BASIC PRINCIPLES OF MAMMOGRAPHY

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MAMMOGRAPHY IS THE PRIMARY MEANS OF DETECTING EARLY BREAST CANCER
The human female breast is a well differentiated apocrine sweat gland which secretes milk during lactation. The two breasts lie anterior to the right and left pectoral muscles, extending from the sternum laterally to the mid-axillary line.

Each breast consists of a thin outer layer of skin, beneath which is a subdermal layer of adipose tissue from several millimeters to about one centimetre thick. Beneath the fat layer lies the supportive connective tissue stroma, which contains blood vessels, lymph channels and variable amounts of adipose tissue. The stroma also contains the glandular tissue, consisting of 15 or 20 lobes which subdivide into milk forming lobules and drain via an extensive ductal system through the external centrally positioned nipple.

The glandular tissue extends throughout the entire breast and is separated from the pectoral muscle by only a thin layer of retromammary adipose tissue.
The upper outer quadrant, because of an additional extension referred to as the axillary tail, is the thickest portion, and extends furthest from the nipple, towards the axilla.

Virtually all breast cancers arise from the glandular tissue. Therefore the objective of mammography should be to visualise the glandular tissue with as much resolution and contrast as feasible, within the constraints of the desired low X-ray exposure.

Most breast cancers occur centrally and laterally, in proportion to the relative amounts of glandular tissue in these areas, and it is important to choose the mammographic views which best evaluate these areas.

They are: CC (Cranio-Caudal, vertical view), MLO (Medio Lateral Oblique, usually a 45 degrees view), MLO (Medio Lateral, 90 degrees view). The most used are CC and MLO.

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2. SPECIALISED MAMMOGRAPHY UNITS

The screen-film method requires a specialised mammography unit. Without the low- energy X-ray beam necessary for high subject contrast, and without the specialised equipment for vigorous uniform compression, it is rarely possible to visualise the smallest calcifications and the masses of the earliest carcinomas. Even large carcinomas are sometimes missed.

IMS GIOTTO is a specialised mammography unit designed for both screening and diagnostic images. The other specialised units are: GE Senograph DMR, SIEMENS Mammomat, INSTRUMENTARIUM Diamond, PLANMED Sophie, LORAD Mark IV, FISCHER Athena.

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A mammography equipment, like all other X-ray units, has two main components: a Generator and an X-ray Tube.

The High Voltage Generator transforms low voltage (200 – 240 V) into high voltage (20 – 40 kV) to feed the X-ray Tube.

The X-ray Tube needs this high voltage to generate the X-ray photons (X-ray, radiation)
3. LOW ENERGY X-RAY BEAMS

Specialized mammography units utilize Molybdenum (Mo) Anode Tubes to produce a low-energy X-ray beam, which is necessary for high subject contrast resulting in improved detection of calcification and soft tissue abnormalities. General radiographic units use x-ray tubes with Tungsten (W) Anode.

For screen-film mammography, settings of less than 28kVp are generally recommended.

Figure 3.1
4. MOLYBDENUM TARGET AND FILTERS (see fig. 6.1)

The use of low-energy photons such as those produced by the 17.9 and 19.56 keV characteristic lines from molybdenum target provide high subject contrast for breasts of average thickness.

When a 0.03 mm molybdenum filter is used, the spectrum is strongly suppressed at photon energies greater than 20 keV.

At the same time, the molybdenum filter also absorbs the energy below the characteristic k-radiation level, which otherwise would be largely absorbed by the breast.

In conclusion, molybdenum pre-filtering of the X-radiation from a molybdenum anode suppresses the contrast reducing hard radiation and the non-image producing soft radiation, while the characteristic k-radiation is transmitted with minimal hindrance giving optimal image contrast.

With thick or dense breasts, the soft radiation absorbed in the object will be too high, resulting in insufficient film density. To obtain better results and lower dose the molybdenum filter is, in all modern mammography units, automatically replaced by a Rhodium (Rh) filter.

5. AUTOMATIC EXPOSURE CONTROL (AEC)

Mammography systems should have AEC systems (also called phototimers) that terminate x-ray emission when the AEC sensor, placed behind the cassette, senses the proper exposure to achieve the preselected film density. By automatically compensating for variance in Kvp setting and patient anatomy, AEC systems should help to provide uniform, reproducible high-quality films, thereby decreasing the number of retakes and reducing radiation exposure to the patient. The performance of the AEC is very important from both image quality and radiation safety perspectives. If AEC is used, tests with phantoms (objects used to simulate the absorption and scatter characteristics of the breasts) must be performed regularly to ensure proper calibration.

Automatic exposure control is available on most specialized mammography units.
6. FOCAL SPOT SIZE - FOCUS/FILM DISTANCE - MAGNIFICATION TECHNIQUE

The size of the focal spot (area of x-ray emission on the Anode) its position and its distance from the film are also of the utmost importance.

The focus/film distance (FFD) is usually around 65 cm in all modern equipment.

The focal spot size are two: Small Focus (0.1 x 0.1 mm) and Large Focus (0.3 x 0.3 mm).

FOCAL SPOT:

The small area of the anode that emits x-rays is referred to as the focal spot. The focal spot on the anode surface receives the accelerated electron beam, and its size and radiation intensity distribution profoundly influence radiographic definition or detail. Generally the smaller the effective focal spot, the sharper the definition.

