Quality assurance (QA) in mammography is a system of checks that helps ensure the proper functioning of imaging equipment and processes. Ergonomics is a scientific approach to arranging the work environment to reduce the risk of work-related injuries while increasing staff productivity and job satisfaction. This article reviews both QA and ergonomics in mammography and explains how they work together to create a safe and healthy environment for radiologic technologists and their patients. QA and quality control requirements in mammography are discussed, along with ergonomic best practices in the mammography setting.

After completing this article, the reader should be able to:
- Define quality assurance.
- Describe the role of quality assurance in mammography.
- List issues that can be addressed using quality assurance or quality control in mammography.
- Describe the role of ergonomics in mammography.
- Cite issues that can be addressed using ergonomics in mammography.

The role of quality assurance (QA) and ergonomics in mammography is to ensure a safe and healthy environment, both for the mammographer and for the patient. Improperly functioning radiology equipment can harm the mammographer physically and expose both the mammographer and the patient to excess radiation. In addition, a poorly designed workstation and working environment can cause excessive musculoskeletal strain, fatigue, and other work-related injuries for radiology department staff. Thus, maintaining a properly functioning and well-designed radiology department is paramount in maintaining the safety and health of everyone involved.

Breast Cancer Statistics
Breast cancer is second only to lung cancer as the most common cause of cancer-related deaths among women. In 2013, nearly 40,000 women were expected to die from breast cancer. Although much less common, men can have breast cancer as well, with an estimated 2,240 diagnoses in men and 410 deaths in 2013. The good news is that early detection via mammography and effective treatment of breast cancer are possible. As of January 2012, an estimated 2.9 million women with a history of breast cancer were either cancer free or receiving treatment.

Age, race, socioeconomic factors, family history, genetics, exposure to certain chemicals and pollutants, and lifestyle all play a part in the development of breast cancer. Breast density can affect mammographic imaging. Women with very dense breasts have a 4- to 6-fold increased risk of developing breast cancer and might need additional imaging with conventional mammography or a more specialized modality such as digital breast tomodraphy.

When detected early, breast cancer is more likely to be smaller and confined...
to the breast, making it easier to treat. In fact, the size of a tumor and the degree to which breast cancer has metastasized are the most important factors in prognosis. According to the American Cancer Society, early detection of breast cancer with screening mammography saves thousands of lives each year.6

The Role of Mammography in Screening and Diagnosis

Screening mammography is used to detect breast cancer, allowing for treatment and long-term survival for an increasing number of women. According to the United States Department of Health and Human Services, to fully achieve the benefits of screening and diagnostic mammography, a mammography system must be of high quality. Routine maintenance of mammography equipment, among other measures, is necessary to ensure that the equipment can produce quality images.4

Diagnostic mammography is indicated when a woman has symptoms of breast cancer or an abnormal screening mammogram.6 The 5-year survival rate is lower when a woman has a more advanced stage of breast cancer at diagnosis. Relative survival rates for breast cancer diagnoses are 89% at 5 years after diagnosis, 83% after 10 years, and 78% after 15 years.5

When mammography quality is poor, a cancer diagnosis might be missed. False-negative results can delay treatment and ultimately lead to otherwise avoidable deaths. Conversely, poor-quality mammography also can lead to false-positive results, giving rise to costly additional imaging, unnecessary biopsies of breast tissue, and patient anxiety.4 In general, approximately 10% of all mammograms are false-positive, resulting in overtreatment and subsequent patient distress lasting as long as 3 years.7 The goal of a QA program is to provide accurate diagnoses, minimizing both false-positive and false-negative results.

In 2009, the U.S. Preventive Services Task Force (USPSTF) revised its breast cancer screening guidelines to indicate that women aged 50 years and older, as opposed to those aged 40 and older, should receive annual screening mammography.8 However, the American College of Radiology (ACR) and the Society of Breast Imaging argued against the USPSTF recommendations in favor of early screening.9 The effect of this debate on quality mammographic imaging remains unclear, as false negatives can occur if screening is delayed and certain cancers go undiagnosed (per the ACR), while it also could be the case that delayed screening actually might reduce false positives and overtreatment (per the USPSTF).8-10 The American Society of Radiologic Technologists continues to support annual screening using mammography and clinical breast examination for all women beginning at age 40.

Mammography Litigation

The 2012 Radiologic Technology Directed Reading “Mammography and Litigation” explored issues with mammography and the high rates of malpractice lawsuits against mammography practitioners, particularly radiologists and other physicians.11 Mammography is arguably the most heavily litigated medical procedure,12 with the most common reason for lawsuits against radiologists being missed diagnosis, or “mammography misread.”13 This highly litigious atmosphere is fueled by the public’s perception that screening mammography has a 100% sensitivity in detecting breast cancer,14 whereas the actual sensitivity of mammography can be as low as 79% when factors such as dense breasts are present.15

Factors that can influence differences among radiologists in interpreting images include training, experience, case and practice variation, and the particular protocol of the program in which they work. In addition, the volume of mammograms interpreted by a radiologist can affect interpretation accuracy but only by about 2.5%, leaving as much as 97% of inconsistency in interpretation attributable to other factors.12

Due in part to a national shortage of trained radiologists, a radiologist might read approximately 50 imaging studies per day. This increasing pressure can lead to work-related strain, fatigue, and job burnout.16

Quality Assurance

Quality assurance, or QA, in its broadest sense is the activity of evaluating goods or services to ensure that certain standards are met.17 QA is a systematic and planned approach to verifying that a product, manufacturing facility, or service adheres to a certain standard. Ensuring quality is an essential step in eliminating
errors that can potentially lead to litigation and in enhancing overall patient care.

