**X - Ray machine**

- X-rays from nature come from extraterrestrial sources, such as distant suns and stars, however these x-rays simply contribute to background radiation that is all around us. The ground and soil are also sources of natural background radiation. Depending on where a person lives will determine how much exposure they will receive from natural background radiation sources, however this type of exposure is typically not dangerous. Medical x-rays come from a machine that is designed to emit radiation on command.
in the previous lecture, we discussed how x-rays are generated at the atomic level. Here, we will begin the discussion on the major components of the x-ray machine. Conventional x-ray radiography produces images of anatomy that are shadow grams based on x-ray absorption. The x-rays are produced in a region that is nearly a point is source and then are directed on the anatomy to be imaged. The x-rays emerging from the anatomy are detected to form a two-dimensional image, where each point in the image has a brightness related to the intensity of the x-rays at that point.

Image production relies on the fact that significant numbers of x-rays penetrate through the anatomy and that different parts of the anatomy absorb different amounts of x-rays.
• **X-Ray machine shape & size:**

• The function of the x-ray machine is to provide a sufficient intensity of electron flow in a controlled manner to produce an X-ray beam of desired quantity and quality. The many different types of x-ray machines are usually identified according to either the energy of the x-rays they produce or the purpose for which those x-rays are identified. Diagnostic x-ray machines come in many different shapes & sizes, they are usually operated at maximum voltage ranging from 25 to 150 KVp and at tube currents from 25 to 1200 mA. Therapeutic X-ray machine, on the other hand, can be operated at higher or lower Voltage but at tube currents not exceeding 20 mA.
• The modern general x-ray examination room usually contains a radiographic unit and a fluoroscopic unit with an electronic image intensifier. The fluoroscopic X-ray tube is usually located under the examining table. The head of the radiographic tube is attached to an overhead movable crane assembly that permits easy positioning of the tube and aiming of the X-ray beam. Rooms with a fluoroscopic examining table and two or more overhead radiographic tubes are generally employed for special and vascular neurologic examination.
Principle parts of X-ray machine:

Every x-ray machine, regardless of its design, has three principle parts:

- The X-ray tube
- The control console
- The high-voltage section or generator

In some X-ray apparatus, such as dental and portable machines, these three components are housed compactly. Most, however, have the head of the X-ray tube located in one room, the control console in an adjoining room, and a protective barrier separating the two.

The protective barrier must have a window for viewing the patient during examination. The high-voltage generator may be housed in a cubicle container, perhaps 1 m on a side located in the corner of the examination room.
• X-Ray tube
• X-Ray tube consists from four major components:
  • Cathode
  • Anode
  • Glass Envelope
  • Protective housing

Fig. (1): illustration of x-ray tube components.
• **Cathode:**
• The cathode is the negative side of the x-ray tube because it is a source of electrons and has two primary parts: filament & focusing cup.

• **The filament:**
• is a coil of wire usually about 2 mm in diameter and 1 to 2 cm long. An X-ray filament emit electrons when it heated. When the current through the filament sufficiently intense, approximately 4 A and above, the outer - shell electrons of the filament atoms are literally boiled off and ejected from the filament. this phenomenon is known as thermionic emission. Filaments are usually made of thoriated tungsten because its melting point is 3410°C, and therefore it is not likely to burn-out. Also tungsten doesn't vaporize easily, if it did, the tube would quickly become gasy and its internal parts coated with
Fig (2): principle parts of x-ray machine.
• The focusing cup:
• When the x-ray machine is powered up, electrons will literally "boil"-off the filament. It glows white hot and the electrons hover around the filament in a "space charge" until the moment of exposure and then they accelerate very rapidly towards the anode which is not very far away. This process is known as "thermionic emission". Thermionic emission occurs when the technologist begins to make an exposure by pressing the "ready" button on the machine. The filament is embedded
in a metal shroud called the focusing cup to eliminate the space charge and concentrate the electron stream in a pre-determined area on the anode target area known as a "focal spot". Since all the electrons accelerated from cathode to anode are electrically negative, the beam tend to spread out owing to electrostatic repulsion and some electrons can even miss the anode completely, the focusing cup is negatively charged so that it condenses the electron beam to a small area of the anode, Figure (4). The filament has its own circuit powered by a relatively low voltage and 4-6 amperes.
Fig. (4): filament without and with a focusing cup.
- tungsten. This is the most common cause of tube failure, the addition of 1% to 2% thoruim to the Tungsten filament increases efficiency of thermionic emission and prolongs tube life.
- Fig. (2) shows a magnified view of the cathode face and it shows dual filaments. Only one filament at a time will work. The small filament is designed to be used with relatively small parts while the large filament is used when larger body parts are being x-rayed.
Fig. (2): Dual filaments.
• The number of electrons that are released will directly influence the number of x-rays that are generated and therefore the dose of radiation also. Figure (3) shows how a low mA will result in fewer x-rays being produced and a high mA will result in a greater number of x-rays. The term ma is a unit of measure of electrical current that is used when the technologist selects the exposure factors.
Fig. (3): Effect of low & high MA on the number of x-rays.
• Fig. (6) please note that as the angle of the anode decreases from 24 degrees to 12 degrees.

• degrees, the focal spot will appear smaller because you are looking up at it at an an angle or obliquely. As the angle decreases, you actually see less of the focal spot dimensions and this will actually enhance the recorded details on the image. In general, the smaller the focal spot is, either real or as changed by the line focus principle, the better the detail will be on the finished image.

• The anode must be a good thermal conductor, when the electrons comprising the tube current slam into the anode more than 99% of their kinetic energy is converted into heat. This heat must be conducted away quickly before it can melt the anode. coppers the most common anode material.
• **Target:**
• The target is the area of the anode struck by the electrons from the cathode. In stationary-anode tubes the target consist of a tungsten-alloy metal embedded in the copper anode. In rotating-anode tubes the entire rotating disc is the target. Alloying the tungsten (usually with rhenium) gives it added mechanical strength to withstand the stress of high rotation.
The Benefits Of Using Tungsten As A Target Material

Atomic number:
- Tungsten's high atomic number, 74, results in higher-efficiency x-ray production and in higher-energy x-rays.

Thermal conductivity:
- Tungsten's has a thermal conductivity nearly equal to that of copper; it is therefore an efficient metal for dissipating the heat produced.

High melting point:
- Any material, if heated sufficiently, will melt and become liquid. Tungsten has a high melting point (3410 C°) and therefore can stand so under high tube current without pitting or bubbling.

