Screen-Film
Mammography Equipment
Unit 3

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Equipment

- Dedicated Mammography Equipment
- Digital Mammography
- FDA/MQSA Requirements
- Quality Control of Equipment
Dedicated Mammography Equipment

- C-arm X-ray tube stand
- Mammography tube
X-ray tube stand

• The range of vertical movement should accommodate very tall patients, as well as those who need to be seated.

• There should be no obstacles under the receptor tray that would interfere with the patient should she need to be seated for the exam.
C-arm X-ray tube stand

- There should be at least 180 degree rotation of the C-arm.

- The point at which the C-arm connects to the tower (the collar) should be isocentrically designed so that when manipulating from the craniocaudal to the oblique position no adjustments in height is needed.

- Almost all current units require the C-arm to be adjusted when changing to the oblique position.
Dedicated Mammography Equipment

- The single most important part of dedicated equipment in mammography is that the tube is designed and constructed specifically for imaging the soft tissue of the breast.
Rationales for Dedication

- Small x-ray attenuation differences between normal and cancerous tissues in the breast require the x-ray equipment dedicated for use to optimize breast cancer detection.
- Attenuation differences between these minute tissues is highest at very low x-ray energies (10 to 15 keV) and is poor at higher energies (>35 keV).
- Low x-ray energies provide best differential attenuation between the tissues; high absorption results in high tissue doses and long exposure time.
Dedicated Mammography Equipment

- Specialized components are
  - target, window,
  - filter, focal spot,
  - Source-to-image distance,
  - object-to-image receptor distance,
  - Generator, automatic exposure control,
  - grids, beam limiting devices,
  - compression devices, and
  - processor, and
  - magnification.
Dedicated Mammography Equipment
Mammography Tube

Stationary Versus Rotating Anodes

• An advantage of the rotating anode is a higher tube loading capacity.

• Higher milliamperage allows for shorter exposure times.

• The disadvantage is that there is off-focus radiation produced with this system.

• Stationary tubes produce less off-focus radiation, which creates less overall haze of the image, but have lower tube rating capabilities.
Anode design

• Anode construction:
  – Molybdenum
  – rhodium & tungsten
• Combination of anode angle and tube tilt
• SID of 65 cm requires the effective anode angle to be at least 20° to avoid field cutoff for the 24 x 30 cm field area
0° Anode angle

Cathode

24° tube tilt

16° Anode angle

6° tube tilt

Approximately same field coverage
Target materials consist of three main types.

- Molybdenum
- Specialized Tungsten
- Rhodium

- Molybdenum
  - the best material to be used in mammography,
  - allows production of low energy spectrums of radiation
  - low kVp (26-30 kVp)

- Tungsten and Rhodium are used for higher beam needs, in dense breast tissues.
Filament design

• Mammographic x-ray tubes typically have dual filaments in a focusing cup that produces
  – 0.3 and 0.1 mm nominal focal spot sizes

• Minimize geometric blurring and maintain spatial resolution necessary for detection of microcalcifications
Focal spot

Important Factors

- **Standard**: is used in obtaining routine mammographic views, where images of the entire breast are needed.
  - 0.30 to 0.60mm

- **Magnified**: is used in imaging of a specific area of the breast using magnification, spot compression or “coning”.
  - 0.10-0.20mm

- **Actual**: is the area of the target bombarded by electrons. The size is dependent on the target angle, and the heat capacity of the anode. As the target angle decreases from 90 degrees, the size of the actual focal spot increases.

- **Effective**: is a downward projection of the actual focal spot and is measured by diameter (mm). The size of the effective output and necessary field size. Two focal spot sizes are used in mammography in order to accommodate views of the entire breast and special views using spot compression, cone-down and magnification.
Source-to-Image distance

- This is the entire distance of the X-ray beam from the focal spot (source) to the image receptor (film-screen). The greater the distance, the less geometric blur occurs.

- This affects the focal spot size, which in turn affects the size of the object being imaged. Typically the larger the SID, the larger the field size.

- With larger distance of the source to the image (65 cm), more beam penetrability will be needed, which then increases the heel effect.
Object to Image receptor Distance

• It is the distance of the object (the breast) to the image receptor.

• An increase of the object to IR distance will increase magnification of an area of breast tissue. It will increase the resolution and contrast of the breast image.

• With an increase in distance, this will also increase the amount of radiation dose to the patient, and the possibility of motion artifact.

• It is very important to explain to the patient that she will need to have a longer breath hold during exposure.
Dedicated Mammography Equipment

Filtration

- Tube filtration
- Exit window filtration
- Heel effect
- Effects on dose
- Effects on contrast
Filtration

• Materials that are placed in the path of the X-ray beam in order to absorb those X-rays with energies above and below the desired spectrum.