Many systems have been developed to ensure quality, one of which is Total Quality Management (TQM). Based on the theories of 2 Americans, W Edwards Deming and Joseph Juran, PhD, this system was instituted in the 1950s in Japan as a way to ensure higher-quality exports than competing countries. TQM was later widely adopted by American businesses. TQM encompasses processes to promote operational excellence, continuous improvement, and increased profit potential by maintaining quality of goods and services.1,6

Another well-known quality system is Six Sigma, first implemented by large corporations such as General Electric and Motorola. Six Sigma is organized like a hierarchical system of martial arts in which individuals who complete the required training in quality improvement techniques can ultimately earn a black belt designation. Using this system, defects in manufactured goods can be reduced to approximately 3.4 parts per million. The goal is to eliminate the high cost of poor quality, which can include financial costs as well as customer dissatisfaction.1,6

Six Sigma often is paired with the concept of “lean,” which applies mostly to streamlining manufacturing processes to minimize waste but can be applied to business practices as well.1,6 In fact, a community hospital in Boca Raton, Florida, implemented a Lean Six Sigma program in its mammography center. The goal was to improve patient-centered care while increasing financial return and enhancing staff morale. The center instituted a multifaceted project plan to address the root causes of delays and rework, which consisted of 3 steps: stabilizing, optimizing, and innovating mammography procedures. An important aspect of this process was that staff members were included as process owners, meaning they had direct input on processes related to and affecting their daily jobs, empowering them to analyze their job tasks and come up with solutions to common workplace problems.21

In mammography, QA involves activities that confirm that quality imaging is performed. Moreover, it ensures that those working in mammography are protected from unnecessary risk of injury and that patient care is delivered in a safe and effective way.22

**History of Quality Assurance in Mammography**

In 1985, the Nationwide Evaluation of X-ray Trends (NEXT) study was conducted by statewide radiation-control agencies in conjunction with the U.S. Food and Drug Administration (FDA) after concerns began to arise over the quality of mammography. Based on a national sample of mammography images from facilities across the United States, the NEXT study found that image quality was “less than desirable” from as many as one-third of mammography facilities, prompting the ACR to create its mammography accreditation program. Approximately 30% of applicants failed their first application for accreditation.4

In 1990, a study conducted by the General Accounting Office found that many mammography providers lacked sufficient QA programs. By 1992, hearings held by the Senate Committee on Labor and Human Resources revealed a range of issues with mammography services in the United States, including poorly trained personnel, lack of facility inspections, poor quality mammography equipment, and lack of QA procedures.1,6

By 1992, the ACR’s efforts were augmented by the Health Care Financing Administration, which conducted inspections of mammography equipment, personnel, and QA procedures to ensure regulatory compliance by Medicare-funded facilities. Several states also instituted programs to ensure that residents received high-quality mammography. That same year, Congress enacted the Mammography Quality Standards Act (MQSA), requiring that all mammography facilities be certified by the federal government by 1994.4

**Costs Associated With Quality**

Ideally, quality goods or services are delivered the first time, particularly when patients are involved. However, when inferior goods or services are delivered, it might be necessary to perform rework. Rework involves correcting a defective, failed, or nonconforming item, including disassembly, repair, or, in the case of mammography, replacement with higher-quality images.23

Repeated imaging involves not only capturing additional projections and exposing the patient to more radiation but also time to capture the additional
images, which the mammographer could have spent on new tasks instead of revisiting old ones. Also, considering the already highly litigious and scrutinized field of mammography, rework can have a negative effect on patient confidence in the mammographic procedure.\(^1\)

The FDA conducted a cost-benefit analysis of the interim requirements of the MQSA. The cost analysis was estimated at $24 million annually nationwide and included staff training, mammography equipment upgrades, enhancement of QA programs, and improved notification of mammography results to patients. The benefit analysis estimated that sensitivity and specificity of average mammography improved between 2% and 10%. Using a value of 3% improvement and a conservative estimate of the dollar value of lives saved, as well as improved quality of life associated with less-invasive treatments associated with early detection of breast cancer, the overall benefit of the MQSA was valued at $108 million to $155 million annually. Thus, the estimated benefits of the MQSA might be as high as 6 times the cost.\(^1\)

**Quality Assurance and Quality Control in Mammography Today**

In mammography, QA refers to the steps that are taken to “ensure confidence that valid mammography studies are being performed at a given facility.”\(^7\) Quality control (QC) is “more narrowly defined as only the QA activities specifically involving the technical aspects of performing the examination.”\(^7\) While the broader concept of QA consists of the theoretical plan for maintaining quality, QC refers to the technical and physical aspects of maintaining quality.\(^7\) For example, in mammography, QC involves carrying out a system of checks to ensure proper equipment function and processes. This includes the daily, weekly, monthly, quarterly, semiannual, and annual checks performed by the radiologic technologist and the annual checks performed by the medical physicist.\(^25\)

Instituting a mammography QA program requires creating effective and validated protocols and standard operating procedures, maintaining ongoing staff training, and conducting routine audits and QC checks of equipment.\(^26\)

**Mammography Equipment**

QC in digital mammography is centered primarily on maintenance of monitor function, with the goal of ensuring consistency of imaging. Even though a monitor is in full working order when installed, it can lose functionality over time. This includes loss of pixilation and proper contrast. Changes in luminance and resolution also can occur. In addition, displays can be affected by changes in ambient lighting in the reading room. The FDA states that the factors that most often affect medical image interpretations are contrast, resolution, and noise.\(^27\)

QC checks of full-field digital mammography imaging equipment should be conducted daily by the radiologic technologist and include measuring a monitor’s grayscale by running tests that involve different patterns of various shapes and shades of gray, allowing the viewer to see the level of contrast in an image. QC tests also can include checking detector uniformity, spatial resolution, contrast resolution, geometric accuracy, and artifact identification. This is done using test patterns provided by the equipment vendor, which were developed by the Society of Motion Picture & Television Engineers (SMPTE) and the American Association of Physicists in Medicine Task Group 18.\(^7\) In addition, the MQSA has guidelines on conducting QC checks of mammography equipment, including printers and monitors.\(^25,28\)

In addition to daily QC tasks and system warm-up, the radiologic technologist also conducts the following weekly QC checks\(^24\):

- Checking the laser printer using the SMPTE pattern from the acquisition workstation.
- Capturing signal-to-noise ratio and contrast-to-noise ratio measurements from an image. Passing criteria for the signal-to-noise ratio is equal to or greater than 40, and the contrast-to-noise ratio should remain within \(\pm 15\%\) of the measurement obtained during acceptance testing of the system.
- Conducting soft-copy workstation QC tasks, including checking room illuminance (which must be below 50 lux for room illuminance or 20 lux for soft-copy displays) and capturing black-and-white level measurements.
- Evaluating phantom image quality by measuring film densities and phantom objects seen on both...
the printer and monitors (eg, 5 fibers, 4 speck groups, 4 masses).

Picture archiving and communication system (PACS) workstations used in mammography also are subject to MQSA requirements and therefore must undergo strict QA and QC procedures. The FDA requires that medical physicists specially trained in digital mammography conduct independent inspections of monitors and other equipment used in PACS workstations.

In general, imaging facility staff members must conduct periodic QC tests to ensure that equipment is in proper working order, including annual acceptance testing of equipment by a medical physicist. This testing process requires obtaining a baseline evaluation of equipment function so that any future variation in function can be identified. With acceptance testing, routine QC tests are conducted in addition to tube-leakage tests and measurements of radiation exposure behind the operator’s console to protect those working in mammography from unnecessary exposure to radiation.