Resists vaporization at high temperatures
- It is availability makes it cost-effective
• The focal spot:
• The focal spot is the area of electron interaction and emanation of x-rays from the target surface. Typical dimensions are nominal sizes of 1.0- to 1.2-mm (large) and 0.3 to 0.6-mm (small) focal spots, where nominal encompasses a range of focal spot sizes that are as acceptable according to manufacturer standards. Ideally, the use of small focal spots is preferred to minimize geometric blurring of patient anatomy with magnification. However, the small focal area constrains x-ray tube output and heat loading factors, mainly due to heat concentrated in a small area. Larger focal spots have higher instantaneous x-ray production capacity and are preferred, as long as blurring does not adversely affect resolution.
• The focal spots which are imbedded in the rotating anode disc are angled in such a way that when the electrons strike the anode focal track, the angle makes it easier for the x-rays to be emitted in a downward direction.
Fig. (6). Anode Angle versus Focal Spot Size
• However depending on the angle of the anode face, this will change the appearance of the focal spot as seen from below or where the x-ray image receptor is positioned. The anode angle and the resulting appearance of the focal spot as it would appear from the image receptor is known as the line Focus Principle'. in the

• Excessive radiation exposure
• Electric shock
• The protective housing also provides mechanical support for the X-ray tube and protects the tube from damage caused rough handling. The protective housing around some x-rays tubes contains oil that serves as both an electrical insulator and a thermal cushion. Some protective housings have a cooling fan to air-cool the tube or the oil in which the x-ray tube is immersed
• The distance between the cathode and the rotating anode disc is very close. This is designed this way to ensure that the projectile electron stream has a reasonably good chance of arriving at the anode in a relatively tight pattern. If the electrons were permitted to spread out, then the x-ray production process would become very inefficient.

• Another important device that limits the beam to a specific size called collimator. The collimator has a series of metal leaves that overlap to different sizes. The technologist can adjust the field of radiation to whatever size image receptor (film) is being used.

• Collimators can also function automatically in that when the film is positioned in the table film tray, the collimator can sense the dimensions of the image receptor and limit the beam to that size. This is known as PBL or positive beam limitation.
• **Glass envelope:**

• Is the container of the x-ray tube components, which supports the anode and cathode structures. which is usually made of Pyrex glass to enable it to withstand the tremendous heat generated, maintains a vacuum inside the tube, this vacuum allows for more efficient x-ray production and longer tube life. if the tube were filled with gas the electron flow from cathode to anode would be reduced, fewer x-rays would be produced and more heat would be created.
• A recent improvement in tube design incorporates metal rather than glass as part or all of the envelope. As glass envelope tubes age, some tungsten vaporizes and coats the inside of the glass envelope. This alters the electric potential of the tube, allowing tube current to stray and interact with the glass envelope, the result is arcing and tube failure.

• Metal envelope tubes maintain a constant electric potential between the electrons of the tube current and the envelope.
• **Anode Heel Effect**

• One unfortunate consequence of the line-focus principle is that the radiation intensity on the cathode side of the x-ray tube is higher than the anode side.

• The heel effect should be considered when positioning areas of the body with different thickness or density.

• The cathode side should be over the area of greatest density.
• **Causes of X-ray Tube Failure**
  
• All causes of tube failure relate to the thermal characteristics of the tube.

• When the temperature of the anode during a single exposure is excessive, localized melting and pitting occurs.

• These surface irregularities lead to variable and reduced radiation output.

• If the melting is severe, the tungsten vaporizes and can plate the port. This can cause added filtering or interference with the flow of electrons.

• If the temperature of the anode increases too rapidly, the anode can crack and then become unstable in rotation.
The operating console

• The operating console is the apparatus that allows the technologist to control the X-ray tube current & voltage so that the useful x-ray beam is of proper intensity and penetrability is attained to produce a good quality radiograph. The console usually: - provides control of line compensation, Kvp. mA, and exposure time.
The operating console

• It is a separate unit connected electrically to the X-ray machine. Control of x-ray energy and quantity is attained through adjustments of the voltage potential in kilovolts (kV), the x-ray tube current in mill amperes (mA), and the exposure time in seconds (s), by meters and switches contained in the operating console to select kVp, mA and exposure time, respectively, at the X-ray generator console. Several electrical circuits and voltage transformers within the x-ray generator assembly provide this capability. Figure illustrates the major x-ray operating console components.
Fig. major operating console components.
• The control panel vary with the type of X-ray machine, but more often following components, or some of them exit:

• *On-Off switch: It is a main switch to turn the unit on. The switch permits flow of current to the tube at 'on' position and prevents the same at 'off' position. For the safely of the X-ray tube and also to avoid an accidental exposure, the switch should remain in 'off' position when the machine is not being used.

• *Voltmeter and voltage compensator control: Most X-ray machines are designed to operate on a 220 voltage power source. A voltmeter measures the voltage of electric Current and voltage compensator allows adjustment of voltage. In most machines these days such a system is automatic.
• The Line Compensation compensates the incoming voltage so that a constant voltage may be used during exposure and not a varying voltage. Most x-ray machines are designed to operate on a 220V power source, although some can operate on 110V or 440V. Unfortunately, power companies are not capable of providing 220V accurately and continuously. Because of variations in power distribution to the hospital and in power consumption by the various sections of the hospital, such variation in input voltage results in larger variation in x-ray output. Which is unacceptable if high-quality radiographs are to be consistently produced.
• The line Compensator a meter to measure the voltage provided to the unit and a control to adjust that voltage to precisely 220V. The control is wired to the autotransformer shown in (Fig. 2).
• **Kilovolt age selector:** It allows precise selection of desired kV. In some machines) this control is automatically linked to a certain milliamperage (mA) value. In such a case, a high kVp is available at a relatively low mA and vice versa. In the modern type of X-ray apparatus and in those operating on a pre-determined milliamperge the kilovolt age control will be directly calibrated (usually in ascending ok 5V values) so that the described value can be easily selected.
X-Ray operating consoles usually have adjustments labeled major KVp and minor KVp, and by selecting a combination of these controls the technologist can provide precisely the required KVp. The major KVp adjustment and the minor KVp adjustment represent two separate series of taps of the autotransformer. Selection of the appropriate taps can be made by an adjustment knob or by a push button. If the primary voltage to the autotransformer is 220V, the output of the autotransformer can be controlled from about 100 to 400V depending on the design of the autotransformer. This low voltage becomes the input to the high-voltage step-up transformer in the high-voltage section that increases the voltage to provide the kilovolt age required.
Autotransformer

- The power supplied to the x-ray machine is delivered to a special transformer called an autotransformer. The autotransformer is designed to supply voltage of varying magnitude to the several different circuits of the x-ray machine, most prominently the filament circuit and the high-voltage circuit. The voltage supplied to the high-voltage transformer is controlled and variable. It is much safer and easier in terms of engineering to vary a lot voltage and then increase it than to increase a low voltage to the kilovolt level and then vary its magnitude.
• **The effect of kilovolt age**

• As already stated. It is the passage of a high voltage current across an X-ray tube which results in a production of X-rays. The higher the kilovolt age employed for this purpose, the more rapidly the electrons travel, the greater the amount of energy released on impact, and the shorter the wave-length of the X-rays produced x-rays of short wave-length are sometimes described as "hard X-rays" while those of longer wave-length may be spoken of as "soft".
Fig (2) : components of X-ray circuits
• **Milliammeter and milliamperage control:**

• X-Ray tube current is controlled through a separate circuit called filament circuit. It indicates the current passing through the tube during an actual X-ray exposure. Voltage for the filament circuit is provided from taps of the autotransformer. Fig1
• **The Villiameter and the Milliamperge Selector**

• It will be found that the small and medium sized X-ray apparants cannot be set to operate at maximum milliamperge and maximum kilo voltage simultaneously.