• Tube filtration types:
  – Molybdenum (Mo) (best used for lower kVp)
  – Rhodium (Rh)
  – Yttrium
  – Aluminum (used for above 30 kVp)
Target/Filter Combinations

- Mo target with 0.03 mm Mo filter (Mo/Mo)
- Rh target with 0.025 mm Rh filter (Rh/Rh)
- Mo target with Rh filter
  - Never use Rh target with Mo filter!
Filtration

• Exit window
  – Beryllium instead of glass in a dedicated mammography tube housing.
  – Glass acts as a filter when dealing with this soft end of the X-ray spectrum, and it filters out photons that would not provide contrast.
Heel effect

- Due to the angle of the anode, some of the X-rays it just produced will be reabsorbed by the anode material. This is called the heel effect.

- The steeper the anode angle (the closer to 0 degrees) the more heat units the tube can withstand but the more pronounced the heel effect will be.

- The greater the heel effect the lower the intensity of the X-ray beam at the anode (nipple) side. The lower the X-ray intensity at the nipple side of the film the less field coverage there is available for the “24” dimension of a 24x30 cm image receptor.
Filtration

Effects on dose

• It is important to use optimal filtration.

• Filtration lowers the amount of radiation dose the patient receives.

• Filtration shortens the exposure time, giving the patient only the radiation dose needed to obtain a good quality radiograph.

• With excessive filtration, a built-in microswitch should prohibit an exposure from being made.
Filtration

Effects on contrast

• With more filtration, image contrast is diminished, less scatter radiation is produced.

• The beam gains penetrability, good quality image is resulted.
Generator

- Types
- Ripple factor
Generators

• **Single phase unit**: uses a slower alternating current to produce radiation. This allows for longer exposures to achieve a quality image, giving the patient a larger dose of radiation.

• **Three phase unit**: uses a faster 6-pulse current to achieve the same quality image. It uses less time, which gives the patient less radiation dose, and less chance for motion artifact.

• **High-frequency/Constant Potential units**: does not use alternating or pulse currents. It uses a constant current creating no ripple effect. Radiation dose to the patient is even less, and the same quality image is achieved.
Generators

Ripple Factor

- occurs in single and three-phase generators. Fluctuations of the current cause the ripple factor.

- A near-constant (minimal ripple) current generated by three-phase rectified or high frequency generator is necessary to produce optimum image quality with the lowest radiation dose to patients.
Generator - Tube Capacity

(mA output)

• The amount of heat a dedicated mammography tube can handle with:
  – a molybdenum target
  – a beryllium window
  – added molybdenum filtration
  – a large focal spot of ≥100mA
  – a small focal spot of ≥25 mA is:
    • ≥250,000hu (heat units)

• The anode cooling rate (Max) is: ≥25,000 hu/min.
Dedicated Mammography Equipment

• Automatic exposure control (AEC)
  – Purpose
  – Types
Dedicated Mammography Equipment

Automatic exposure control (AEC)

- Radiation that is transmitted through the breast is converted into an electronic signal, which terminates the exposure when the predetermined level of radiation has been reached.
Automatic exposure control (AEC)

Photomultipliers

- a series of photocells rather than a single pickup.
- A high-technology microprocessor chip allows the phototimer to average the multiple photocell readings.
Automatic exposure control (AEC)

Solid State

- allows the new phototimers to “remember” and to “repeat” kVp settings.
- are able to respond to varying kVp settings.
Grids

Reciprocating

• These grids are best.
• The movement helps clean up scatter radiation.
• The ratios of these grids is usually 4:1 or 5:1, with some units having higher grid ratios.
• The higher is the grid ratio, the better the clean-up of scatter radiation, giving better contrast.
• Dose to the patient increases in this case.
• Materials used for this type of grid can be of carbon fiber, pressed cardboard, or wood. These materials allow to keep buky factors low, between 2 and 2.5.
Grids

Stationary:

- These grids are focused and must be centered to the central ray in order to minimize the grid lines.
- Offsetting the grid will increase the shadowing of the lead lines on the radiograph.
- The grid ratio for these grids is typically with a 3-5:1.
- Since these grids are so thin, aluminum interspace material is used to provide some rigidity.
Beam limiting devices

• The purpose to having beam limiting devices is to allow the proper collimation of the X-ray beam on the image receptor.

• This allows for only the primary beam to be used, instead of scatter radiation.
Beam limiting devices

• Three types are currently used:
  – fixed apertures,
  – a set of interchangeable cones of various sizes,
  – an internal set of collimating blades.

