MAMMOGRAPHIC POSITIONING

Mi Hwa Joo, R.T.
Dept. of Radiology, Asan Medical Center, Seoul, Korea

• Introduction

If breast cancer is found early, its successful cure rate is very high(1). Early diagnosis would need not only diagnostic capacity but accurate mammography. To get an accurate mammography, the operator has to explain patients about the procedure before the examination in detail, and he and she should take a modified mammography according to each shape of breast(2). Therefore, the aim of this lecture is to discuss patient care and mammographic positioning for high quality mammography.

• Patient Care

Patient's cooperation is more important than operator's technique during the examination. In the mammography, the important patient care is as follows:
- Be careful of speech and behavior
- Explain the procedure before the examination in detail
- Massage to relax the breast
- Make your effort to mitigate uncomfortable touch that comes from equipment.

• Mammographic Positioning

1. Check point before examination
   - Ascertain the relevant facts of risk factor
   - Record the history and the present condition of breast
   - Record the patient's skin wart, mole, and scar (including post operative scar), keloid

2. Positioning requires
   - Trained technologist
   - Adequate compression
   - Breast manipulation
3. The effect of compression(3).
- Reduce the amount of radiation absorbed by the breast
- Separate overlapping structures
- Immobilize breast tissue
- Reduce the change for motion not to make unsharpness
- Make the difference between finding or missing an early breast cancer

4. Screening Mammography(Routine view); why two-views ?
1) Mediolateral oblique view
   To view axilla and lateral portion of the breast parenchyma, the variation of angle is needed because the shape of the pectoral muscle is various. The image has to include inframammary fold and the pectoral muscle has to be shown up to the level of the nipple. It is necessary to use compression technique to spread breast tissue involving the parenchyma(2,4).

2) Craniocaudal view
   This view is a method to show the medial and central portion. The image has to start to move the inferior portion up, including pectoral muscle as much as possible, and showing the nipple in profile(2).

5. Diagnostic mammography(5).
- 90° Lateral view - Latero-medial or mediolateral
- Problem-solving craniocaudal view - Exaggerated craniocaudal(XCCL view), Cleavage view, Rolled view.
- Cleopatra view or 30° Oblique view
- Change-of-angle view, View to bring lesion closer to the film
- Spot Compression view, Tangential view, Magnification view
- Special positioning - View of mastectomy site, Anterior compression view, Caudocranial view, Axillary view, Bed rest patient view, Male or small female breast view
- The Augmented Breast - Higher kVp, no AEC, Eklund pinch technique(6).
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MAMMOGRAPHIC QUALITY CONTROL

Mi Hye Kim, M.D.
Department of Diagnostic Radiology,
Yonsei University, Seoul, Korea

Introduction

Widespread mammographic screening has the potential to significantly reduce mortality from breast cancer. However, the effectiveness and success of such screening depends on consistent production of high-resolution, high-contrast, low-dose mammographic images. Poor quality mammograms will lower the detection rate of early breast cancer and undermine the public’s confidence in the value of mammography. The technical quality of mammography in the USA improved during the 1980s as conventional x-ray units were replaced with dedicated mammography systems and direct-film or conventional screen-film image receptors were replaced with screen-film receptors designed specifically for mammography. In the mid-1980s, however, it became apparent that despite these technical advances, image quality and breast radiation doses from mammography varied greatly. The American College of Radiology (ACR) developed the Mammography Accreditation Program (MAP) in 1987 to identify facilities with high-quality mammography. MAP was a voluntary accreditation program with a strong education component that evaluated mammography facilities for qualifications of personnel, clinical and phantom image quality, radiation dose, and processor quality control. In 1992, Congress passed the Mammography Quality Standard Act (MQSA). In October 1, 1994, all mammography facilities had to be certified by the FDA and accredited by an FDA-approved accrediting body. In October 28, 1997, “Quality Mammography Standards; Final rule” was published by the Food and Drug Administration (FDA) and the majority of final regulations will become effective April 28, 1999. Quality Assurance (QA) is defined as all of the policies and systematic procedures that provide confidence that a valid mammography was performed, including everything from recruitment and monitoring of patients to assessment of outcome data. Quality control (QC) is an integral part of quality assurance. It refers only
to those QA activities that specifically involve the technical aspects of performing the mammography examination. I reviewed the quality control procedures performed by the radiologic technologist and medical physicist.

**Quality Control performed by Radiologic Technologist**

I. Responsibility of Quality Control

It is recommended that one radiologic technologist be designed as the “QC technologist” responsible for performing and overseeing most of the regular QC tasks. The QC technologist must have a critical eye for detecting clinical image deficiencies, some of which can be subtle. The ACR Committee on Quality Assurance in Mammography has developed guideline and performance criteria for the duties of the QC technologist. These procedure written below are based on “Mammography Quality Control Manual” published by American College of Radiology in 1994 and “Quality Mammography Standards; Final Rule” published by Food and Drug Administration (FDA) in October 28, 1997.