The physicist must perform the following additional checks annually:
- Evaluating mammographic unit assembly.
- Assessing collimation.
- Evaluating artifacts.
- Checking for kilovolt peak accuracy and reproducibility.
- Measuring output from half-value layer filters.
- Evaluating system resolution.
- Measuring breast entrance exposure and glandular average dose.
- Verifying radiation output rate.
- Conducting phantom image quality evaluation.
- Capturing signal-to-noise ratio and contrast-to-noise ratio measurements.
- Checking viewbox luminance and room illuminance.
- Conducting soft-copy workstation QC tasks.

Radiologists are not permitted to read images from a display that has not been tested by a physicist. Any issues identified via QC tests must be addressed within 30 days and before any equipment can be used on patients.

For more information about imaging equipment QC, the ACR provides QC forms organized by manufacturer online at http://www.acr.org/Quality-Safety/Accreditation/Mammography/Testing-and-QC-Forms/RadTech-QC-Forms.

**Image Quality**

To be considered high quality, digital mammography should be able to demonstrate the characteristics of breast cancer, including the morphology of a mass, the shape and spatial configuration of calcifications, distortion of normal breast structures and tissue, asymmetry between images of the left and right breasts, and the development of anatomical changes compared with prior images. Thus, checks to ensure that imaging adheres to a standard of quality are necessary.

Radiographs of phantoms should be obtained weekly. Images should be taken in accordance with the mammography department’s QA procedures to assess image density, contrast, and uniformity. Masses, speck groups representing calcifications, and fibers are simulated on the phantom. The technologist conducting the QC checks assesses the phantom image and records the number of objects visible on the image. Phantom images then are compared with previous phantom images to assess for artifacts and nonuniform areas so a quality baseline can be established.

**Artifacts**

Artifacts in mammographic imaging can result from various causes related to the detector, machine, patient, process and positioning, or storage. Motion artifacts on mammography usually occur on the mediolateral oblique (MLO) projection because the breast is not supported by the Bucky tray as it is for the craniocaudal (CC) projection. Patient movement during imaging also can result in image artifacts. Recurrent motion artifacts on mammography for multiple patients might indicate that the compression mechanism is malfunctioning. Mammograms with motion artifacts are suboptimal and should be repeated to achieve quality images.

Items such as jewelry, clothing, hair, or implanted medical devices can result in superimposition and obscuring of images. Substances such as deodorant,
powders, and lotions that contain zinc, aluminum, and magnesium can appear opaque and mimic calcifications on imaging. Nicotine or estrogen skin patches can create a pseudomass, a poorly defined area of opacity usually found on the MLO projection. The radiologic technologist should carefully examine the patient for any such items and remove any pharmaceutical skin patches prior to imaging.

**Process Quality**

Mammogram quality depends on the radiologic technologist’s understanding of the technical elements of the process as well as proper patient positioning. The “3 Cs”—carefully, correctly, and consistently—can serve as a reminder about quality in imaging. Examining the patient for items that could cause artifacts and capturing a thorough patient history are important first steps in the imaging process. A complete medical history includes information about ethnicity, family medical history, first menstrual period, number of childbirths, age at menopause, previous breast surgery, radiation or chemotherapy, hormone-replacement therapy, or any other information relating to medication or treatment that can help determine a patient’s risk for developing breast cancer.

**Patient Positioning**

Patient positioning also is subject to evaluation to ensure proper technique. With mammography, the goal is to visualize the maximum amount of breast tissue, and MLO and CC projections are standard. Diagnostic mammography includes imaging techniques that differ from the standard CC and MLO projections, including the spot compression projection with or without magnification, exaggerated CC projection, roll view in the CC projection, and the lateral medial or 90° projection.

An MLO projection shows the most breast tissue in a single image when used effectively. A properly positioned MLO projection includes:

- A pectoralis muscle that is well visualized, with its inferior extent at the nipple line.
- An image of a breast that is not sagging.
- Fibroglandular tissue that is well separated.
- No blurring.
- An open inframammary fold with a visualized posterior extent.
- Depth of breast tissue on the nipple line that is the same as that shown on previous imaging examinations. For MLO projections, this line extends posteriorly from the nipple to the pectoralis muscle or the edge of the receptor, whichever comes first, and approximately perpendicular to the pectoralis muscle. (Note: This measurement is used to evaluate the depth of tissue on the CC view and on previous imaging.)

With proper MLO technique, the pectoralis muscle and all breast tissue should be visible, as well as retro-mammary fat behind the fibroglandular tissue. The x-ray tube angle should be adjusted depending on patient body type (eg, a decreased angle should be used for women with larger body types, whereas an increased angle is appropriate for women with smaller body types.) The patient should stand with her feet pointed toward the mammography machine with the angle of the detector close to the anterior superior iliac spine, and the detector height should be level with the axilla and parallel to the pectoralis muscle. Compression should occur close to the patient’s collar bone, against the ribs and sternum medially. A best practice for MLO projections is to ask the patient to inhale deeply, then exhale slowly during compression, which allows the mammographer to see the rib cage move out of the way. Having the patient slouch slightly might help the pectoralis muscle come forward, allowing for better manipulation of the breast tissue away from the chest wall.

In contrast, CC projections are used to visualize medial tissue. Proper CC positioning includes:

- Visualization of all medial tissue.
- The nipple centered on the Bucky grid.
- Depth of breast tissue measured along the nipple line within 1 cm of the nipple line measured on the MLO view; the nipple line is drawn directly posteriorly from the nipple to the edge of the receptor.
- As much lateral tissue as possible without compromising or obscuring medial tissue.

With proper positioning on the CC projection, all medial tissue and some lateral tissue should be visualized. The contralateral breast also should be positioned
Positioning Techniques for Special Patient Populations

Because patients’ bodies vary, so too must positioning techniques. The radiologic technologist must first examine the patient’s breast type and select the compression paddle that best fits. Using a large paddle for a small breast, for example, does not produce better quality images. Instead, it wears out the detector faster and causes discomfort for the patient, while providing inadequate visualization of axillary tissue.

The radiologic technologist should aim to be as symmetrical as possible with both the CC and MLO projections because it is important to capture the same amount of pectoralis muscle and retromammary fat. Proper compression technique is less painful for patients and ensures quality imaging. Before the final compression, it is important to check for folds medially and laterally, with proper positioning of the nipple. The same level of compression should be applied for all projections in an examination.