A magnification technique - deliberately moving the breast closer to the tube to obtain an enlarged image - is often used in mammography. An enlarged image (1.5X-1.8X) makes microcalcifications and other pathologies easier to detect because the significance of the resolution of the screen-film receptor is decreased. However, magnification techniques require extremely small focal spot sizes (0.1 x 0.1 mm) with low load-ability, requiring longer exposure times. Another trade-off is the increased dose that results from moving the breast closer to the x-ray tube.

FILM FOCAL DISTANCE.

The second geometric variable on which image sharpness depends is FFD. Commercially available mammographic units have distances that range from about 60cm to 70cm. The longer distances result in greater geometrical sharpness, however, the beam intensity at the image receptor dramatically decreases (following the square of the distance). Therefore, larger tube currents are required to adequately image the breast (difficult task to achieve with the limited focal spot dimension).
7. X-RAY SCATTERING / GRIDS

When radiation strikes a substance (the breast tissue in our case), there is always a certain scattering of radioactive particles. This is comparable to light striking a glass surface; a certain portion of the light is always reflected.

- **Primary radiation** – radiation emitted from the X-ray tube (incident on a patient).
- **Secondary radiation** – is the product of interactions between primary x-ray photons and patient body.

Scattered radiation reduces subject contrast in mammography and do not bring any useful information, but contribute into film density increase, reducing image contrast and resolution. Should be minimized.

To overcome this problem moving grids have been developed for mammography. Grids may absorb more than 50% of the X-rays exiting from the breast, potentially causing the dose to be more than doubled. It may be possible to offset the increased radiation exposure required when grids are used by using higher kilovoltage settings, increased beam filtration, or a recording system that provides higher speed, or with a combination of two or three of these.
MOVING GRIDS (BUCKY)

General purpose, moving grids cannot be utilised for mammography because of high absorption of X-rays by the interspace material. Moving grids designed for mammography are thinner than convention grids and have carbon fibre interspace material. All the new mammography X-ray machines contain these grids mounted in a reciprocating Bucky mechanism, to make the grid lines invisible.

8. COMPRESSION DEVICE

A stiff compression device which is parallel to the film surface should be utilised. The sharp posterior angle of the compression paddle allows the compression device to grip the posterior aspect of the breast tissue during operation. This enables improved visualisation of the posterior aspect of the breast. Vigorous compression is essential for screen-film mammography. The average breast can usually be compressed to about 4cm in thickness. The value of compression should be carefully explained to the patient, and her co-operation requested.

Compression is important for the following reasons:

a) Contrast improvement: Compression improved subject contrast by reducing scatter. The increased subject contrast improves detection of calcification and visualisation of the outline of masses.

b) Diminished motion unsharpness: With vigorous compression the films should seldom need to be repeated because of motion unsharpness. Even arterial motion should be suppressed.
With inadequate compression, considerable motion unsharpness can occur even with exposure times of only 0.2 second.

c) Reduction of x-ray dose: Vigorous breast compression reduces the average glandular dose.

d) More uniform film density. When the compression device is stiff and parallel to the film surface, vigorous compression enables the posterior aspect of the breast to be as well visualised as the anterior aspect.

9. SELECTION OF SCREEN-FILM COMBINATIONS

Intensifying screens convert the invisible energy of a x-ray beam into visible light energy. About 99% of the latent image on x-ray film is formed because of this visible light created by intensifying screen.

The phosphor layer is the key to the conversion power of the intensifying screen. Rare-earth screen, most containing a gadolynium oxysulfide compound, are in wide use today.

The screens are usually contained within the specialised cassettes designed for mammography.

Screens should be cleaned each day with a screen cleaning solution. The darkroom should be kept free of dust, because dust marks on the film can interfere with detection of calcifications.

10. IMAGE QUALITY

In general the concept "image quality" can be considered to indicate the accuracy with which details can be perceived in an image. Resolution or resolving power has often been used as a criterion for image quality but other criteria have also been proposed.

In mammography the concept of "image quality" become more important because of the "early detection of breast cancer" which implies the ability to detect a very small detail able to differentiate a benign lesion from a malignant one.
11. BREAST IMAGING PHANTOMS

Breast image phantoms have been used to gain insight into image quality in mammography ever since its inception as a radiographic discipline.

A "good" breast phantom should:

(one) have an established correlation with clinical image quality
(two) allow objective rather than subjective analysis
(three) be sensitive to small changes in mammographic techniques.

ACR phantoms are those approved by an highly competent body: ACR (American College of Radiologists)

12. QUALITY ASSURANCE

The entire mammographic system should periodically be evaluated. The review should include the mammographic unit, the automatic exposure control devices, screens and cassettes, film processing, darkroom and viewing conditions.

Monitoring and maintenance of the film processor is required on a daily basis.

Breast phantom images should be evaluated regularly.

CONCLUSION

Mammography is technically one of the most demanding radiographic investigations and the consistently high quality mammograms are difficult to obtain.

Poor quality films can only lead to mistaken diagnosis and increase the number of inappropriate biopsies.

Quality control in mammography is vital and implies the need for purpose build apparatus optimum film screen combinations and dedicated film processing. Correct positioning of the patient by committed and dedicated staff is of prime importance.

Unless these criteria can be met image quality will suffer, the films will lack credibility, interpretation becomes difficult and small cancers will be missed.