• The significance of the minilliamperge is that it affects the amount of X-rays produced and a level has to be selected which is sufficient to produce an easily recognizable image on the X-ray film without obliterating that image by over exposures. However, the amount of radiation is also controlled by the length of the exposure and is best to be expressed in milliamperge-seconds (i.e., the milliamperge multiplied by the time in seconds).
• **The effect of Milliamperage:** The amount of current which travels across an X-ray tube during an exposure depends on the number of electrons available to carry that current, which in turn varies with the current supplies to the filament in the cathode. The tube current (measured in milliamperes) is directly related to the amount of X-rays produced.

• The above effect are often summarized by stating that kilovoltage affects the quality and the milliamperge (more correctly the mAs) the quantity of the X-ray produced by a particular apparatus.

• electronic switches (called triodes or tetrodes) are
• Timer and exposure button:
• In any given radiographic examination, the quantity of X-rays reaching the film is directly related to the X-ray, tube current and the time for which the tube is energized i.e. the exposure time.
• **Exposure timing circuitry** starts and ends the application of high voltage across the X-ray tube electrodes. Exposure duration, defined as the time X-rays are being produced for image formation, varies depending on the diagnostic imaging procedure and modality being used for radiography, exposure durations are extremely short, typically 100 ms, combined with large tube current (200 - 1000 mA) to achieve high photon fluence (directly proportional to the mAs). High-power...
• placed in the high-voltage circuit and can turn on and off the power rapidly (1ms is typical).
• The electronic timer provides an accurate control of exposure is provided, which can reduce voluntary and involuntary patient motion artists and preserve image quality. For fluoroscopy, the exposure duration is continuous and is usually initiated and terminated by foot pedals that signal mechanical contactor switches in the low-voltage section of the x-ray generator.
• Timer accuracy is somewhat poor (no greater than about 8ms or V120s. but for fluoroscopy applications 1 to 5 mA tube current) this is more than acceptable. For CT operation, exposure durations of 0.4 to tens of seconds with tube currents of 50 - 40 mA are required for typical operation depending on the type of examination and acquisition protocol. Electronic timing is computer controlled to synchronize the x-ray exposure with the data collection subsystem.
• The timer circuit is separate from the other main circuits of the x-ray machine. It consists of mechanical or electronic devices. There are five basic types of timing circuits, four are technologist, and one is automatic.

- Mechanical timer
- Synchronous timers
- Electronic timers
- mAs timers
- Automatic exposure control timers (photo timers)

**Mechanical timers:**

- The mechanical timer operates by clockwork. A preset exposure time is dialed by turning a knob that winds a spring. When the exposure button is depressed, the spring is released and unwinds. The time required to unwind corresponds to the exposure time. Mechanical timers are inexpensive but not very accurate.
• **Synchronous timers:**
  - Is a precision device that driven by a synchronous motor which operates at 60 revolutions per second.

• **Electronic timers:**
  - The most expensive, most complicated and most accurate of the x-ray timers. Consist of complex circuitry based on the time required to charge a capacitor through a Lable resistance. They allow for a wide range of intervals that can be used to make final exposures.
• **mAs timers**: 
  
  Special kind of electronic timer called an MAS timer monitors the product of MA and time and terminates the exposure when the desired mAs is attained.

• **Automatic exposure control timers (phototimers)**: 
  
  A phototimer is a device that measures the quantity of radiation reaching the image receptor and automatically terminates the exposure when sufficient radiation to provide the required optical density has reached the image receptor.
• **Mammography**

  Mammography is a specialized medical imaging that uses a low-dose x-ray system, is a specific type of breast imaging to look for changes that are not normal, and detect cancer early - before women experience symptoms - when it is most treatable. The results are recorded on x-ray film or directly into a computer.

  A mammography exam, called a mammogram, aids in the early detection and diagnosis of breast diseases in women, and allows the doctor to have a closer look for changes in breast tissue that cannot be felt during a breast exam. It is used for women who have no breast complaints and for women who have breast symptoms, such as a change in the shape or size of a breast, a lump, nipple discharge, or pain.

  Breast changes occur in almost all women. In fact, most of these changes are not cancer and are called "benign," but only a doctor can know for sure.
• An X-ray (radiograph) is a noninvasive medical test that helps physicians diagnose and treat medical conditions. Imaging with x-rays involves exposing a part of the body to a small dose of ionizing radiation to produce pictures of the inside of the body. X-rays are the oldest and most frequently used form of medical imaging.

• Three recent advances in mammography include
  • digital mammography.
  • computer-aided detection.
  • breast tomosynthesis.
1. Digital mammography, also called full-field digital mammography (FFDM), is a mammography system in which the X-ray film is replaced by electronics that convert x-rays into mammographic pictures of the breast. These systems are similar to those found in digital cameras and their efficiency enables better pictures with a lower radiation dose. These images of the breast are transferred to a computer for review by the radiologist and for long term storage. The patient's experience during a digital mammogram is similar to having a conventional film mammogram.
2. Computer-aided detection (CAD) systems search digitized mammographic images for abnormal areas of density, mass, or calcification that may indicate the presence of cancer. The CAD system highlights these areas on the images, alerting the radiologist to carefully assess this area.
• 3. Breast tomosynthesis, also called three-dimensional (3-D) mammography and digital breast tomosynthesis (DBT), is an advanced form of breast imaging where multiple images of the breast from different angles are captured and reconstructed ("synthesized") into a three dimensional image set. In this way, 3-D breast imaging is similar to computed tomography (CT) imaging in which a series of thin "slices" are assembled together to create a 3-D reconstruction of the body.
Although the radiation dose for some breast tomosynthesis systems is slightly higher than the dosage used in standard mammography, it remains within the FDA-approved safe levels for radiation from mammograms. Some systems have doses very similar to conventional mammography. Large population studies have shown that screening with breast tomosynthesis results in improved breast cancer detection rates and fewer "call-backs," instances where women are called back from screening for additional testing because of a potentially abnormal finding.
- Breast tomosynthesis may also result in:
  1. Earlier detection of small breast cancers that may be hidden on a conventional mammogram.
  2. Greater accuracy in pinpointing the size, shape and location of breast abnormalities.
  3. Fewer unnecessary biopsies or additional tests.
  5. Clearer images of abnormalities within dense breast tissue.