Patients with breast implants require special attention when undergoing mammography. Although the indications for screening mammography are the same for women with breast implants, compression techniques and procedures for capturing mammographic images differ. With breast implants, improper compression techniques can result in damaging or even rupturing the implant. Because implants appear opaque on mammography, they can obscure the view of breast tissue and hide abnormalities or findings, thereby potentially delaying a cancer diagnosis. In addition, implants can result in calcifications and scarring that can mimic breast cancer, causing a false-positive result that could lead to additional imaging or unnecessary treatment. Implants placed posterior to the pectoral muscle are less likely to interfere with imaging than subglandular implants and allow for almost twice the amount of breast tissue to be imaged.

Proper imaging of implanted breasts requires implant displacement, also known as the Eklund technique. This technique involves moving the breast tissue forward and away from the implant while displacing the implant posteriorly against the chest wall so it is out of the field of view. The radiologic technologist then applies compression to the tissue in front of the implant, and standard MLO and CC projections are captured.
Because additional images are needed in women with breast implants, screening mammography is conducted more like diagnostic mammography. The higher radiation dose required for women with breast implants has raised concerns. It is estimated that over a lifetime, a woman with breast implants might be exposed to as much as 3 times the radiation. Thus, caution should be taken to correctly and efficiently image patients with implants to avoid any rework or additional images.

Patients at higher risk for breast cancer, such as those who have mutations of the BRCA genes or who have dense breast tissue, might require supplemental screening with another imaging modality such as ultrasonography, digital breast tomoscopy, or magnetic resonance (MR) imaging. When MR imaging is indicated, patient positioning remains paramount. Best practice involves the radiologic technologist placing the breast in the MR breast coil with the nipple in profile so the interpreting radiologist can correlate mammographic images with breast MR images.

**ALARA and Radiation Dose in Mammography**

QA in mammography, like in all radiology, is an important part of ensuring adherence to ALARA (as low as reasonably achievable) in regard to radiation dose. An important factor in mammography QA is monitoring the radiation output of imaging equipment. Once proper functioning of equipment has been established, the radiologic technologist must conduct all patient examinations with concern for minimizing the patient’s radiation dose while securing high-quality images. The goal is to produce radiologic images with maximum visualization of breast anatomy and any signs of disease without exposing the patient to unnecessary radiation. Thus, the ALARA principle governs the radiologic technologist’s practice and directly affects patient care.

Radiation is measured in mean glandular dose (MGD), which can be used to gauge the potential risk of mammography radiation exposure. MGD can be calculated using the following equation:

\[
\text{MGD} = \text{exposure normalized glandular dose} \times \text{entrance surface exposure}
\]

Mean glandular dose, which can be calculated manually or with software, depends on 3 factors: the characteristics of the equipment used, the examination technique used, and the size and density of the patient’s breasts. Generally, radiation dose increases with larger breast size and increased density, but the examination technique also can influence radiation dose depending on the selected kilovolt and anode/filter combination. Lower kilovolt values can be used to enhance contrast, except with thick or dense breast tissue, which might not be penetrable at lower doses and therefore might require a higher kilovolt value. When kilovoltage is reduced, the milliampere second level must be increased, resulting in a higher radiation dose.

ALARA is useful not only in ensuring patient safety but also in safeguarding those working in radiology. The goal is to reduce the radiologic technologist’s exposure to radiation by following 3 steps:

- **Time** – keep exposure time to a minimum.
- **Distance** – maintain distance from the radiation source.
- **Shielding** – place a shield between oneself and the source.

A radiologic technologist who becomes pregnant might need to take additional precautions to ensure that the fetus is not affected by the radiation dose, particularly if she works with ionizing radiation. The maximum level of radiation exposure to a fetus should not exceed 0.5 rem before birth. A fetal monitoring badge can be used to measure the level of radiation.

Digital mammography offers the advantage of decreased radiation dose compared with film-screen mammography, and digital mammography might be more accurate in women with dense breast tissue.

**Communicating Mammography Results**

Effective communication of mammography results is an important part of a high-quality mammography program. This includes conveying health information not only to patients but also to other health care providers, such as the referring physician. According to the MQSA, a patient must be given a written summary of the results of a mammogram in lay terms no later than 30 days after the date of the examination. However, when the patient has BI-RADS category
4 or 5 results, communication of such results should be given to the patient as soon as possible, but no more than 5 working days from the date of the mammography interpretation. BI-RADS categories are summarized in Table 1. Communication of mammogram results with other health care providers should include all pertinent patient information such as the patient’s name and unique identifier and should be issued no later than 30 days after the date of the examination. With a BI-RADS category 4 or 5 result, however, results should be communicated as soon as possible but no more than 3 working days from the date of interpretation. If a provider is unavailable, the report should be given to the provider’s designee immediately. Direct communication, either with the patient or the patient’s referring health care provider or designee, should be documented in the medical records and, ideally, also in the mammography report.

**Image Labeling**

Another important aspect of quality mammography is correct and complete image labeling. Because images are used by different facilities and members of the health care team, the ACR Committee on Breast Imaging established standardized labeling guidelines to eliminate confusion that can result from different labeling processes. The guidelines include image labeling elements that are either required, strongly recommended, or recommended. Required elements include the use of a permanent identification label with the facility name, patient’s first and last names, unique patient identifier number, and the date of the examination. Identifying the technical aspects of the examination is recommended, such as milliampere second and kilovolt settings, amount of compression, thickness of the compressed breast, and the degree of obliquity for MLO projections.

**Other Breast Imaging Modalities and Computer-Aided Detection**

Other breast imaging modalities include positron emission tomography (PET), digital breast tomography, and ultrasonography, each of which has a particular role in producing quality images. PET is used to stage breast cancer and monitor breast cancer treatment response. PET, positron emission mammography (PEM), and PET-CT (computed tomography) are used to assess metastatic breast cancer. In addition, research has indicated that PEM might be useful in detecting breast tumors as small as 2 mm.

According to a study by Xing, the QA protocol for PET imaging should not be limited to checking the function of the scanner but also should include data transfer, image acquisition, and quantitation of data for delineating tumors and other structures. Assessment of PET scanner performance is based on National Electrical Measurement Association standards, which can be used for acceptance testing and comparison of different PET imaging systems.

Digital breast tomography has shown promise in mammography in that it can be used to detect cancers in overlapping breast tissue, which would be obscured on conventional mammography. Breast ultrasonography can be used in conjunction with MR imaging to enhance detection and assessment of breast cancer.