The specific quality control procedures to be conducted by the radiologic technologist include:

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1. Darkroom cleanliness

Darkroom cleanliness is performed at the beginning of each workday before any film are handled or processed. The darkroom should be as free as possible of dust and dirt that
could result in film artifacts.

2. Processor quality control
Processor quality control procedures are designed to verify that the film processor-chemical system (film, developer chemistry, processor, and developer temperature is consistent with the film manufacture) is consistent with the film manufacturer’s specifications. Processor QC is performed at the beginning of each workday, prior to the processing of any films. A digital thermometer, a sensitometer, and a densitometer are required for daily processor QC.

If the Mid-Density (MD) and Density Difference (DD) are within ±0.10 of their respective operating levels, and the B+F is within +0.03 of its operating level, the processor is in control and no further action is required. If the MD or DD exceeds the control limit of ±0.15, the source of the problem must be determined and corrected before clinical mammograms are processed. If the B+F exceed +0.03, immediate corrective action must be taken before clinical mammograms are processed.

3. Screen cleanliness
Screen cleanliness refers specifically to the maintenance of the cassette screen to reduce dust and dirt particles which may degrade image quality or mimic microcalcifications. Cleaning is performed with a special radiographic screen cleaning agent and lint-free cloths, gauze pads, camel hairbrushes, or canned air.

4. Viewbox maintenance
Viewbox must be kept clean. And the QC technologist is responsible for documentation of the performance and frequency of viewbox cleaning.

5. Phantom images
Phantom image radiographs are obtained to assess film density, contrast (density difference), uniformity, and image quality due to the X-ray imaging system and film processor. Masses, speck groups (calcifications), and fibers are simulated in the phantom. The QC technologist assesses the phantom image and records the optical density of the
phantom, the mAs used to obtain the image, and the number of test objects that are seen. The density of the film should be greater than 1.2 with control limits of ±0.05 for a 4-mm thick disc and for films exposed at 28 kVp.

It is not acceptable to have one unit producing film densities of 1.20 and another producing densities of 1.60. The exposure time or mAs noted on the generator read-out should not change by more than ±15%.

The present criteria for the number of objects to pass the ACR Mammography Accreditation is a minimum of the four largest fibers, the three largest peck groups, and the three largest masses.

### 6. Visual check list

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### 7. Repeat analysis

Facilities collect and analyze repeated and rejected films. If the repeat or reject rate, calculated as a percentage of the total films included in the analysis, changes by more than 2 % points from the rate determined the previous quarter, the cause of the change must be identified.

### 8. Analysis of fixer retention in film

Facilities must perform a test to determine the quantity of residual fixer on processed film. The residual fixer must be no more than 5 micrograms per square cm.
9. Darkroom fog
Darkroom fog is unwanted film density due to development of unexposed silver halide grains by light or heat exposure during film storage or handling. After a 2-minute interval to allow the eyes to adapt to the dark, the darkroom should be visually inspected for light leaks and the condition of safelight filters. As part of this inspection, in total darkness, one of each type of film is exposed with a sensitometer. One half of each exposed film is covered with an opaque card. After turning on the safelights, each half-covered film lays on the counter for approximately 2 minutes before it is processed. The difference between the densities of the sensitometric strips of the fogged and unfogged halves of the film are then compared with a densitometer. The fog should be no greater than 0.05. If the fog is greater than 0.05 then the source of fog must be determined and immediate corrective action taken.

10. Screen-film contact
Poor contact between screen and film causes image blur. Possible causes of loss of screen-film contact are dust or dirt particles, improperly designed or damaged cassettes, and deterioration of the foam or sponge on which the screen is mounted. After placing the cassette to be tested on top of the cassette holder, put the copper screen (fine 40-wire per inch) on top of the cassette and radiographed. Areas of increased density indicate areas of poor screen-film contact. Cassettes with large areas (>1cm) of poor screen-film contact or with more than two or three small areas (<1cm) of poor contact are not acceptable.

11. Compression
Facilities must conduct compression testing to ensure that each mammography system in use provide that each mammographic system in use provides adequate compression and, at the same time, does no allow dangerous levels of compression to be applied. Mammography units must demonstrate a compression force of at least 111 newtons (25 pounds). After October 28, 2002, the maximum compression force for the initial power drive must be between 111 newtons (25 pounds) and 209 newtons (47 pounds) for all systems and the manual depression may not be used to meet this requirement.
Quality Control performed by Radiologic Physicist

The primary duties of the medical physicist include a) acceptance testing of newly installed equipment, b) establishment of the baseline performance of the mammography equipment, c) evaluation of changes in equipment performance with supervision of corrective measures, d) supervision of the QC radiologic technologist’s performance of procedures, and e) assistance in determining that the mammography equipment which the facility will purchase meets specifications. During his or her annual visit, the medical physicist should review the QC technologist’s records, including the procedures manual and all test data. It is responsibility of the medical physicist to prepare a written report of the findings of the annual visit for the supervising interpreting physician. This report should include the medical physicist’s recommendations for corrective actions to improve any deficiencies in QC activities or mammography equipment performance, especially when these are not in compliance with MQSA requirement. The medical physicist’s responsibilities are related to the equipment performance, including image quality, patient doses, and operator safety. Specific tests which should be performed at least annually include:

1. Mammographic unit assembly evaluation
2. Collimation assessment
3. Evaluation of focal spot performance
4. kVp/accuracy/reproducibility
5. Beam quality assessment (half-value layer measurement)
6. Automatic exposure control (AEC) system performance assessment
7. Uniformity of screen speed
8. Breast entrance exposure, average glandular dose, and AEC reproducibility
9. Image quality evaluation
10. Artifact evaluation

Appropriate tests should be repeated by the medical physicist after replacement of the X-ray tube or other major service to the mammography unit.
Conclusion

Quality control (QC), a part of Quality assurance (QC), refers to the technical aspects of the examination, including positioning, technical factors and processing of films. An interpreting physician should oversee all aspects of the QA program. Radiologist is ultimately responsible for clinical image quality and the standard of patient care. Responsibility of interpreting physician related to QC includes 1) Knowledge of the technical aspects of breast imaging, 2) Critical assessment of day-to-day image quality, 3) oversight of QC activities and selection of QC personnel, 4) oversight of radiation protection program. A designated interpreting physician should meet with the medical physicist at least annually and with the QC technologist at least quarterly to review the QC tests and reports. Everyone working in the mammography facility plays an important role in the QA program, and the interpreting physician has the overall responsibility for seeing that the program is carried out regularly and effectively.

References

DIGITAL MAMMOGRAPHY

Mal Shook Shim, RT
Center for the Health Promotion, Sungkyunkwan University
Samsung Medical Center, Seoul, Korea

Until recently, film-screen mammography has been using film as a tool for image acquisition and as a medium for storage. However, the use of film has severe physical limitations, limiting the efficiency of the operation. Mammography needs a balanced film gradient as well as a lenient light bandwidth. Due to a noise in the film, it is difficult to discover the microcalcifications and observe the margin of a breast mass. Artificial elements added during the film development and daily changes made in the quality, experts predict that digital mammography would be the method for the mammography of the future.

1. Advantages of Digital Mammography

Digital mammography uses a broad dynamic range detector and post-processing technique after the image acquisition, making it possible to independently acquire, exhibit, and store the image to optimize the result. Digital mammography not only improves the contrast, but also makes the operations such as histogram modification and spatial frequency filtering easier (1). Other advantages include decreased amount of radiation with use of digital system, low maintenance cost and saved film storage space.

2. Prerequisite for Digital Mammography

It is difficult to acquire 100% contrast in mammography. Therefore, the ability to detect the lesion is not dependent on the resolution, but on the contrast or signal-to-noise ratio. According to a research(2,3), digital system with 10 line pairs per millimeter (lp / mm) resolution showed better result than a film-screen system with 20 lp / mm resolution. The acceptable resolution in digital system is 100 micron pixel, and the ideal one is 50 micron. Another important aspect is deciding the number of gray scale in digital images. The detector must absorb the particle radiation effectively, show fan-shaped response in broad particle radiation intensity, and have low noise, minimum size of 18 x 24cm field, short
image acquisition time, and small heat load of X-ray plate.

3. Types of Detectors
There are two types of detectors: area detector and scanned beam detector. Area detector acquires the image in a similar method as the film-screen, exposing the full field to the X-ray at once. Another method to acquire the digital breast image is to use the scanned beam detector. Scanned beam detector can be made by connecting a wide-area phosphor with a small-area photodetector such as a charged-coupled device array with lens or fiber optic cables. High quality results can be obtained with good optical facilities and sufficient photodetectors, but there is a size limitation of 5x5 cm.

Photostimulable phosphor system is a technique to obtain image by holding the electrons created by the X-ray in a phosphor crystal trap, stimulating them with fine focus laser and scanning the short-wave light spot-by-spot with laser. This system has problems in space resolution, because the laser disperses in phosphor’s volume and the stimulated areas are bigger than the width of the laser beam. Signal-to-noise ratio also decreases because it is difficult to gather the radiated shot-wave lights. Our experiences at Samsung Medical Center with Fuji CR (developed by Fuji Film) showed sufficient contrast and resolution. Amorphous selenium is the same material used in the xeroradiography sensor. Selenium has an advantage over the phosphor in its status as an optic conductor and has the ability to create a high-resolution image with an electric stoppage effect. In silicon system, light-sensitive diodes are arranged on a silicon plate. Such elements become the pixel of the image. Diodes are covered with X-ray absorbing phosphor and the electric charges are saved in the condenser of the diodes to be read. Scanned beam detector is a method of scanning the entire area using a small-area detector. It takes a long time to acquire the images, but can reduce the dispersion line effect and increase the signal-to-noise ratio. It can be divided by dot, line and slot. But dot-based and line-based facilities are unprofitable due to the lengthy acquisition time.