- Some common uses of the procedure:
  Mammograms are used as a screening tool to detect early breast cancer in women experiencing no symptoms. They can also be used to detect and diagnose breast disease in women experiencing symptoms such as a lump, pain, skin dimpling or nipple discharge.
1. Screening Mammography

Mammography plays a central part in early detection of breast cancers because it can show changes in the breast up to two years before a patient or physician can feel them. Current guidelines from the U.S. Department of Health and Human Services (HHS) and the American College of Radiology (ACR) recommend screening mammography every year for women, beginning at age 40.
• Research has shown that annual mammograms lead to early detection of breast cancers, when they are most curable and breast-conservation therapies are available. The National Cancer Institute (NCI) adds that women who have had breast cancer, and those who are at increased risk due to a family history of breast or ovarian cancer, should seek expert medical advice about whether they should begin screening before age 40 and the need for other types of screening. For example; at high risk for breast cancer, may need to obtain a breast MRI in addition to the annual mammogram.
• 2. Diagnostic Mammography

• Diagnostic mammography is used to evaluate a patient with abnormal clinical findings—such as a breast lump or nipple discharge—that have been found by the woman or her doctor. Diagnostic mammography may also be done after an abnormal screening mammogram in order to evaluate the area of concern on the screening exam.

• The mammography equipment:

• A mammography unit is a rectangular box that houses the tube in which x-rays are produced. The unit is used exclusively for x-ray exams of the breast, with special accessories that allow only the breast to be exposed to the x-rays. Attached to the unit is a device that holds and compresses the breast and positions it so images can be obtained at different angles.

• Breast tomosynthesis is performed using digital mammography units, but not all digital mammography machines are equipped to perform tomosynthesis imaging.
- Mammography X-ray tubes; Target Material:
  Whereas most x-ray tubes use tungsten as the anode material, mammography equipment uses molybdenum anodes or in some designs, a dual material anode with an additional rhodium track.

2 - Beam collimation:
  Beam collimation has to be consistently accurate to protect patient & enhance contrast, X-Rays beam is collimated by means of a cone which produces a D-shaped field

3- Compression:
  The shape of the breast tends to create image density gradients. This variation may lead to misdiagnosis. Compression is achieved by means of attaching adapters to the mammography unit. The radiographer controls the pressure which is normally gradual for applied and immediate for release.
  A compressed breast is of more uniform thickness, and therefore the optical density of image will be more uniform. Tissues near the chest wall are less apt to be under exposed.
4- Tube mounting:
• with mammography equipment the tube housing is more compact than a standard X-ray tube. The lower kVp's employed is a favorable factor in permitting smaller tube housing.

5 - Radiation protection; Filtration:
• Filtration removes the low energy photons from the beam and minimize skin dose to patients. At the low tube potentials employed for mammography it is important to have the proper type and thickness of filtration in the beam. Most mammographic tubes have inherent filtration of approximately 0.1 mm Al equivalent.

Breast compression is necessary in order to:
• Even out the breast thickness so that all of the tissue can be visualized.
• Spread out the tissue so that small abnormalities are less likely to be hidden by overlying breast tissue.
• Allow the use of a lower X-ray dose since a thinner amount of breast tissue is being imaged.
• Hold the breast still in order to minimize blurring of the image caused by motion.
• Reduce x-ray scatter to increase sharpness of picture.
• Positions will be changed between images. The routine views are a top-to-bottom view and an angled side view. The process will be repeated for the other breast.
• In conventional film and digital mammography, a stationery x-ray tube captures an image from the side and an image from above the compressed breast. In breast tomosynthesis, the X-ray tube moves in an arc over the breast, capturing multiple images from different angles. During screening breast tomosynthesis, two-dimensional images are also obtained or created from the synthesized 3-D images. Compression is still necessary for tomosynthesis imaging in order to minimize motion, which degrades the images.
• **Benefits**

• Imaging of the breast improves a physician's ability to detect small tumors. When cancers are small, the woman has more treatment options.

• The use of screening mammography increases the detection of small abnormal tissue growths confined to the milk ducts in the breast, called ductal carcinoma in situ (DCIS). These early tumors cannot harm patients if they are removed at this stage and mammography is an excellent way to detect these.
• tumors. It is also useful for detecting all types of breast cancer, including invasive ductal and invasive lobular cancer.

• No radiation remains in a patient's body after an X-ray examination.

• X-rays usually have no side effects in the typical diagnostic range for this exam.
• **Risks**
  
  • There is always a slight chance of cancer from excessive exposure to radiation. However, the benefit of an accurate diagnosis far outweighs the risk.

  • *False Positive Mammograms.* Five percent to 15 percent of screening mammograms require more testing such as additional mammograms or ultrasound. Most of these tests turn out to be normal. If there is an abnormal finding, a follow-up or biopsy may have to be performed. Most of the biopsies confirm that no cancer was present. It is estimated that a woman who has yearly mammograms between ages 40 and 49 has about a 30 percent chance of having a false-positive mammogram at some point in that decade and about a 7 percent to 8 percent chance of having a breast biopsy within the 10-year period.

  • Women should always inform their physician or X-ray technologist if there is any possibility that they are pregnant. See the Safety page for more information about pregnancy and x-rays.
FLUOROSCOPY
A. Overview:

Fluoroscopy is an imaging technique commonly used by physicians to obtain real-time moving images of the internal structures of a patient through the use of a fluoroscope. Modern fluoroscopes couple the screen to an X-ray image intensifier and video camera allowing the images to be recorded and played on a monitor.
The layout of a modern fluoroscopic system is shown in Fig (1) the x-ray tube is usually hidden under the patient couch. Over the patient couch are the image intensifier and other image - detection devices. Other fluoroscopes have the x-ray tube over the patient couch and the image receptors under the patient couch. Some fluoroscopes are operated remotely from outside the x-ray room. During image -intensified fluoroscopy the radiologic image usually is displayed on a television monitor.
During fluoroscopy maximum image detail is desired, and if this is to be achieved, much brightness must be high. This is the principal reason for using the image intensifier. It raises the illumination form the low level of conventional fluoroscopy.

Fig (1): fluoroscopy and associated parts.
Fig (2): C-arm fluoroscopy
B. Image Intensifier tube:

Image Intensifier tube is a complex electronic imaging device that receives the beam and converts it to light and increases the intensity of the light. The tube is usually contained in a glass envelope in a vacuum that provides some structural support. The tube is mounted inside a metal container to protect it from rough handling and possible breakage. The image - intensifier tube is approximately 50 cm long.