Computer-aided detection (CAD) is useful in improving mammogram interpretation, as it serves as a type of “second opinion” in detection and diagnosis of breast cancer by analyzing computer output data. The radiologist interprets the images then verifies his or her findings with the CAD results. Furthermore, CAD in conjunction with ultrasonic images of the breast has

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**Table 1**

<table>
<thead>
<tr>
<th>BI-RADS Categories</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>0</td>
<td>Additional studies or comparison to prior images is needed.</td>
</tr>
<tr>
<td>1</td>
<td>Negative; no significant abnormalities.</td>
</tr>
<tr>
<td>2</td>
<td>Negative, but benign calcifications, lymph nodes, or fibroadenomas may be present.</td>
</tr>
<tr>
<td>3</td>
<td>Probable benign findings but requires follow-up imaging every 6 months for at least 2 years.</td>
</tr>
<tr>
<td>4</td>
<td>Suspicious abnormalities, consider biopsy.</td>
</tr>
<tr>
<td>5</td>
<td>Findings are highly suggestive of cancer.</td>
</tr>
<tr>
<td>6</td>
<td>Used for malignant findings already proven through biopsy.</td>
</tr>
</tbody>
</table>

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BI-RADS Categories

1

September/October 2014, Volume 86, Number 1

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69M
been shown to be effective in distinguishing between benign and malignant tumors.\textsuperscript{7}

**Quality Guidelines**

The 2013 ACR Practice Guideline for the Performance of Screening and Diagnostic Mammography contains recommendations and standards for performing high-quality mammography in accordance with MQSA and regulations of the FDA. The practice guideline contains information on various aspects of mammography, including indications for screening mammography in breast cancer detection as well as diagnostic mammography; qualifications and responsibilities of those working in mammography, including interpreting physicians, radiologists, and radiologic technologists; mammography examination specifications and image identification specifics; communication of results; mammography equipment specifications and requirements; and radiation safety guidelines.\textsuperscript{41,45}

The ACR Practice Guideline also includes a QC section with specifications for maintaining compliance with the MQSA, which is composed of QC procedures outlined in the ACR Mammography Quality Control Manual. This manual contains a list of tests to ensure mammography equipment is in working order, including peripheral devices such as monitors and film printers.\textsuperscript{41,45}

**Mammographer Training**

The FDA regulates the use of radiation-emitting products such as mammography equipment as well as radiologic technologist–specific training requirements for mammographic imaging. Such training requirements fall under Citation 900.12(a)(2)(ii)(A)(B) and (C) mammography requirements, which require\textsuperscript{46}:

- (A) Training in breast anatomy and physiology, positioning and compression, quality assurance/quality control techniques, imaging of patients with breast implants.
- (B) The performance of a minimum of 25 examinations under the direct supervision of a qualified individual (requirements specified in paragraph (a)(2) of the section).
- (C) At least 8 hours of training in each mammographic modality to be used by the technologist in performing mammography examinations.

**Facility Accreditation and Certification**

The MQSA, as mandated by Congress, requires that all mammography facilities in the United States be accredited, certified by the U.S. Department of Health and Human Services, and inspected by the Department of Health and Human Services or another agency on behalf of the department.\textsuperscript{47} The MQSA was enacted in response to concerns about the quality of mammography imaging in the United States. Because of mammography’s importance in the diagnosis and treatment of breast cancer, its regulation is imperative.\textsuperscript{4}

The FDA’s accreditation body states the regulations necessary to implement the MQSA. In addition to information on eligibility and application for mammography accreditation or reaccreditation, these guidelines also state the standards for clinical image review needed for accreditation or reaccreditation, including\textsuperscript{48}:

- Review of clinical images by the accrediting body at least once every 3 years.
- Review of clinical image attributes, such as positioning, so that sufficient breast tissue is visible to ensure that a cancer diagnosis is not missed; compression needed to minimize obscuring overlying breast tissue and artifacts; radiation exposure level; contrast, sharpness, and noise of images; and image labeling.
- Selection of clinical images for review, including CC and MLO projections from 2 examinations during a specified period of time.
- Review of physicians, including adherence to interpreting and training requirements.
- Reports of mammography equipment inspection.

The FDA has approved accrediting bodies for both film-screen and digital mammography systems, and the ACR requirements are identical or equivalent to the FDA’s final rules. The ACR’s Mammography Accreditation Program, created in 1987 by the ACR Task Force on Breast Cancer and the largest accreditation program in the United States, includes specifics on staff qualifications, equipment, QA/QC, image quality, and radiation dose.\textsuperscript{47}

In accord with the ACR and MQSA requirements, all radiologic technologists working in mammography must meet the MQSA qualifications (see Table 2). The ACR also suggests that radiologic technologists performing
Statistics reported that the industries with the highest rates of musculoskeletal disorders included transportation and warehousing, retail and wholesale trade and construction, and health care. According to the Bureau of Labor Statistics, there were 387,820 cases of musculoskeletal disorders in 2011, which accounted for 33% of all worker injuries and illness.

The United States Department of Labor, Occupational Safety & Health Administration (OSHA) estimated that work-related musculoskeletal injuries in the United States cause approximately 700,000 lost workdays and more than 2.7 million claims for worker compensation per year as a result of improperly designed workplaces. The cost of worker compensation claims due to musculoskeletal disorders accounts for 1 out of every 3 dollars spent on worker compensation as a whole. According to OSHA statistics, employers spend an estimated $20 billion per year in direct costs for worker compensation, with up to 5 times that amount in indirect costs.

The quality of life cost to those who suffer work-related injuries is more difficult to quantify. These individuals can be left with permanent disabilities and partial or complete inability to work.

**Ergonomics**

Ergonomics is a science that deals with designing and arranging items so they can be used quickly and safely. In the workplace, this means designing equipment and work-related tasks that are comfortable and safe for workers, particularly those tasks associated with risks of musculoskeletal disorders of the muscles, nerves, and tendons. An effective ergonomic system allows for increased productivity, prevention of workplace-related injury and illness, and increased employee satisfaction.

**The Cost of Workplace Injuries**

Work-related musculoskeletal disorders—particularly those of the neck, upper extremities, and lower back—are one of the leading causes of lost workdays due to injury and illness. Lifting heavy weights or pushing or pulling heavy loads, bending, reaching overhead, or working with the body in awkward positions repeatedly exposes workers to risk of developing musculoskeletal disorders. In 2011, the U.S. Bureau of Labor Statistics reported that the industries with the highest rates of musculoskeletal disorders included transportation and warehousing, retail and wholesale trade and construction, and health care. According to the Bureau of Labor Statistics, there were 387,820 cases of musculoskeletal disorders in 2011, which accounted for 33% of all worker injuries and illness.