4. Application of Digital Mammography
4-0. REAL TIME IMAGE DISPLAY, IMAGE SAVING AND LOADING.
It is possible to decrease the time it takes to develop the films and modify the daily changes in the developer with real time image display. Patient processing will be more effective and cost for photographing, film developing, film storage and management will decrease. Identifying the mass from the shade of dense breast tissues will be easier. Needle localization of mass will also be faster and more effective, and the patient will receive less radiation.

4-1. TECHNIQUES for ENHANCEMENT after IMAGE ACQUISITION
Signal processing technology is used to enhance the general quality of the image and to make the specific area clearer. Modifying the window and level brings about sufficient intensity and contrast, and the magnification and unsharp masking technique makes it easier to see the fine structures such as the microcalcifications. Other border strengthening and noise suppression techniques can strengthen the outline of the mass, making it easier to identify the structures with low contrast. Intensity equalization makes it easier to identify the skin and subcutis structures which maybe unclear in the film-screen system (1). Digital system can also modify the overexposed or underexposed parts through the image processing operation.

4-2. IMAGE PROCESSING PARAMETER
The image is modified by the seven parameters for the image processing, broadly classified into the gradation and the frequency process.
The gradation processing conditions are controlled by four parameters - gradation type (GT), rotation amount (GA), rotation center (GC) and gradation shifting amount (GS).
Gradation type is the most basic parameter of the four, indicates the fundamental form of nonlinear conversion curve. It is indicated by sixteen types which are type alphabet A to B. Rotation amount defines gradation amount as contrast.
Rotation center is a the middle point for the change in GA and it is usually set to the region of interest. Gradation shift moves the gradation curve defined by GT, therefore it controls the overall image density. Frequency processing (that is unsharp masking technique) controls image sharpness. In the computed radiography system, frequency processing improves the
image contrast with the frequency response. There are three parameters - frequency rank (RN), frequency type (RT), and frequency enhancement (RE).

5-3. DUAL ENERGY SUBTRACTION IMAGING
Taking low kVp and high kVp technique consecutively shows that the breast absorbs the wave of certain kVp more than the other. If two images were subtracted and breast tissue background was excluded, it would be possible to detect even minor changes in density. This will be useful especially in finding the microcalcification, which absorbs much low energy beams.

References
BREAST SONOGRAPHY: NORMAL ANATOMY AND TECHNIQUE

Eun-Kyung Kim, M.D.
Pundang CHA General Hospital, CHA University, Korea

As sonography has become widely established as an adjunct to mammography, there has been increasing concern about the varying image quality produced by a wide range of ultrasound instruments, about technical parameters, and about examination techniques. Familiarity with normal sonographic anatomy of the breast is another key to correct interpretation of the image.

Normal Developmental Anatomy
- ectodermal origin as skin glands
- develop from the mammary ridges, which begin as ventral streaks in the 5th week of gestation
- mammary ridge: from base of the forelimb (primitive axilla) along the ventral surface of the embryo (the chest and abdomen to be)
- normally, upper third of the mammary ridge persists to form the breast bud on the chest wall and eventually the tail of Spence, extending into the axilla while the remainder of the structure disappear
- failure of involution: accessory breast tissue anywhere along the milk line accessory nipple

1) Pubertal Breast
   - a few small ducts, fibrous stroma
   - breast bud: may asymmetric enlargement

2) Mature Breast
   - increased branching ductal systems
   - abundant connective and glandular tissue

3) Involution
   - fatty replacement
   - inhibited by hormone therapy

4) Pregnancy and Lactation
   - proliferation of lobular acini: replacement (crowding out) of the intralobular and interlobular connective tissue, until by the onset of lactation only fibrous septae separate the enlarged, secretion-distended lobules
Normal US anatomy

The overall echogenicity of the breast depends on the relative proportions of connective, epithelial, and fatty components, which vary among individuals and according to age and parity. Because of the prevailing connective tissue, a young woman’s breast appears more echogenic than a fat-replaced postmenopausal breast. With high-frequency transducer, the breast can be divided into four distinct regions: 1) the skin, nipple, and subareolar structures, 2) the subcutaneous region, 3) the parenchyma, and 4) the retromammary region.

1) The skin, Nipple, and Subareolar Structures

Skin
- appears as a uniform, highly reflective line 0.5 to 2 mm thick.
- may be visualized as two echogenic lines separated by a thin hypoechoic zone.

Nipple
- contains a large amount of connective tissue with surrounding the subareolar ducts
- can lead to acoustic shadowing (due to large amount of connective tissue and reflection and refraction from the oblique oriented sides of the protruding nipple)
- The degree of shadowing can be reduced by applying sufficient compression.

Lactiferous ducts
- identified as thin, anechoic, branching tubular structures from 2 to 8 mm in diameter converging in the retroareolar region

2) The Subcutaneous Region

- displays fine, weakly echogenic reflections from fat lobules, interspersed with strong echoes from the suspensory ligaments of Cooper
- Cooper ligaments: connective tissue septa that enclose parenchymal lobules throughout the breast from the juxtathoracic deep fascia to the skin.

