**X-Ray Radiology**

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X-Ray technology was first discovered in Germany by a scientist named Wilhelm Conrad, who was the director of the physics institute at the University of Weurzburg [11]. His specific interest of research regarded high voltages of electricity in tubes which have had some of the air inside of them extracted [11]. In November of 1895, he turned on the electricity in the tube he was currently working with to make sure that the electricity was moving through the tube [11]. When he did this the tube illuminated with light indicating that the electricity was moving though, and Conrad decided to place a piece of black cardboard in front of the illuminated tube [11]. When he did this, he noticed a glow from a paper coated with barium platinum cyanide some distance away from the tube, and soon realized he had discovered a different kind of radiation [11]. He worked to understand this radiation and eventually discovered that if he placed his hand between the barium platinum cyanide paper and the tube, he could see the bones of his hand; his wife’s hand was the first ever radiograph of a living person’s body [11]. After publishing his work, scientists around the world began creating their own X-Ray devices [11]. In the beginning, many people were skeptical of the devices, and X-rays were even used for entertainment purposes as people would go to get their own bone portraits [4]. However, some scientists did see the potential of X-Ray technology for medical purposes, and on February 3rd, 1896, the first medical X-Ray was performed at Dartmouth college which presented a fractured bone in a patient’s hand [4].

The mechanism behind an X -Ray involves a source of electrons, an increase in acceleration of the electrons and a rapid decrease in acceleration of the electrons [2]. The electrons, along with the events of acceleration and deceleration take place in an X-Ray tube [2]. On one side of the X-Ray tube there will be a cathode, and on the other side there will be an anode [2]. The electrons are first generated in the cathode portion of the X-Ray tube [2]. The cathode is connected to an electrical circuit which contains a generator that receives current from a power source and converts it to direct current before it reaches the cathode [9]. In this portion, thermionic emission occurs where electrons are released in response to heat created from an electric current in the cathode metal [2]. The electrons which are released from the metal create an electron cloud [2]. To accelerate the electrons at an extremely high speed, there is a large negative charge in the X-Ray tube [2]. The electrons will repel this negative charge and will be attracted to the positive charge on the anode, and therefore will quickly accelerate to the other side of the tube [2]. When the electrons hit the anode, and abruptly decelerate, the kinetic energy they contained while accelerating through the X-Ray tube will now be released as heat and X-Rays [2].

The number of X-Rays which will be produced depends on the current in the tube which causes the separation of the electrons from the metal in the cathode [2]. If the current is increased, the number of electrons separated from the metal will increase, causing more X-Rays to be emitted [2]. If the voltage difference or the potential in the X-Ray tube is increased, the energy which the electrons hold will increase, and the energy of the X-Rays emitted will increase as well [2]. The fraction of energy which is converted to X-Rays depends on the energy that the electrons hold, and the atomic number of the anode [9]. Most X-Ray models use a rhenium tungsten alloy as the anode material because it has a high atomic number of 74, it can keep strength at high temperatures, has a high melting point and a low rate of evaporation [9]. These characteristics convey that tungsten is suited to withstand the high temperatures created by the electron beam, and that it has the capability to efficiently produce X-Rays [9].

The X-Rays which are emitted are electromagnetic waves that have very short wavelengths, because when the electrons hit the tungsten anode, they experience a large drop in energy [8;10]. The short wavelengths allow the rays to move through most of the tissues in the body unchanged [10]. If the rays interact with material, they lose photons either by absorption or scattering; this loss of photons is called the attenuation of the X-ray beam [5]. The calcium in bones is denser than most other materials in the body; therefore, it does not allow X-Rays to pass through readily, and instead absorbs photons from the X-Ray beam [10]. This creates a shadow behind the bones which can be detected and is the reason why X-Rays can provide an image of human bones [10]. The absorbance of photons of material which comes in contact with X-rays is given by the Beer-Lambert equation:

Where A is the photons which hit the material originally minus the photons which fully pass through the material, ε is the molar absorption coefficient, c is the molar concentration, and l is the optical path length. If a material has a larger thickness or a larger absorption coefficient, the absorbance of the material will be greater, and less photons from the X-Ray beam will pass through the material [7]. The absorbance of a material is then related to transmittance by the following:

Where T is the transmittance, given by the ratio of the transmitted intensity over the initial intensity of the X-Ray beam [7].