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**History of Ergonomics**

OSHA has been involved with the ergonomic movement since the late 1970s. At that time, OSHA was just starting to issue citations for violations of the
Occupational Safety and Health Act that resulted in workers suffering musculoskeletal disorders. In 1983, OSHA began training compliance officers and consultants in ergonomics, and by 1988 OSHA had entered into several settlement agreements with large corporations, primarily in the meatpacking and automotive industries.52

Since the start of OSHA’s enforcement efforts, repeated-trauma disorders in the meatpacking and automotive industries have decreased. Today, OSHA continues to regulate workplace activities and has published many guidance documents on the topic of ergonomics and injury prevention.52 Additionally, the Centers for Disease Control and Prevention issued several publications on worker safety and ergonomics in agriculture, construction, mining, and health care.53

**Ergonomics Research Findings**

The National Health Service Breast Cancer Screening Programme, based in the United Kingdom, conducted an ergonomic screening assessment of mammography machines in 1997 to investigate whether mammographers were experiencing musculoskeletal discomfort or injury and to what extent the design or layout of the equipment was a contributing factor. Many changes were adopted by manufacturers based on the findings of the assessment, including the introduction of motorized mammography units, lightweight units with isocentric rotation, and more accessible controls.54

The assessment also revealed that wrist and thumb injuries were among the most common injuries reported by the mammographers studied. Such wrist and thumb injuries were identified as resulting from inserting and ejecting x-ray film from the Bucky, mounting film onto the viewer and changing the detector settings, and the location of the controls. Digital mammography does away with many of these injury-causing features, but certain ergonomic problems remain. According to the assessment, the biggest problem is patient positioning because it requires the mammographer to assume awkward postures.54

In other ergonomics research, Moin et al conducted an observer study of computer-aided reading protocol (CARP) in the digital screening mammography setting to investigate workflow efficiency.55 The goal was to shorten mammography reading time using CARP in an effort to increase detection sensitivity compared with quadrant view protocols. Two hundred cases were selected for receiver-operating characteristic evaluation, with electronic scoring, reporting (ie, BI-RADS), and statistical analysis of results. Six radiologists participated; their skill levels ranged from dedicated mammographers to senior radiology residents. There was no significant difference in reader performance with either protocol; however, there was a significant reduction in average interpretation time of negative cases using CARP (58.8 seconds vs 64.7 seconds using quadrant view). The authors determined that CARP can reduce interpretation times for digital mammography with negative findings without significantly affecting sensitivity, allowing for improved workflow and efficiency in the screening mammography setting.55

A study by Liang et al found that the response time for liquid crystal displays (LCDs) used in radiologic imaging affected lesion contrast and observer performance.56 Because of the increasing demands on radiologists, the authors sought to identify factors that affect diagnostic performance. Stack-mode image display allows for browsing of large 3-D datasets with refresh rates as high as 30 images per second. However, the slow response of LCDs can compromise image quality when images are browsed in a fast sequence. After assessments using images with Gaussian and non-Gaussian lumpy backgrounds, the authors were able to quantify the observer performance, which indicated that the slow response of the LCD greatly affects lesion contrast and observer performance, with a detectability decrease of more than 40%. Thus, results can be applied to recommendations for improved browsing of large volumetric datasets when read in stack mode.56

With LCD screens, research has shown that an increase in ambient lighting in reading rooms can improve mass detection on mammography. A study by Pollard et al investigated a measured increase in ambient lighting in mammography reading rooms to determine its effect on diagnostic performance. Four radiologists read 86 mammograms under low (1 lux) and elevated (50 lux) lighting using calibrated medical-grade LCDs.
There were no statistically significant differences in observer performance or interobserver variability; however, average selection times under increased ambient lighting remained constant or decreased, with the greatest decrease for false-positive (20.4 ± 18.9 seconds to 14.4 ± 9.6 seconds) and true-positive images (18.0 ± 13.8 seconds to 12.9 ± 9.4 seconds). Although these results were not statistically significant, the authors, in conjunction with ACR recommendations on reading room lighting, suggested that a moderate increase of ambient lighting in mammography reading rooms is preferred, although additional research should be considered.⁹⁷

A 2013 article presented findings on visual search training techniques to improve search performance in industries including radiology. The goal was to investigate whether perceptual or conceptual training is effective in improving the speed and accuracy of a visual search.⁸⁴ Perceptual training involves intensive practice or application with a limited set of stimuli,⁹⁹ whereas conceptual training involves learning from concepts or theories without actual application.⁶⁰ Results suggested that when a visual search involves detecting heterogeneous or unpredictable stimuli, perceptual training might improve the speed and accuracy of search performance. Thus, perceptual training might be useful in radiology to increase efficiency and job performance.⁵⁸

**Ergonomic Issues and Advances in Radiology**

OSHA defines ergonomics as the science of fitting workplace conditions and job-related tasks to the capabilities of the working population. This means adjusting equipment and work-related tasks to the needs of the worker,⁵¹ taking into consideration human anatomy and capabilities.⁴¹ When the physical demands of a job do not match the physical capabilities of the worker, work-related musculoskeletal disorders can occur. Common risk factors for musculoskeletal injury include repetitive motion, frequent or heavy lifting, and prolonged postures that are awkward or unhealthy. A proactive stance on workplace design can help eliminate risks of injury while promoting productivity and employee job satisfaction.⁵¹

In radiology, radiologic technologists and radiologist assistants are at increased risk for musculoskeletal injuries caused by repeated strain on the upper extremities and lower back. These are most often caused by transferring, positioning, and transporting patients, as well as certain types of equipment, such as ultrasound probes, heavy protective garments, and poorly designed workstations.⁶²

Other common injuries associated with radiology include eye strain, backache, and shoulder and neck pain due to ergonomic deficiencies in radiology reading rooms (see Table 3).³ Increased use of computers in radiology has led to certain injuries, illnesses, and fatigue, prompting some to investigate modern ergonomic solutions, such as PACS workstations.³

**The PACS Workstation**

The PACS workstation was developed out of the need for radiologists to view images away from the film library. It continued to evolve as software developments allowed for even more flexibility in image viewing from nearly any location in a health care facility. Hardware developments allowed for thinner and more accurate monitors for viewing images, further increasing portability.⁶³

The transition from a film-based system to the filmless PACS system has modernized the radiology suite and improved workflow by increasing productivity, diagnostic accuracy, and job satisfaction. However, optimal workstation ergonomics must be incorporated to ensure success and avoid injury, including positioning of the workstation chair, table, keyboard, mouse, and monitors as well as monitor refresh rates and ambient lighting (see Figures 2-5).³