Fig (3): fluoroscopy with image intensifier.
• Image Intensifier tube consists of:
  
  Input phosphor: (conversion of incident x-rays into light photons)
  
  X-rays that exit the patient and are incident on the image-intensifier tube are transmitted through the glass envelope and interact with the input phosphor. Input phosphor constructed of cesium iodide, it is responsible for converting the incident photon's energy to a burst of visible light photon, as occur with radiographic intensifying screen.
Photocathode: (conversion of light photons into electrons)
Thick metal layer bonded directly to the input phosphor. Usually made of cesium and antimony compounds that respond to light stimulation and photoemission (electron emission after light stimulation). The number of electrons emitted is directly proportional to the light intensity of the incident x-rays photons.
A potential difference of about 25,000 V is maintained across the tube between photocathode and anode so that the electrons of photoemission will be accelerated to the anode.
• Electrostatic Lenses: (focalization of electrons onto the output screen)

A series of lenses located along the length of the tube to maintain proper focus of the photoelectrons emitted from the photocathode by maintaining the kinetic energy of the them.

• Output phosphor: (conversion of accelerated electrons into light photons)

Serves to increase illumination of the images by converting photoelectrons to light photons. Upon interaction, the incident photoelectron is multiplied and converted to 50 - 75 times as many light photons.
• **C. Brightness Gain:**
The ability of the tube to increase the illumination level of the image.

Brightness Gain = Magnification gain * Flux gain

• **Magnification gain:** The ratio of the square of the diameter of the input phosphor to the square of the diameter of the output phosphor.

• **Flux gain:** The ratio of number of light photons at the output phosphor to the number at the input phosphor.
X-RAY GENERATOR

• X-ray generators supply the electrical power to the x-ray tube and provide Selection of the technique parameters.

• High voltage is obtained with a step-up X-ray generator configurations include; single-phase, 3-phase, high-frequency, and constant-potential designs.

• On the other hand, high-frequency generators have been the most widely used over the past decade, chiefly for their superb accuracy, self-calibration, near constant-potential waveform, small size, reliability, and modular design.
X-RAY GENERATOR

• High - voltage transformer:

• The high voltage transformer is a, step – up transformer, that is, the secondary (induced) Voltage is greater than the primary (supply) Voltage because the number of secondary windings is greater than the number of primary windings.

• The ratio of the number of secondary windings to the number of primary windings is called the turn's ratio.
Fig. 1: Step-up transformer (top), step-down transformer (bottom).
• The voltage increase is proportional to the turn's ratio, also the current is reducer proportionately. The turns ratio of the high-voltage transformer is usually between 500 and 1000. Since transformers operate only on alternating current, the voltage waveform on both sides of a high-voltage transformer sinusoidal.
The only difference between the primary & secondary waveform is their amplitude. The primary Voltage is measured in volt, and the secondary voltage is measured in kilovolts.

\[ \frac{V_s}{V_p} = \frac{N_s}{N_p} \quad (\text{turn 's ratio}) \]
• **Voltage rectification:**

• Although transformers operate with alternating current, x-ray tubes must be provided with direct current. Rectification is the process of converting alternating voltage into direct voltage and therefore alternating current into direct current. Rectification is accomplished with a device called diodes (two electrodes).
• Types of voltage rectification:
• There are two types of voltage rectification:
• **Half -Wave rectification:**
• The inverse voltage is removed from the supply to the x-ray Tube by rectification, this represents a condition in which the voltage is not allowed to swing negatively during the negative half of its cycle. Half – wave rectification is accomplished with two diodes placed in the high – voltage section
Fig 2: A half-wave - rectified circuit usually contains two diodes.
- Full-wave rectification:
- Full-wave rectified x-ray machine contain at least four diodes in the high voltage circuit.
- In Full-Wave rectified circuit the negative half-cycle corresponding to the inverse voltage is reversed so that a positive voltage is always directed across the X-ray tube.

Fig 3: A full-wave-rectified circuit contains at least four diodes.
Three - Phase power:

The X -ray produced when the signal – phase voltage waveform has a value near zero are of little diagnostic value because of their low energy and therefore low penetrability. One method of overcoming this deficiency is to employ the principle of generating three simultaneous voltage waveforms, such a manipulation result in a three – phase power.
With three – phase power, multiple voltage waveforms are superimposed on one another, , resulting in a waveform that maintains a nearly constant voltage, consequently, the voltage impressed across X - ray tube never dropping to zero during exposure. There are six pulses per 1/60 second, compared to the two pulses of single - phase power.
• The principal advantage to three-phase power is the higher radiation quantity & quality resulting from the nearly constant voltage apply to the x-ray tube. The radiation quantity is higher because the efficiency of x-ray production increases with increasing x-ray tube potential.

• The radiation quality is increased with three-phase power because there are no low-energy projectile electrons passing from cathode to anode to produce low energy x-rays. Consequently, the average x-ray energy is increased over that resulting from single-phase operation.
Fig 4: the voltage waveforms for single-phase, rectified, three-phase, and associated rectified three-phase power. Three-phase power is a more efficient way to produce x-rays than single-phase power.
• **High frequency generator:**

• The latest development in high-voltage generator design uses a high-frequency electric circuit to the x-ray tube. Three-phase power is increased from 60 Hz to a higher frequency, usually 500 to 1000 Hz. Consequently, "When rectified and smoothed, the voltage waveform has less than 1% ripple, which is even better than three-phase power for x-ray production."
Fig 5: Voltage waveforms resulting from various power supplies.
What is Scatter Radiation
By definition, Scatter radiation occurs when radiation deflects off an object, causing X-rays to be scattered. It is important to keep in mind that scatter radiation has the ability to travel in all different directions." In the case of X-rays, the most common source of scatter radiation for most humans is the patient, and those scattered rays can continue to scatter around the room based on various design features.
Scatter radiation is probably the biggest single factor contributing to decreased film quality. It is the result of a redirection of the primary x-ray beam and production of new X-rays following the interaction with the patient. Therefore, scatter radiation is present in each radiographic examination. The effect of scatter radiation is to produce a generalized photographic fog on the film, which reduces the contrast between adjacent areas on the radiograph.
Image-forming X-rays: when a radiographic exposure is performed using a grid device, the primary photons will either: Pass through the body tissue unaffected. (without interacting). Become absorbed by the tissues within the body. Interact with body tissues and change direction (Compton's scatter). X-rays that exit the patient interact with the IR are image-forming.
Primary x-ray photon

X-ray photons that are absorbed by the part

X-ray photons that become scatter radiation

Image receptor

X-ray photons that penetrate the part to help form the image

Image-forming x-rays

Image receptor
• The Principal characteristics of any image are:
• Spatial resolution is the ability to image two small adjacent structures that have high subject contrast (eg. bone-soft tissue interface, calcified lung nodules), or the distinctness of an edge in the image (ie, sharpness), and visually distinguish one from the other.
• **Spatial resolution** losses occur because of blurring caused by geometric factors (eg, the size of the Modality, focal spot, light diffusion in the receptor). The more blurring, the lower is the resolution.
• **Contrast Resolution** is the comparison of areas of light, dark and shades of gray on the image that makes an object distinguishable. The contrast of an image is affected by the properties of the receptor used to form the image. Contrast agents, also known as contrast media are used during the medical imaging examination to highlight specific parts of the body and make them easier to see.