Medically used X-Ray machines contain a circular disk rhenium tungsten alloy anode, most commonly a glass X-Ray tube and a coil of wire with a cupped portion cathode [8;9]. Since the electrons’ collision with the tungsten creates a great amount of heat, there is a mechanism which rotates the anode so that the electrons do not always hit the same spot to keep it from melting [8]. The tube portion and a surrounding cool oil also aid in dissipating the heat in the apparatus [9]. The portion of the anode that the electron stream hits is called the focal point of the anode [9]. Although the focal point only ranges from about .1mm to 2mm, a smaller focal point will provide a more precise image; whereas, a larger focal point will have a better ability to dissipate heat on the anode [9]. The entire X-Ray tube, including the cathode and anode, is enclosed by lead, except for a small opening, to ensure that the X-Rays do not scatter everywhere [8]. The small opening allows X-Rays to escape, but there are a series of filters the rays go through before reaching totally outside of the machine [8]. After the rays travel out of the machine, they are directed towards the area of interest in a person [8]. There is a detector which records the X-Rays that pass through the area of interest [8]. For better viewing, the image is usually a negative, meaning that the parts of the body which transmit more X-Rays such as muscles, appear dark, while the parts of the body which absorb more X-Ray, such as bones, appear light [8]. The quantities which can be adjusted on X-Ray machines are the electrical potential in the tube, the electrical current through the tube, and the time that the X-Ray beam is placed on a surface [9].

Although all X-Ray procedures work on the same basis of a detector recording the image that represents photons which have passed through the body versus photons which have been absorbed, there are numerous medical uses of X-Ray technology, including radiography, CT, and fluoroscopy [1]. Radiography results in just a single picture captured by a detector or a film behind the body; these pictures are processed by a computer and are later evaluated by a medical professional [1]. This method is commonly used to detect broken or fractured bones in the body, but can also be used to detect bone cancer, and check the alignment of structures in the body [12]. CT scans are composed of many X-Ray images taken while a detector is moved around an individual’s body [1]. When a CT scan’s many pictures are processed through a computer, they can create cross sectional images which are 3-dimensional, providing a much more detailed image than normal radiography can produce [3]. This method is commonly used to diagnose places of discomfort in the body, or to test the progression of disease or tumor in the body [3]. Fluoroscopy is a technique where X-Rays are used to create real time imaging, usually used for monitoring purposes or during procedures [1]. Fluoroscopy is often used in conjunction with a contrast media [8]. The contrast media is a substance which absorbs X-Rays and can be put in the body [8]. With fluoroscopy, the movement of this substance can be seen in real time [8]. Some specific uses of fluoroscopy include the monitoring of blood movement through arteries, the detection of foreign bodies, as an aid for doctors when giving injections, or guiding a catheter through the body [6].

X-Rays provide an easy and efficient way for doctors and health care professionals to diagnose or rule out a diagnosis for patients. The procedure of taking an X-Ray is quick, noninvasive, and the equipment is relatively inexpensive [12]. Also, X-Ray machines are abundant and present in most hospitals and in many medical offices [12]. However, there are some limitations and drawbacks to X-Ray methods for diagnosis. When a person is exposed to ionization radiation, which is the kind of radiation that X-rays are, there is a risk that the exposure to radiation can alter DNA and cause cancer [12]. Although exposure to radiation can cause cancer, X-Ray related cancer incidences are rare [13]. However, children are more susceptible to the radiation effects [13]. Radiation in the long term can also cause vomiting, hair loss, and bleeding along with many other symptoms [13]. The radiation from a usually medical X-Ray is a low dosage of radiation though, and it is not likely that someone will experience these symptoms [13]. Also, the largest limitation regarding X-Rays is that they do not give much information about any part of the body that does not have a high X-Ray absorbance, such as muscles and tendons do [12]. For injuries which do not involve parts of the body with high X-Ray absorbance, usually a more expensive MRI is needed for a diagnosis. [12].

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