Increasingly, PACS workstations are being adapted to accommodate digital mammography, which previously required a dedicated workstation.⁶₃ Moreover, full-field digital mammography workstations are being compared with PACS workstations for image quality and diagnostic performance, with full-field digital mammography workstations offering higher sensitivity in imaging microcalcifications.⁶⁴

**Additional Advances**

Additional advances are being made to incorporate new technology into the radiology setting, such as wireless access and hand-held user interface devices instead...
of a stationary keyboard and mouse setup. The goal is to use these software and hardware advances to free the radiologist from unnecessary tasks to minimize the physical and mental effects of everyday workplace stress. Attention to factors such as lighting, room temperature, background noise, and proper body positioning while viewing images also improves workstation design and decreases job-related stress.\footnote{2}

### Table 3

<table>
<thead>
<tr>
<th>Common Ergonomic Problems With Radiology Workstations and Possible Solutions\footnote{2}</th>
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<td>Problems</td>
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| Monitors placed too high or too close or inadequately adjusted | - The top of the monitor edge should be 15°-50° below eye level.  
- The distance from the eye to the screen should be 22-26 in (55-65 cm); it is preferable to make characters or images bigger rather than moving the monitor closer.  
- The monitor should be directly in front of the user, not off to the side, which requires twisting the body to view.  
- The top of the monitor should be slightly farther from the eye than the bottom of the monitor to avoid having to crane the neck back to view the screen.  
- The document holder should be placed at approximately the same height and distance as the monitor to minimize extraneous head and neck movement. |
| Monitor glare                                    | Use indirect or glare-free lighting and blinds or shades to control outside light. |
| Reading images continuously without a break, resulting in prolonged focus | Take frequent short breaks away from the workstation. |
| Eye issues that include strain, irritation, and fatigue as indicated by sore, tired, itchy, dry, or burning eyes; headaches; blurred or double vision; color fringes after images; or photophobia (light sensitivity) | Avert gaze periodically (eg, look 20 feet away for 20 seconds every 20 minutes); use software applications or alarm clocks as reminders to take a break and rest the eyes. |
| Improperly adjusted chair, resulting in flattening and reversing of the inward curve of the lower back | - The workstation chair should adequately support the lumbar spine; adjust the height or select a chair with proper fit because an overly high chair causes sliding forward and an oversized seat cushion digs into the backs of the legs.  
- Make an effort to sit upright. |
| Awkward hand angle while using computer keyboard, mouse, or both, potentially leading to carpal tunnel syndrome and tendon inflammation | - Upper arms should be in a relaxed position at the sides of the body, as close to the body as possible.  
- Forearms should be horizontal and at right angles to the upper arms.  
- Elbow rests can be used for additional support.  
- Keyboard should be parallel to the edge of the desk.  
- Position the mouse as close to the body as possible.  
- If possible, periodically alternate the hand used to operate the mouse. |
| General concerns                                 | - Try to avoid reaching and twisting.  
- Adjust room temperature, humidity, ventilation, and lighting.  
- Work with the body in a neutral position, using good posture and changing positions often. |

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Ergonomic Evaluation and Recommendations

Khan M Siddiqui, MD, investigated the radiology environment, including the number of images a radiologist can read in a given day and the setup of the typical radiology workstation.\footnote{16} According to Siddiqui, optimizing the work environment will improve staff morale and patient care. Some solutions are removing clutter, evaluating lighting, and redesigning workstation
Figure 2. Recommended picture archiving and communication system (PACS) workstation monitor placement, with the top edge of the monitor at 15° to 50° below eye level (indicated by the blue line). Reprinted with permission from Harisinghani MG, Blake MA, Saksena M, et al. Importance and effects of altered workplace ergonomics in modern radiology suites. Radiographics. 2004;24(2):617.

Figure 3. Optimal placement of the PACS workstation monitor and keyboard directly in front of the radiologist, with the document holder off to the side, creating an ergonomically correct posture that minimizes neck and upper back strain. Reprinted with permission from Harisinghani MG, Blake MA, Saksena M, et al. Importance and effects of altered workplace ergonomics in modern radiology suites. Radiographics. 2004;24(2):619.

Figure 4. Upper arms relaxed and at the sides of the body, resulting from sitting the correct distance from the keyboard. Reprinted with permission from Harisinghani MG, Blake MA, Saksena M, et al. Importance and effects of altered workplace ergonomics in modern radiology suites. Radiographics. 2004;24(2):620.

Figure 5. Optimal chair height, which should be adjusted so that the forearms and hands are horizontal to the floor, with the elbows directly under the shoulders and no angle at the wrists. Reprinted with permission from Harisinghani MG, Blake MA, Saksena M, et al. Importance and effects of altered workplace ergonomics in modern radiology suites. Radiographics. 2004;24(2):620.
setup, all of which can affect diagnostic accuracy and employee fatigue and stress.16

In his evaluation of the Baltimore Veteran’s Administration Medical Center, Siddiqui and his team employed a charrette process approach in which a group convenes to address a design problem. The team found that lighting, noise, and furniture design all played a role in radiologists’ comfort, fatigue, and productivity. The following solutions were derived16:

- Lighting only halfway on or completely off minimized fatigue, whereas lighting on high caused high levels of fatigue.
- Balanced lighting maximized diagnostic accuracy, whereas lighting fully on or off decreased accuracy by approximately 14%.
- Sound-absorbing materials or acoustic paneling can significantly reduce outside noise.
- Chairs should have a back rest and adjustable back, elbow, and shoulder supports to reduce the potential for carpal tunnel and cubital tunnel strains.
- Clutter should be minimized.
- The 20/20/20 rule can be useful in decreasing eye fatigue; that is, every 20 minutes look 20 feet away for 20 seconds.
- Avoid staring at the words while using voice recognition dictation; staring at the images is preferred because it does not cause the eye to jump from the white background used for text to the dark background used for images.
- The use of programmable devices to automate common tasks with the PACS workstation can reduce the number of clicks required to access certain features, thereby decreasing strain on the hands.

In mammography, the mammographer spends the majority of time positioning patients for imaging. Because patients vary in size and shape, the mammographer must tailor the imaging approach accordingly but always maintain good posture to avoid back strain or injury. Good posture is achieved by standing straight instead of slouching forward or bending laterally. The knees should be bent slightly to maintain balance, with the feet slightly apart. If awkward body movements are necessary for patient positioning, the mammographer should use the entire body to diffuse the patient’s weight and return to a neutral position as soon as possible.33

Other ergonomically sound practices for the mammographer include3:

- Keep the shoulders relaxed and the arms slightly bent by standing close to the patient.
- Avoid extra stretching for movements that could strain the muscles or tendons.
- Use securely locked stools or chairs, when possible, to help steady the patient during imaging.
- Keep imaging equipment foot pedals within reach to avoid excessive reaching or straining.
- Use 2 hands to position the patient for CC images, keeping the elbows and wrists on the same plane.
- Keep the wrist and forearm on the same plane while positioning the patient for MLO images.
- Wear comfortable, loose-fitting clothing to allow for easy movement and good posture.

