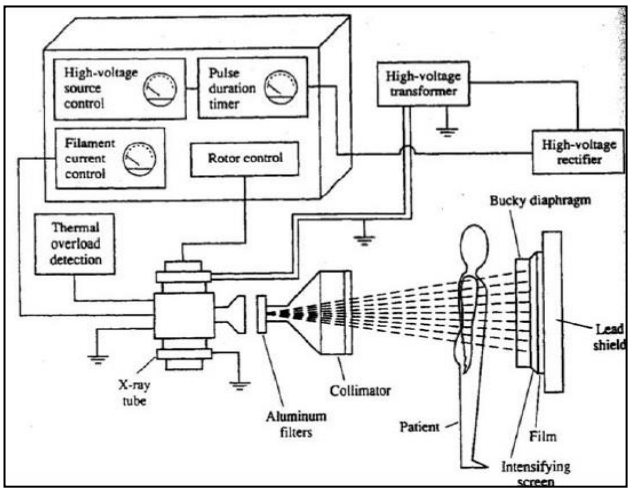

Fig.3. Projectional Radiography

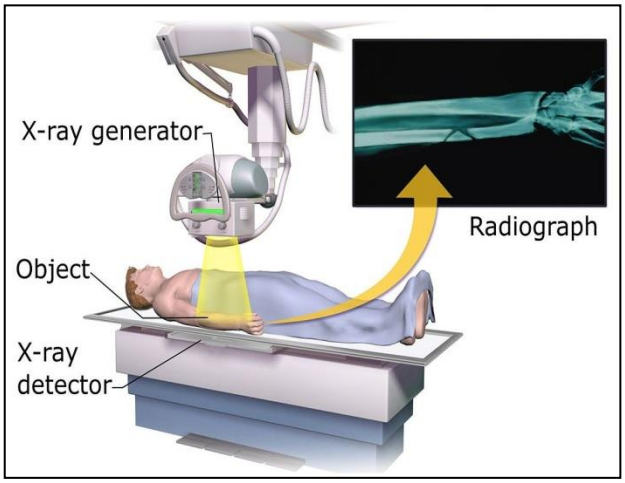

Fig.4 Block diagram of a typical X-ray machine

Projectional Radiography is the practice of 2-dimensional imaging of the body's internal structures using X-ray which is often used to see bone fracture, to look at implanted devices such as artificial knee or hip or metallic plates inside the body, to look for foreign body (objects in the body that is not supposed to be there) etc. It can also detect soft tissue malformation as well physiological and pathological changes in the body. A typical projectional radiography system consists of X-ray tube where X-ray is produced and converted to comparatively low energy X-ray (~5 KeV), Collimator for focusing X-ray to a certain direction on a particular portion of body of the patient, Table and/or wall

stand (for patient to lie down or stand) , Image Detector to collect X-ray that went through the patient to form image[8]. Conventional X-ray images can be very useful to doctors in evaluating symptoms that originate inside the body as well as diagnosing injuries. But sometimes there is necessity to go beyond a conventional2-dimensional image to visualize the actual situation inside the body.

Fig5. A modern X-ray machine

Tomography is the solution to this problem. Tomography is the method of producing a 3-dimensional image by sections or sectioning [9]. CT Scan or Computed Tomography formerly known as CAT (Computed Axial Tomography), developed by South African American Physicist Allan M. Cormack and British Engineer Godfrey Hounsfield , is a modified X-ray system- a combination of X-ray and a computer to create cross sectional picture of a body part like bones, blood vessels and soft tissues. CT scanner is a large dough nut shaped machine with a moving platform for a patient to lie down. The platform with the patient travels through the centre of the scanner. Here the X-ray machine itself revolves around the moving platform. In this way it captures multiple X-ray images of the object from

Fig.6 A CT Scan machine

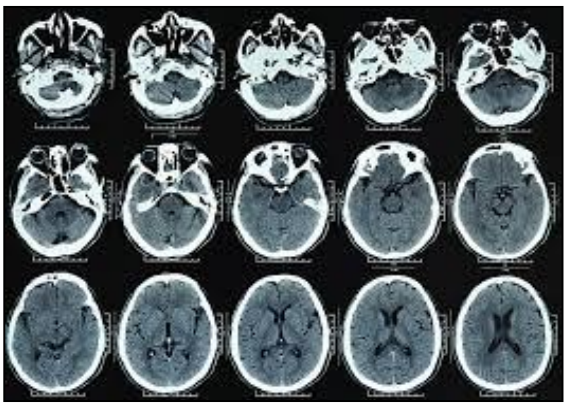

Fig. 7.A computed Tomography of Brain

different angles and different positions. A computer analyses all the information received and then process to produce detailed cross-sectional images of different body parts. Like a piece in a loaf of bread, this 2-dimensional scan shows a 'slice' of the inside of the body. Although the principle of imaging in CT scan is same as X-ray radiography, here processing is done solely by a computer. 2-Dimensional images or conventional images can be taken out in printed form but the 3-Dimensional images of CT Scan are available in computer only. CT scan has greater image resolution with finer details compared to traditional 2-dimensional medical radiography. This improved resolution of CT has permitted the development of new investigations such as CT angiography, virtual colonoscopy etc[10]. That's why the use of CT scan has dramatically been increased throughout the world during the last decade.

Risks and safety measures: There is a reverse side of the coin also. As X-ray damages or destroys living tissues and organisms, over exposure to X-ray causes damage to tissue protein which slightly increases the risk of cancer[11]. Compared to conventional radiography, CT scan exposes a subject to much more radiation as multiple X-ray photographs are taken in this case. One CT scan exposure may be considered as roughly equivalent to four hundred normal X-ray photographs. Exposure to high radiation levels can have a range of effects such as vomiting, bleeding, fainting, hair loss etc. However with advancement of technology, this exposure risk is being minimized using very low dose radiation. Recent research claims that this exposure is not enough to cause any long lasting damage[12].

Impact and relevance: Overall, this age-old, low-cost technique of imaging is far more beneficial than it is dangerous. It has been proved to be a boon in medical science saving millions of lives and is still relevant in diagnostic purposes in spite of invention of advanced imaging processes like MRI (Magnetic Resonance Imaging), PET (Positron Emission Tomography) or DSA (Digital Subtraction Angiography) etc. In spite of its disadvantages, X-ray is very useful for diagnosis purposes if used in safest and controlled environment as much as possible. With this motto, 8thNovember (anniversary of discovery of X-ray) is celebrated worldwide as "World Radiography Day" since 2007 to raise public awareness of radiographic imaging and therapy.

Acknowledgement: The author is highly obliged to Dr. S.N. Saha, CMO, CMS Cell, ECL Headquarters, Sanctoria, Paschim Bardhaman", for his help.

Acknowledgement: The author give a sincere thanks to the respected Editors and Reviewers for their valuable suggestions to improve the quality of the work.

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