3) Parenchymal Region

- includes the functional elements (mammary lobules and ducts), connective tissue, suspensory ligaments, and varying amount of fat
- US appearance of breast parenchyma: varies with the relative amounts of fat and connective tissue
- In the dense glandular breast, the parenchymal region is filled with tissue that produces strong coalescent echoes similar in intensity to those of the skin. In very dense breasts, additional compression is frequently required for adequate sonic penetration.
- In the fatty breast, hypoechoic fat lobules have replaced nearly all of the parenchymal tissue. In the mixed fatty and dense breast, the fat lobules are
dispersed within dense tissue and may mask or be mistaken for masses. To avoid mistaking a fat lobule for a mass, imaging should be done in more than one plane. A fat lobule that is shown to be round in one plane is likely to be oblong in another. Fat lobules may contain central echogenic foci of connective tissue.

- Normal intramammary lymph nodes are not visualized; however, enlarged fat-infiltrated nodes are often seen as brightly echogenic, well-defined, rounded structures.

4) The Retromammary Region

- Retromammary fat is thinner than in the subcutaneous region and the fat lobules are smaller.
- The fat separated the parenchyma from the fascia overlying the pectoral muscle.
- In longitudinal sections, the ribs cast strong acoustic shadows. A thin, deep fat layer is seen anterior to the pectoralis major muscle, and ribs are identified by their marked acoustic shadowing. Because them, the pleura appears as a bright flat interface that moves with respiration.

US Technique

- Breast sonography should be performed with high resolution real-time US equipment, preferably linear array transducers of 7- to 10-MHz frequency. Linear array transducers have a wider near field and are more appropriate for guidance of interventional procedures than mechanical sector transducers. The most effective transducers allow one to change the number and location of the focal zones so that the region of best focus can be placed at the depth of interest. The equipment must be properly calibrated and maintained. Substandard equipment, technique, or interpretation will diminish the potential benefit of US for breast imaging.
- The US equipment operator should have a thorough knowledge of breast anatomy and pathology as well as the technical aspects of both mammography and US. It is best to have breast US performed in the mammography facility by the same technologists of physicians who perform or interpret mammography. The mammogram must be available when sonography is performed so that the proper area is examined. When a palpable abnormality is examined, correlative clinical breast exam should be performed to ensure that the sonographic findings correspond to the palpable lesion. For nonpalpable, mammographically detected masses, the operator must determine the proper area to scan from the mammogram and correlate the size and location of the sonographically visualized lesion with the mammographic findings.
- If the lesion is superficial and the focal zone cannot be moved electronically, a standoff pad should be used to physically move the transducer away from the breast, thus placing the focal zone in the superficial region of the breast. The time or depth compensated gain (TGC of DGC) must be set appropriately for proper assessment of the internal matrix of the lesion. If the gain is set too low, a hypoechoic solid mass may appear to be anechoic, whereas if the gain is too high, a simple cyst will fill in with low level internal echos, leading to the erroneous diagnosis of a solid mass.
Breast sonography is usually performed with the patient supine on a cart, with her ipsilateral arm abducted over her head. The operator should strive to minimize the thickness of the breast, maintain a normal angle of incidence of the US beam to the breast parenchyma, and use of the chest wall for compression of the posterior aspect of the breast. Thus, for lateral lesions, the patient should be placed in the contralateral posterior oblique position with the aid of a pillow or sponge wedge. Appropriate compression with the transducer will minimize the breast thickness and provide optimal image quality.

Artifacts and pitfalls in breast US

Artifacts and pitfalls are generally identified by changing the position of the transducer or of the patient.

1) Reverberation artifacts
   - from the anterior wall of the cyst, from the reflective skin also occur when a standoff pad is used
   - Their identifications based on their displacement when the distance between the transducer and the causal reflector is modified by either increasing or decreasing the pressure on the transducer.

2) Shadowing
   - may result from scattering of the beam by a thick or irregular Cooper ligament, the uneven surface of the nipple, or a loose contact between the skin and the transducer or standoff pad.
   - Compression of the examined area by increasing the pressure on the transducer often clears the artifact. Shadowing or enhancement associated with lesions may be less conspicuous when the lesion is not placed in the focal zone of the transducer.

3) The section-thickness artifact
   - responsible for the display to artifactual echos within small cysts
   - can be cleared by using a transducer of higher frequency that has a thinner scan plane.