• **Contrast Resolution** Determined by scatter radiation and other sources of radiographic noise. Radiographic noise (image fog) = A uniform signal produced by scattered x-rays.
• **Effects of Scatter Radiation on Image Contrast**

• If one could radiograph a long bone in cross section using only primary beam X-rays (transmitted), the image would be very sharp, and the radiographic contrast would be high.

• If the radiograph were taken with only scatter radiation and no primary beam x-rays reached the film, the image would be dull gray, and the radiograph contrast would be very low or even nonexistent.
• In the normal situation the X-rays arriving at the film consist of both primary and scattered X-rays. If the radiograph were properly exposed, the image in cross-sectional view would appear neither sharp nor dull, it would have moderate contrast.
• **Scatter Radiation Occurs in Three Ways:**

• **Scatter radiation.** The bulk of this type of radiation derives from the X-rays bouncing off the patient's body.

• **Back scatter.** This type of scatter radiation is created from behind the film and directed towards the X-ray tune. To prevent backscatter the modesty has adopted the standard procedure of adding a 0.005" lead screen in front and a 0.010" screen behind the film for added protection. Additionally, a letter "B" is placed on the back of the cassette to indicate an abundance of backscatter. If the "B" is visible in the resulting
• image, backscatter is occurring, the strength of the "B"s visibility indicating the level of backscatter taking place.

• **Side scatter.** Side scatter is caused by objects in the immediate areas, such as walls, floors and tables. To mitigate side scatter, you may have noticed that x-ray room are typically void of other objects and the table is located in the center of the space. This isolates the X-rays as much as possible so they are less prone to side scatter.
Factors contribute to an increase in scatter are:

- **increased kVp**
- As X-ray energy increases, Photoelectric decrease and Compton interactions increases. At 50 kVp 79% photoelectric, 21% Compton & less than 1% transmission. At 80 kVp 46% photoelectric, 52% Compton & 2% transmission.

- **Increased x-ray field size**
- As field size increases, the intensity of scatter radiation also increases rapidly. Especially during fluoroscopy.
• **Increased patient thickness**

• Imaging thick parts of the body results in more scatter radiation than thin. The radiographer can control the patient thickness by Compression devices, to improve the spatial resolution and bringing the object closer to the IR (image receptor). Compression also Improves spatial & contrast resolution, Reduces patient dose, (reducing fog or noise).
Control of Scatter Radiation

Technologists routinely use two types of devices to reduce the amount of scatter radiation reaching the IR-Beam restrictors & Grids.

Beam-restricting devices affect what reaches the patient. Grids affect the remnant beam.

beam-restricting devices, which include:

- Aperture Diaphragm
- Cones or Cylinders
- Variable aperture collimator
• Aperture Diaphragm

• The simplest of all beam-restricting devices. Lead or lead-lined metal diaphragm attached to the x-ray tube head. The opening in the diaphragm is usually designed to cover just less than the IR used.

• Cones & Cylinders

• Are modifications of the aperture diaphragm. Alignment is one difficulty when using cones.
• **Variable Aperture Collimator**

• The most common beam-restricting device is the light-localizing variable aperture collimator. The first part of the collimator serves to control off-focus radiation. The collimator lamp must be adjusted so that the projected light field coincides with the x-ray beam. Misalignment of the light field and beam can result in collimator cutoff of anatomic structures. Always the collimated area must be smaller than the size of the cassette.
• The Beam resting devices are helpful to improve contrast resolution, however the inherent problem is they are placed between the source and the patient. Even under the most favorable conditions, most of the remnant x-rays are scattered.
• **Grids**

  • Grids a device placed between the patient and film to prevent as much scattered radiation as possible from reaching an X-ray film during the exposure of a radiogram.

  • **Is use** to improve contrast on a radiographic image. by absorption of scatter radiation produced by the patient as the primary beam interacts with the patients. Grids are very effective device for reducing and clean up" scatter radiation. A high quality can attenuate 80-90 percent of scatter radiation. It is positioned between patient and film.
• Grid Construction
• It is a flat plate with a series of lead foil strips that is made in various sizes. Grid strips should be very thin and have high photon absorption properties. Lead is most common: Tungsten, platinum, gold, and uranium have been tried, but Pb is still most desirable.

• Interspace Material (Aluminum or Plastic Fiber) used to maintain precise separation between the delicate lead strips. The grid is encased completely by a thin cover of aluminum, because it provides rigidity for the grid and helps to seal out moisture.
• There are some advantages of using aluminum interspaced material than plastic:
• aluminum has a higher atomic number, therefore, may provide some selective filtration of scattered x-rays not absorbed in the grid material.
• aluminum is no hygroscopic; that is; doesn't absorb moisture as plastic fiber will which result in it to become warped because of its hygroscopicity.
• aluminum - interspace grids are easier to manufacture with high quality because it's easier to form and roll into sheets of precise thickness than fiber.
Grid Ratio: Three important dimensions of a grid:

- The thickness of the grid strips (T).
- The width of the interspace material (D).
- The height of the grid (h).
- The grid ratio is the height of the grid divided by the interspace width: Grid ratio = h/D
• High-ratio grids are more effective in cleaning up scatter radiation than low-ratio grids. The angle of deviation is smaller for high-ratio grids and the photon will be traveling in a straighter line to make it through the grid.