• **Three-sided collimation** is also used to collimate the sides of the bucky that are lateral, medial and anterior to the breast. The side closest to the patients’ chest wall, is not collimated.
Compression devices

- Purpose
- Compression testing
- Types
- Paddle shapes, sizes and purposes
Compression devices

Purpose

- Vigorous compression of the breast has an important role in screen-film and digital mammography.

- It creates decreased motion unsharpness, geometric unsharpness, increased contrast, separation of superimposed breast tissues, reduced radiation dose, more uniform film density and more useful assessment of the apparent density of masses.

- The only negative aspect of compression is the varying degree of discomfort that each patient will experience. Every woman will have her own level of tolerance for compression.
Compression devices

Compression testing

• It is very important to test the compression of the compression paddle at least every six months.

• The degrees of compression of any mammography unit may be:
  – maximum 40 lbs. of pressure
  – minimum is 25 lbs. of pressure.
Compression testing

Scale used to measure degree of pressure
Compression devices

Types

• **Manual**
  
  This type of compression is used by the technologist using her hand to manually compress the breast, using the compression paddle.

• It may be necessary to use this type of compression for very anxious women, or if doing an invasive procedure requiring slow and controlled compression.
Compression devices

Motorized

- Foot-controlled by the technologist
- Allows the technologist to have two free hands to position the breast.
- The RT still is in control of how fast and how much compression is used, but it is done so to allow the technologist maneuverability.

- This type of compression is used for most mammography exams.
Paddle shapes, sizes and purposes

Shapes

• There is a paddle used for 18x24cm and 24x30cm cassettes, and there are paddles used for spot compression, which are much smaller.

• There are also paddles that are fenestrated which are used for wire-localization procedures.
Compression devices

• The purpose of having the proper shaped paddle, is to allow for proper compression of the entire breast.

• In situations where spot compression or magnification are necessary, the smaller paddle is used to compress a small area of the breast.

• This is to try to smooth out tissue that was not well compressed, or to magnify only a small area of the breast for better visualization.
Dedicated Mammography Equipment
Magnification

- Purpose
- Focal spot size
- Air gap technique
- Effect of dose
- Magnification factor
Magnification

- Used to better visualize smaller areas of breast tissue.
- Calcifications are not visualized well on standard views.
- They can only be diagnosed, whether benign or suspicious for malignancy, if they are magnified.
Magnification

• Improved resolution occurs with a smaller focal spot size.

• Most mammographic units have magnification factors of 1.5x to 2.0x.

• An air gap technique is used between the breast and the image receptor to achieve magnification.

• The larger the magnification factor the better the resolution, giving more radiation to the patient.
Dedicated Mammography Equipment

The further away the image receptor is to the tube, the larger the magnification is obtained.
Digital Mammography

- Theory
- Approaches of digital mammography
- Benefits
Digital Mammography

- The theory behind digital mammography is that it is to increase the incidence of detecting more breast cancers, that would not normally be detected as easily in film-screen systems.

- It allows for faster image production, with less radiation to the patient.

- This new system is more costly, but in the long run will save the facility money in storage and film processing costs.
Digital Mammography

- Direct digital systems use amorphous selenium photodetector screens. These screens have high X-ray absorption efficiency, high intrinsic resolution, low noise and a well-established manufacturing process.

- Indirect digital systems use cesium iodide doped with thallium to absorb the X-rays. These systems generate light scintillation that then is detected by an array of photodiodes.

- Indirect systems have resolution degradation caused by light spread in the scintillator, and poor quantum efficiency with thin scintillators.

- Some systems use a charged-couple-device (CCDs) as an alternative light collection array and readout method.
Digital Mammography

• In producing the image, spatial resolution plays a big part.

• Spatial resolution is determined by the pixel size. With fewer microns per pixel, the spatial resolution of the detector is improved.

• The amount of contrast information available in the image is defined by the bit depth per pixel.

• The digital image is formed as a 2-dimensional matrix of square picture elements of a fixed size, typically 0.04mm to 0.1mm on a side. It is a sampled representation of the pattern of X-ray transmission through the breast.
Digital Mammography

Noise to Radiation Dose Ratio

• A lower the dose, the noisier is the image.
• A higher dose means less noise in the image.

• Radiation dose in digital systems may be the same or less than that used in film-screen mammography.
• The reduction in dose is the direct result of greater sensitivity and the lower overall system noise of the charge-coupled devices found in digital systems.
Digital Mammography

• With digital systems image enhancement is much greater than that with film-screen systems.

• Digital mammography’s excellent contrast resolution, especially in dense breast tissues, will eventually make way for more accurate breast cancer detection.

• In film-screen systems there are blind areas where the film is very dark or very light, and lesions are more likely to be overlooked.