4) Pseudomass
   - Hypoechoic fatty lobules within the breast parenchyma may mimic discrete masses.
   - The correct identification of the pseudomass effect is achieved by scanning the fatty lobule in multiple directions until one scan shows the lesion blending with the rest of the subcutaneous fat.
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Two MR techniques, fat-suppression and dynamic enhancement techniques, will be explained in this lecture. Fat is known not to involve in breast diseases, and fat-suppression is necessary in most of examination. Dynamic study with injection of the MR contrast agent such as Gd-DTPA may be one of the best strategies for differentiation of lesion.[1]

1. Fat-suppression

The molecules being imaged in MR are water and fat in the biological tissues, with long spin-spin relaxation times ($T_2$) owing to their fast motions. Often fat needs to be suppressed in MRI for the better discrimination of the malignant lesion from the normal tissues. The high signal intensity from the fat in breast may sometimes obstruct the small enhancing lesion by partial volume average in Gd-DTPA enhancement examination.

The protons in water and fat molecules have two distinct NMR properties. One is their different precession frequency caused by the chemical binding, so-called chemical shift. The electron cloud surrounding proton nuclei in either molecule differs from the other’s, which shields the external static magnetic field in different amount. The difference of the chemical shift between two molecules is 3.5 ppm, which corresponds to 224 Hz at 1.5 T and 157 Hz at 1.0 T. The other difference is the spin-lattice relaxation time $T_1$. $T_1$ of the water in biological tissues ranges 500–1200 msec at 1.5 T magnetic field, while that of fat is about 250 msec.

1-1. Chemical-shift fat suppression[1]

In MR imaging pulse sequence, an rf pulse with fat precession frequency and several tens Hz width is applied before the slice-selective rf pulse to destroy the fat magnetization vector. The effectiveness of this chemical fat-saturation highly relies on how well two resonances are separated, which are affected by the homogeneity of the main field, shimming, field strength. At low field below 1.0 T, the separation between two peaks is not good enough, so that the rf pulse focused onto the fat frequency
greatly smear into the water resonance. This makes the chemical shift fat-suppression ineffective in low field MRI. Figure 1 represents a graphical description of the separation of water and fat resonances with respect to the field strength. The NMR lines of fat/water in the magnetic field of 1.0 T or below 1.0 T may belong to the third figure, depending upon the shimming.

The first pulse in Figure 2 represents the rf for the suppression of fat resonance,

![Diagram](image1)

Figure 1. Separation of water and fat resonances in different field strength.

after which only the water magnetization remains along the longitudinal axis, so then the following pulse sequence.

![Diagram](image2)

Figure 2. Schematic block diagram of fat suppression.

1-2. Inversion Recovery[2]

Long TR, 4–5 times of the specific $T_1$ allows its magnetization fully relaxed back to the thermal equilibrium. In inversion recovery technique, all the magnetization vectors (water and fat) are inverted against the longitudinal axis, and they gradually recover to their equilibrium, in the middle, passing through zero at certain time $T_{i\text{null}}$. $T_{i\text{null}}$ is 0.69 times $T_1$ of the tissues to be suppressed, for instance, $T_{i\text{null}}^{\text{fat}}(B_0=1.5 \text{ T}) = \sim170$ msec, and $T_{i\text{null}}^{\text{CSF}}(B_0=1.5 \text{ T}) = \sim2800$ msec assuming TR to be long enough. The slice-selection rf is applied at time $T_{i\text{null}}$, when the magnetization of fat becomes zero, and the resultant image lacks of fat. The advantage of the IR-fat suppression is its applicability at low field MRI, while the dis-advantage is long scan time.
2. Dynamic contrast-enhanced technique[1]

$T_1$ contrast media, such as Gd-DTPA, dynamically changes the signal intensity of the tissues as the positive enhancement. It is due to the Gd$^{3+}$ which has strong paramagnetic moment, through which proton nuclei in the water molecules can relax to the equilibrium. The rate and the amount of the signal enhancement may reflect the vascularities of the tissues of interest. Since the dynamics of the signal change has short and long term effects, the temporal resolution of the imaging ranges from a few seconds to 1 min. The spatial resolution may sacrifice for the better temporal resolution. Spin-echo or gradient-echo pulse techniques can be used with IR or spectral fat suppression. Various quantitative analysis can be achieved using the obtained dynamic MR images, including signal enhancement, image subtraction, rate of signal change, etc.

References

Figure 3. Inversion recovery pulse sequence. First 180° rf pulse inverts water and fat magnetization vectors to along $z$ axis.
QUALITY CONTROL OF DIAGNOSTIC ULTRASOUND EQUIPMENT
Viewpoint of Performance in Ultrasound Scanner

Chan Yo Weon
Regulatory Affairs Manager, Medison Co., Ltd., Korea

Quality issues continue to present manufacturers with a major dilemma. In this presentation, basic aspects of performance of the diagnostic ultrasound system will be discussed together with the content of the available. I will point out some of the performances from the supplier of the test object that have been applied to the ultrasound system for the premarket clearance and/or type testing. Today I’d like to introduce quality control of the ultrasound system especially for B-mode image quality because it is basic quality of the typical diagnostic ultrasound system.