• High – ratio grids are made by reducing the width of the interspace or increasing the height of the grid material, or as is usual, a combination of both.
However, the higher the ratio the more radiation exposure necessary to get a sufficient number of x-rays through the grid to the IR. Grid ratios range from 5:1 to 16:1 that will clean up 85% and 97% respectively. Most common 8:1 to 10:1.
Grid Frequency. The number of grid strips or grid lines per inch or centimeter. The higher the frequency the more strips, and less interspace material and the higher the grid ratio. As grid frequency increases, patient dose is increase because more scatter will be absorbed. Some grids reduce the thickness of the strips to reduce the exposure to the patient, this overall reduces the grid clean up. Grids have frequencies in the range of 25 to 45 lines per centimeter (60 to 110 lines per inch).
Example:
A certain grid is made of lead 30 μm thick sandwiched between fiber interspace material 300 um thick. The height of the grid is 2.4 mm, what is the grid ratio?
A/ grid ratio = h/D = 2400/300 = 8:1

Grid frequency law:
Grid frequency = 10000 μm/ cm / (T+D) line pairs

Example:
What is the grid frequency of the previously described grid that had a grid strip thickness of 30 μm and an interspace thickness of 300 μm?
A/ if 1 line pair = 300 μm + 30 μm = 330 μm , how many line pairs are in 10000 μm (10000 μm = 1 cm)?

\[
\frac{10000 \text{ μm/cm}}{330 \text{ μm/line pairs}} = 30.3 \text{ lines/cm}
\]

(30.3 line/cm) (2.54 cm/in) = 77 lines / in
• Grid Performance.

• The principal function of a grid is to improve image contrast. Contrast Improvement Factor (k) = the ratio of the contrast of a radiograph made with a grid to the contrast of the radiograph made without a grid.

• A contrast improvement factor of 1 indicates no improvements. The higher the grid ratio & frequency the higher the k.

• Grid Performance or Efficiency. The ability of a grid to clean up scatter and improve contrast. Criteria for efficiency measurement

• Selectivity

• Contrast Improvement Ability
• **Selectivity** measures a grid's ability to absorb a greater percentage of scatter than primary radiation. Thus, a grid with high lead content would have a greater selectivity.

• **Contrast Improvement Ability** is measured by how well a grid function to improve contrast in the clinical-setting.

• Grid Efficiency measured by:

• **K** = Radiographic contrast with the grid Radiographic contrast on the grid.

• Note that this is dependent upon the kVp used and the volume of tissue irradiated Most grids have a K of 1.5 to 3.5. Thus the higher the K factor, the greater the contrast improvement.
• **How a grid works:**
  
  The grid is designed to transmit only those x-rays whose direction are in a straight line from the source to the image receptor. X-rays that travel obliquely (at an angle) are absorbed in the grid material.

  • Primary - beam photons incident on the interspace material are transmitted through to the films. Scattered x-ray photons incident on interspace material may or may not be absorbed, depending on their angle of incidence & the physical characteristic of the grid.

  • If the deviation of the scattered x-ray is great enough, it will be absorbed. If the deviation is slight, the scattered x-ray will be transmitted like a primary X-ray.
• **HoGrid Types**

• 1. Parallel Grid

• It is the simplest type, which all lead grid strips are parallel. This type is the easiest to manufacture, but it has some properties that clinically undesirable. The undesirable absorption of primary - beam x-rays in the grid to the grid cutoff, it happened especially with short SID's. Grid cutoff may be partial or complete and result in reduced optical density or total absence of film exposure.
The term is derived from the fact that the useful x-rays are "cut off" from getting the film. Grid cutoff can occur with any type of grid if the grid is improperly positioned, but it is most common with linear grids. Best used with longer beam is straighter and more perpendicular at longer SID's.
• Crossed Grid.
• Crossed grids are usually constructed by placing two linear grids one over the other with the lead strips at right angles to each other. Crossed grids are much more efficient than linear grids in cleaning up scatter, a 6:1 crossed grid will clean up more scatter radiation than a 12:1 linear grid. The disadvantage of using crossed grid represent by positioning the grid is critical; the central axis (central ray) of the X-ray beam must coincide with center of the grid, grid cut-off will occur. Crossed Grid Have twice the grid ratio as linear grids."
• Focused Grid Lead strips are tilted/aligned progressively as they move away from divergence correspond with the divergence of the X-ray beam. Designed to minimize grid cutoff.
• The arrows lines drawn through each of these strips converge at a point somewhere above the grid; this point is known as the grid focus. This is where the X-ray tube should be located for perfect alignment of the primary ray with each of the strips. Every focused grid will be marked with its intended focal distance. If radiographs are made at distances other than those intended, grid cutoff will occur.
4. Moving Grids

All stationary grids will give you grid lines on your radiograph. Thinner Pb strips will give you less noticeable lines. However, thinner strips have less Pb content, and not "cleaning up" as well. Grid Lines are made when primary x-rays are absorbed in the grid strips. The grid is placed in a holding mechanism that begins moving at the X-ray exposure and continues moving after the exposure ends. Focused grids are usually used as moving grids.
• **There are three basic types of moving grid mechanism:**

• single-stroke grid: The single-stroke grid mechanism causes the grid to move continuously across the film while the x-ray exposure is being made, usually it is spring loaded which designed for the shortest possible exposure times because long exposure times are accommodated by damping the mechanism so that it moves more slowly. The total grid movement is usually about 2 to 3 cm.
• Reciprocating = moves several times about 2cm back and forth during the exposure.
• Oscillating = A powerful electromagnet pulls the grid to one side and release it at the beginning of the exposure. thereafter the grid oscillates in circular fashion around the grid frame. The main difference between reciprocating & oscillating grid is their pattern of motion, the motion of the reciprocating grid is to and fro, whereas that of an oscillating grid is circular.
• Grid problems
1. The biggest problem with grids is misalignment. Increased SID, especially with moving grids.

2. Off Level

3. Off Center: A problem with focused & crossed grids.

4. Off SID
5. **Upside-Down**: A problem with focused & crossed grids
• A clever technique that may be used as an alternative to the use of radiographic grids by creating an air gap between the patient and the film. The air-gap technique is another method of reducing scatter radiation, thereby enhancing image contrast.
• When the air-gap technique is used, the image receptor is moved 10 to 15 cm from the patient. A portion of the scattered x-rays generated in the patient would be scattered away from the image receptor leaving a patient's body with more divergent than the primary x-ray beam and not be detected. The end result is that less scatter radiation reaches the image receptor. The reduction of scattered radiation increases with air-gap distance. The technique factors usually are about the same as those for an 8:1 grid.
• Several factors must be considered when using this method of scatter reduction. Patient exposure is increased, Because fewer scattered x-rays interact with the image receptor, Usually the mAs is increased approximately 10% for every centimeter of air gap. The use of an air gap introduces magnification.
• Therefore, a larger receptor size is required to obtain the same patient area coverage. One common use of the magnification is in mammography. Since an air gap is produced by separating the breast from the receptor to produce magnification, it can be used for scatter reduction. The usual procedure is to remove the grid and rely on the air gap in magnification mammography,
• Also, this magnification is usually acceptable in other application particularly in areas of chest radiography & cerebral angiography. Disadvantage is a loss in detail and sharpness of the image.
Intensifying screens