• Because there is a linear response of digital detectors to incident radiation, there is more contrast between areas of similar X-ray absorption. In addition, image contrast can be manipulated on the computer monitor for improved conspicuity.
Digital Mammography

• Another benefit to digital mammography systems is the amount of time it takes to produce an image. It takes approximately four seconds to image the breast in one projection.

• The technologist is able to look at her positioning right away, and let the patient go when the exam is finished.

• If any additional imaging is needed, enhancement of the image is done instead. The patient does not have to be called back to the facility to have more X-rays taken. This alleviates any additional anxiety patients may have.
Computer-Aided Detection

• This computer digitizes mammography film. It aids the radiologist in detecting breast cancer. It is like having a second radiologist looking at the patient’s mammogram.

• The computer can pick up to 20% more breast cancers than with standard/previous methods of diagnoses.

• This system is less costly than going to an all digital mammography system, but does not alleviate additional imaging procedures from being performed.
Digital Mammography

- R2 unit is a CAD (Computer aided detection) system used to digitize mammograms.
Telemammography

- This is being used more and more, as facilities become all digital. Radiologists are able to be off-site, and look at a woman’s mammogram from a remote location.

- The benefit of this is that other physicians within the network may review a patient’s mammogram. It saves time and money. Immediate reading of mammograms can be performed in mobile units.

- The downside to this is that the patient does not have a physician to talk to in person, at the time of her exam.
FDA/MQSA Requirements

Mammography Equipment

- Dedicated
- Gantry assembly motion
- Image receptors
- Compression
- Beam limitation and light fields
Mammography equipment

- **Dedicated:** MQSA requires that all radiographic equipment used for mammography shall be specifically designed for mammography and shall be certified.
Gantry assembly motion

- The assembly shall be capable of being fixed in any position where it is designed to operate. Once fixed in any such position, it shall not undergo unintended motion.

- The mechanism ensuring compliance shall not fail in the event of power interruption.

- The gantry shall have visual indicators of the gantry angle, and must be able to rotate 180 degrees.
FDA/MQSA Requirements

Image receptors

- Systems using screen-film image receptors shall provide, at a minimum, for operation with image receptors of 18x24cm and 24x30cm.

- Systems using screen-film image receptors shall be equipped with moving grids matched to all image receptor sizes provided.

- Systems used for magnification procedures shall be capable of operation with the grid removed from between the source and image receptor.
FDA/MQSA Requirements

Compression

– All mammography systems shall incorporate a compression device.

– Each system shall provide: an initial power-driven compression activated by hands-free controls operable from both sides of the patient; and fine adjustment compression controls operable from both sides of the patient.
FDA/MQSA Requirements

Beam limitation and light fields

- All systems shall have beam-limiting devices that allows the entire chest wall edge of the X-ray field to extend to the chest wall edge of the image receptor and provide means to assure that the X-ray field does not extend beyond any edge of the image receptor by more than 2% of the SID.
FDA/MQSA Requirements

Beam limitation and light fields

- **Illumination** requirements: The facility shall make special lights for film illumination, i.e., hot-lights, capable of producing light levels greater than that provided by the view box, available to the interpreting physicians.

- Exposure **interlock** systems: should forbid exposure when in the open position. Any interlocks on the machine should be checked by attempting exposure while they are in the open position.
FDA/MQSA Requirements

Source-to-image receptor distance

- The source-to-image receptor distance (SID) may be fixed or it may be variable. In either case the size of the focal spot must match the SID of the unit to provide good resolution as well as to allow the use of acceptable technical factors when dealing with the inverse square law.
Dose limitations

MQSA requires that the average glandular dose delivered during a single cranio-caudal view of an FDA-accepted phantom simulating a standard breast shall not exceed 3.0 milligray (mGy) (0.3 rad) per exposure.

The dose shall be determined with technique factors and conditions used clinically for a standard breast.
Infection control

- Facilities shall establish and comply with a system specifying procedures to be followed by the facility for cleaning and disinfecting mammography equipment after contact with blood or other potentially infectious materials. This system shall specify the methods for documenting facility compliance with the infection control procedures established and shall:

- Comply with all applicable Federal, State, and local regulations pertaining to infection control; and comply with the manufacturer’s recommended procedures for the cleaning and disinfection of the mammography equipment used in the facility.
FDA/MQSA Requirements

Foaming cleanser is used for cleaning hands in between patients.
FDA/MQSA Requirements
Quality Assurance of Equipment

Each mammography facility shall have a quality assurance program in place.

• The required maintenance of log books, phantom images, clinical image monitoring, clinical image interpretation, a physicist survey, and all medical records.

• For the sake of not missing a lesion, it is our responsibility to adhere to and uphold the final regulations mandated by the FDA/MQSA.