Tissue Mimicking QC Phantom (Tissue Mimicking QC Phantom)
Test any of these parameters with the Tissue Mimicking QC Phantom:

- Distance accuracy
- Depth of penetration
- Image uniformity
- Dead zone measurement
- Axial and lateral resolution
- Cyst imaging capability

**B-Mode Image Quality Indicators**

**Depth of Penetration**

The point at which usable tissue information disappears or maximum depth of penetration is reached, can be defined simply as how far one can "see" into the phantom. Equipment sensitivity and noise determines the deepest echo signal which can be detected and clearly displayed.

Depth of penetration, also called maximum depth of visualization or sensitivity, is the greatest distance in a phantom for which echo signals due to the scatters within the tissue-mimicking background material can be detected on the display. The depth of penetration is determined by the frequency of the transducer, the attenuation of the medium being imaged and the system settings.
Image Uniformity
Ultrasound systems can produce various image artifacts and non-uniformities which in some cases mask variations in tissue texture. Common non-uniformities are horizontal bands in the image caused by inadequate handling of transitions between focal zones or vertical bands indicating inactive or damaged transducer elements.

*Uniformity is defined as the ability of the machine to display echoes of the same magnitude and depth with equal brightness on the display. This is a good test to ensure all crystals within the transducer are functioning.*

Axial Resolution
Axial resolution describes the scanner's ability to detect and clearly display closely spaced objects that lie on the beam's axis. Using pin targets of decreased vertical spacing, the system's axial resolution is determined by locating the two resolvable pins with the smallest separation.
The axial resolution target consists of six pairs of parallel, 0.1 mm diameter wires horizontally spaced 6 mm apart from center to center. The lower wire in each pair is horizontally offset from the upper wire by 1 mm to further reduce any acoustic shadowing effects. The vertical distance between each pair of wires is 5, 4, 3, 2, 1, and 0.5 mm from center to center.

Axial resolution is defined as the ability of an ultrasound system to resolve objects in close proximity along the axis of the beam. In other words, how close can two objects be along the axis of the beam and still be detected as two distinct objects? Axial resolution is proportional to the length of the system's transmitted ultrasonic pulse or pulse length.

**Distance Accuracy**
Vertical and horizontal distance measurement errors can easily go unnoticed on clinical images. Distance accuracy as a quality indicator is determined by comparing the measured distance between selected pin targets in the phantom with the known distance. Vertical distance is defined as the distance along the axis of the beam. Distances are used to measure areas, volumes, depths and sizes of objects. Accurate measurements are therefore necessary to ensure proper diagnosis. The vertical plane target allows one to assess the accuracy of vertical measurements.
Horizontal target group is used to determine the accuracy of measurements made perpendicular to the beam axis and is critical for the same reasons as vertical distance measurements above. The horizontal plane target consists of a group of seven (7), 0.1 mm parallel wires positioned 2 cm apart in a horizontal plane at mid-depth in the phantom. Refer to target diagram attached to your phantom.

**Lateral Resolution**

Lateral resolution is described as the distinction of small adjacent structures perpendicular to the beam's major axis. The lateral resolution is measured indirectly by measuring the width of pin targets at depths corresponding to the transducer's near, mid, and far field ranges.

In another example, this target may be positioned at depths of 3 cm and 10 cm. Five parallel wires are horizontally spaced precisely at distances of 5, 4, 3, 2, and 1 mm from center to center. This target is designed to accurately assess the lateral resolution of the imaging system.

Lateral resolution is similar to axial resolution except it is concerned with the resolution perpendicular to the beam axis. Lateral resolution will improve with a narrowing of the
beam width. Therefore, within the focal zone, the lateral resolution will be at its best.

**Dead Zone**

The dead or "ring down" zone is the portion of the image directly under the transducer where image detail is missing or distorted. The depth of an instrument's dead zone is determined by identifying the shallowest pin target that can be clearly visualized.

![Dead Zone Diagram](image)

**DESCRIPTION OF THE PHANTOM**

The phantom is constructed from tissue-mimicking materials. At normal or room temperatures, tissue-mimicking material will accurately simulate the ultrasound characteristics found in human liver tissue. The speed of sound in the phantom can be adjusted between 1430 and 1650 meters per second. The acoustic attenuation can be adjusted between 0.05 dB/cm/MHz and 1.50 dB/cm/MHz.

All resolution targets are made from monofilament nylon wire with a diameter of 0.1mm. These wires have a positional accuracy of 0.13 mm All phantoms are encased in a rugged, shatter-proof container with a thin film membrane and water dam to facilitate scanning. Each phantom comes packaged in a foam lined, air tight carrying case and zipper sealed plastic bag to minimize desiccation and damage. All phantoms include an attached certification sheet indicating the exact speed of sound and attenuation for that phantom.