• A. Screen construction:
  • X-ray intensifying screens resemble flexible sheets of plastic or cardboard; they come in sizes corresponding to film sizes usually the radiographic film is sandwiched between two screens; the film so used is double-emulsion film.
  • In most screens there are four distinct layers:
    • Protective coating:
      • The layer of the intensifying screen closest to the x-ray film is the protective coating. It is 15 to 25 μm thick and is applied to the face of the screen to make the screen resistant to abrasion & damaged caused by handling. Naturally, the protective layer must be transparent to light.
• Phosphor:
• The active layer of the x-ray intensifying screen is phosphor. The phosphor emits light during stimulation by x-ray. Phosphor layers vary in thickness from perhaps 150 to 300 μm, depending on the type of screen. The phosphor has one purpose: to convert the energy of the x-ray beam into visible light.
Fig. 1: Cross-sectional view of an intensifying screen, showing its four principal layers.
Luminescence involves outer-shell electrons. When a luminescent material is stimulated, the outer-shell electrons are raised to excited energy levels somewhat more removed from the nucleus. This effectively creates a hole in the outer electron shell, which is an unstable condition from the atom. The hole is filled when the excited electron returns to its normal state, and this transition is accompanied by the emission of electromagnetic energy in the form of a visible-light photon. Fig. 3
The physicist identifies two types of luminescence. If visible light is emitted only during the stimulation of the phosphor, the process is called fluorescence. If on the other hand the phosphor continues to emit light after stimulation, then the process is called phosphorescence. X-ray intensifying screens mainly fluoresce. Phosphorescence in an intensifying screen is called screen lag, and can be objectionable.
• Reflective layer.
• Between the phosphor & the base is a reflective layer approximately 25 um thick made of a shiny substance such as magnesium oxide or titanium dioxide. Its function is demonstrated in Fig. 2. When x-rays interact with the active phosphor, light is emitted isotropically, that is, with equal intensity in all directions. Less than half the light is emitted in the direction of the film. The reflective layer intercepts light headed in other directions and redirects it to the film.
Fig. 2: A. Screen without reflective layer B, Screen with reflective layer. Screens without reflective layers are not as efficient as those with reflective layers because fewer light photons reach the film.
• **Base:**
  The layer farthest from the film is called the base. The base perhaps 1 mm thick and serves principally as a mechanical support for the active phosphor layer. It is made of high-grade cardboard or polyester.

• **B. Luminescence:**
  Any material that emits light in response to outside stimulation is called a luminescent material or phosphor, and, the visible light so emitted is called luminescence. Materials can cause to luminescence by a number of different stimuli such as: electric current (the fluorescent light), biochemical reactions (the lightening bug), visible light (a watch dial), x-rays (an intensifying screen).
Processing the latent image

• **Film construction:**
• Radiographic film basically has two parts, the base and the emulsion. fig(1). Most x-ray film has the emulsion coated on both sides and therefore called double-emulsion film. Between the emulsion and the base is a thin coating of material, called the adhesive layer, this adhesive layer allows the emulsion and base to maintain proper contact and integrity during use and processing. The emulsion is enclosed by a protective covering of gelatin, called the super coating. This super coating protects the emulsion from scratching, pressure, and contamination during use and processing. The thickness of a sheet of radiographic film ranges from 200 to 300 μm (0.2 to 0.3 mm).
Fig (1): Cross-sectional view of radiographic film. The bulk of the film is the base. The emulsion contains the diagnostic information.
• The emulsion is the heart of the x-ray film. Its the material in which

• X-rays or light photons from screens interact and transfer information. The emulsion consists of homogeneous mixture of gelatin and silver halide crystals. The gelatin is clear, so that it transmits light, and is sufficiently porous for the processing chemicals to penetrate to the crystal of silver halide during processing.

• Its principle function is to provide mechanical support for the silver halide crystal by holding them uniformly dispersed in place.

• the silver halide crystal is the active ingredient of the radiograph mulsion. In the typical emulsion, 95% of the silver halide is silver bromide the remainder is usually silver iodide.
Fig (2): Silver halide crystal is triangular. The arrangement of atoms in the crystal is cubic.
• Formation of the latent image:
• The radiation exiting the patient and incident on the radiographic film deposits energy in the emulsion primarily by photoelectric interaction with the atoms of the silver halide crystal. This energy is deposited in a pattern representative of the object or part of the anatomy being radiographed. If one observed the film immediately after exposure, no image would be seen there is, however, an image present, called a latent image. The latent image is the invisible change induced in the various silver halide crystals. With proper chemical processing the latent image becomes a manifest image.
• **Sequence of events in processing a radiograph:**
  
  • Nearly all radiographic processing is done automatically today, the chemicals involved in both (manual & automatic) are basically the same. But in automatic processing the times for each step are shorter and the chemical concentrations and temperature are higher.
  
  • The first step in the processing sequence is to wet the film to loosen the emulsion so that subsequent chemical baths can reach all parts of the emulsion uniformly. The wetting agent is water, it penetrates through the gelatin of the emulsion, swelling it and causing it to expand. This step is often omitted in automatic processing, and the wetting agent then is incorporated into the second step, development.
  
  • Development is the stage of processing in which the latent image is converted to a manifest image. The principle action during development involves changing silver ions of the exposed crystals into metallic silver.
• After development, the film rinsed in an acid solution designed to stop the development process and remove excess developer chemicals from the emulsion. Photographers call this step stop bath, and in processing radiographs the stop bath is sometimes included in the next step, fixation.

• During fixation, the silver halide that was not exposed to radiation is dissolved and removed from the emulsion, the gelatin portion of the emulsion is hardened.
• Fixation is followed by a vigorous washing of the film to remove any remaining chemicals from the previous processing steps.
• Finally, the film is dried to remove the water used to wash it and to make the film acceptable for handling and viewing.
• The steps of development and fixation are the most important to the processing of radiographic film.
# Table (1): Sequence of events in processing a radiograph

<table>
<thead>
<tr>
<th>Step</th>
<th>Purpose</th>
<th>Approximate time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wetting</td>
<td>Swelling of the emulsion to permit subsequent chemicals penetration.</td>
<td>15 s</td>
</tr>
<tr>
<td>Development</td>
<td>Production of a manifest image from the latent image.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 min 22 s</td>
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<tr>
<td>Stop bath</td>
<td>Termination of development and removal of excess chemicals from emulsion.</td>
<td>30 s</td>
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<tr>
<td></td>
<td></td>
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</tr>
<tr>
<td>Fixing</td>
<td>Removal of remaining silver halide from emulsion and hardening the gelatin.</td>
<td>15 min 22 s</td>
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<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Washing</td>
<td>Removal of excess gelatin.</td>
<td>20 min 20 s</td>
</tr>
<tr>
<td>Drying</td>
<td>Removal of water and preparation of radiograph for viewing.</td>
<td>30 min 26 s</td>
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<td>&gt; 1 hr 90 s</td>
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