Tissue mimicking gels are ultrasonically similar to soft human tissue. Because our phantoms have the same speed of sound, attenuation and backscatter coefficients as human tissue, they can be scanned with normal scanner control settings. As a result, the phantom demonstrates the scanner's performance in a clinical examination.
ESTABLISHING A BASE LINE WITH YOUR NEW PHANTOM

The first step before scanning any phantom should be to refer to the user's manual of your ultrasound scanner and note the stated accuracies of the system's general imaging measurements. These stated accuracies may greatly influence the conclusions made when evaluating the phantom. For example, if the measurement accuracy for your system is 10% for distances up to 2.0 cm, the scanner may detect 2.0 cm as being anywhere from 1.8 cm to 2.2 cm.

Analysis

It is recommended that all these measurements be performed at the most frequently used imaging arrangements. The importance of these tests is not so much from a one time analysis as it is to make sure the system performance remains constant over an extended period of time. All these measurements may also be used to compare the performance of various setups of the same machine or to compare different machines with one another in a quantitative manner.

*Note:* Time-gain properties and sector scanner errors can be evaluated using the vertical plane target in accordance with suggested AIUM techniques. For targets with minimum scattering, lower gain levels can be used; however, higher gain settings enable evaluation at more clinical type settings. When evaluating any machine, settings should be recorded and remain consistent over time. For further instruction on measuring performance refer to Standard Methods for Measuring Performance of Pulse-Echo Ultrasound Imaging Equipment, AIUM Standards Committee, July 1990.
QUALITY CONTROL: RADIOISOTOPE SCANNING

Hee-Joung Kim, Ph.D.

Dept. of Diagnostic Radiology, Yonsei University College of Medicine
Research Institute of Radiological Science, Yonsei University, Seoul, Korea

Joint committee accreditation hospitals’ manual suggests that the instrument calibration procedures sufficient to affirm proper performance shall be conducted each day instrument is used, and the results are recorded. All interpretation of radioisotope breast imaging procedure is based on the assumption that the sufficient to performance of the system is reliable and accurate. To provide evidence of reliability and accuracies of the system, a standardized program of quality assurance (Q.A) and quality control (Q.C) is essential. Figure 1 shows a typical SPECT camera to be used for radioisotope scanning and figure 2 shows a comparison of scintimammographic images obtained by specially designed for the scintimammography (Figure 2A) and by Anger camera (Figure 2B).

1. Quality Assurance (Q.A)

Q.A in radioisotope breast imaging need to put all efforts to be free from all errors and artifacts. This will need to cover all aspects of clinical practice including the preparation and dispensing of radiopharmaceuticals, the protection of patients, staff and the general public against radiation hazards and accidents by the faulty equipment, the scheduling of patients, the setting-up, use and maintenance of electronic instruments, the methodology of the actual procedures, the analysis and
interpretation of data, the reporting of results, and the keeping all records. Successful Q.A requires integrated programs. These will include clinical conference, administrative meeting, follow-up studies, technologists' staff meeting, lectures, research meeting, SPECT and PET meeting, radiation safety committee, validation of nuclear medicine results, phantom Q.A. program, and procedure review meeting.

2. Instrumentation Quality Control (Q.C)

An important question will be why we need Q.C? The objectives of Q.C in breast imaging are monitoring, maintaining and characterizing a high standard of performance of breast imaging studies (Figure 3). System performance, image quality, and quantitation are regulated by these measurements which range from daily checks of system uniformity and integrity to periodic checks of both the accuracy and precision of nuclear medicine instruments and their corrections. Radiotiope scanning Q.Cs are well described and guided by IAEA(International Atomic Energy Agency) TECDOC-602 (1), NEMA(National Electrical Manufacturers Association) scintillation camera (2), and NEMA PET (3). The types of tests are acceptance testing and recalibration for preventive maintenance as a benchmark. Acceptance tests include intrinsic spatial resolution, intrinsic spatial linearity, intrinsic energy resolution, intrinsic flood field uniformity, intrinsic count rate performance, multiple window spatial registration, system spatial resolution, system sensitivity, angular variation of flood uniformity and sensitivity, system spatial resolution with/without scatter, and system count rate performance with scatter. Routine tests include flood field uniformity(Figure 4), spatial resolution, and spatial linearity (Figure 5). These tests generally perform by nuclear
medicine technologist and weekly testing is recommended. Resolution and linearity testing may be performed simultaneously with the aid of a flood source and either a parallel-line-equal-space, bar, orthogonal hole or resolution-quadrant phantom (4-5). This may be performed extrinsically or intrinsically using a point source or sheet source. At least monthly there should be a full system test using a phantom which can evaluate system uniformity and resolution simultaneously.

Figure 4. A set-up for uniformity QC with Co-57 Flood source

Figure 5. Pincushion and Barrel effects, and without linearity correction and with linearity correction

Resolution phantoms should have a variety of sizes of cold lesions. Data acquisition with clinical parameters will allow the user to optimally evaluate parameter selection to provide the most information. Types of Instruments to be tested by standardized Q.C program include dose calibrators, area survey meter, gamma camera, SPECT, and PET.

In the symposium, more detailed measurements and objectives will be discussed. These may provide a guideline to radioisotope breast imaging to optimize and maintain their instruments for clinical and research applications.

References