**Conclusion**

QA is a system of evaluating goods and services to ensure that a level of quality is being met or delivered.17 In mammography, QA plans and QC procedures are used to guarantee that equipment is in good working order.22 With breast cancer ranking as the second most deadly cancer among women, it is crucial that screening and diagnostic mammography be performed using properly functioning equipment and patient-centered best practices. This keeps both the patient and the mammographer safe from unnecessary exposure to radiation, and it increases accuracy, reduces the risk of rework, and promotes patient satisfaction with the procedure.4,23

Ergonomics is a science concerned with arranging things for safe and effective use.49 In the workplace, this means designing and arranging equipment in a way that is comfortable and safe for workers, thus mitigating the risk of work-related injury. Ideally, ergonomically designed equipment and tasks also promote increased efficiency and worker satisfaction.60

In radiology, radiologic technologists are at risk for musculoskeletal injuries most often caused by transferring, positioning, and transporting patients, as well as from misuse of equipment and poorly designed workstations.62 In the mammography setting, examples of
ergonomic advances include wireless and hand-held devices, the PACS workstation, appropriate lighting, and proper body positioning while viewing images. Together, QA and ergonomics in mammography create an environment in which patients benefit from the delivery of high-quality images, while workers are protected by a safe working environment designed around their specific job demands. Furthermore, a properly functioning and safe work environment is paramount in maintaining the health and well-being of both the radiology professional and the patient.

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References


Quality Assurance and Ergonomics in the Mammography Department

1. Breast cancer is second only to _______ cancer as a cause of cancer-related deaths among women.
   a. liver
   b. lung
   c. colon
   d. skin

2. Approximately what percentage of mammograms are false positives?
   a. 5
   b. 10
   c. 15
   d. 20

3. Which organization revised its breast cancer screening guidelines in 2009 to state that women should begin screening at age 50 years, rather than 40 years?
   a. American College of Radiology
   b. U.S. Food and Drug Administration (FDA)
   c. American Cancer Society
   d. U.S. Preventative Services Task Force

4. What is the most common reason cited for lawsuits against radiologists who interpret mammograms?
   a. mammography misread
   b. false-positive readings
   c. incorrect image labeling
   d. delay in reporting findings

5. In its broadest sense, quality assurance (QA) is:
   a. a way to reduce manufacturing defects.
   b. a means of increasing profitability.
   c. the activity of evaluating goods or services to ensure that certain standards are met.
   d. a technique for avoiding lawsuits.

Read the preceding Directed Reading and choose the answer that is most correct based on the article.
6. In the early 1990s, hearings held by the Senate Committee on Labor and Human Resources revealed several issues with mammography services in the United States, including:
   1. lack of QA procedures.
   2. poorly trained personnel.
   3. poor equipment.

   a. 1 and 2
   b. 1 and 3
   c. 2 and 3
   d. 1, 2, and 3

7. Rework in mammography consists of:
   a. examining the patient with a second imaging modality.
   b. replacing inferior images with higher-quality images.
   c. upgrading mammography equipment.
   d. revising an imaging protocol.

8. According to an FDA analysis, the benefits of the Mammography Quality Standards Act (MQSA) might be _______ times higher than its costs.
   a. 2
   b. 4
   c. 6
   d. 8

9. In mammography quality control (QC), who is responsible for performing periodic checks of equipment and processes?
   a. a radiologist and medical physicist
   b. a radiologic technologist and medical physicist
   c. the department manager
   d. an outside consultant

10. QC in digital mammography focuses primarily on:
    a. the setup of the picture archiving and communication system workstation.
    b. maintaining darkroom cleanliness.
    c. visually inspecting equipment.
    d. maintaining proper monitor function.

11. Which of the following QC checks should be performed annually?
    1. collimation assessment
    2. glandular average dose measurement
    3. kilovolt peak accuracy and reproducibility

    a. 1 and 2
    b. 1 and 3
    c. 2 and 3
    d. 1, 2, and 3

12. If a QC test identifies a problem with mammography equipment, it must be addressed:
    a. immediately.
    b. within 5 working days.
    c. within 30 days and before the equipment can be used on patients.
    d. when it will not disrupt patient imaging.

13. How frequently should the quality of phantom images be evaluated as part of mammography QC?
    a. daily
    b. weekly
    c. quarterly
    d. only when concerns arise

14. Recurrent motion artifacts on mammography for multiple patients might indicate:
    a. improper compression technique.
    b. a malfunctioning compression mechanism.
    c. incorrect positioning.
    d. improper handling of images.

continued on next page
15. Which of the following is not part of the “3 Cs” of proper patient positioning?
   a. cautiously
   b. carefully
   c. correctly
   d. consistently

16. On craniocaudal (CC) projections, how should the nipple be centered?
   a. lateral to midline
   b. posterior to midline
   c. inferior to midline
   d. centered on the Bucky grid

17. For patients with breast implants, the implant should be displaced posteriorly so that it is out of the field of view and the following projections captured:
   1. mediolateral oblique.
   2. CC.
   3. spot compression.
   a. 1 and 2
   b. 1 and 3
   c. 2 and 3
   d. 1, 2, and 3

18. Digital mammography offers the advantage of decreased radiation dose compared with film-screen mammography.
   a. true
   b. false

19. Which of the following is not one of the required elements for a mammogram label?
   a. examination date
   b. facility name
   c. technical factors used
   d. unique patient identifier number

20. Under MQSA regulations, a radiologic technologist who performs mammography must complete 40 hours of training, including 25 mammography examinations under the direct supervision of an MQSA-qualified individual and training in:
   1. digital breast tomodraphy and breast ultrasonography.
   2. positioning and compression.
   3. mammography QA and QC.
   a. 1 and 2
   b. 1 and 3
   c. 2 and 3
   d. 1, 2, and 3

21. Ergonomics is defined as a:
   a. discipline that deals with arranging items for maximum flow of energy, or chi.
   b. discipline aimed at maximizing patient satisfaction.
   c. science that deals with designing and arranging items so they can be used quickly and safely.
   d. science aimed at increasing mammographer compliance with imaging protocols.

22. According to an assessment by the National Health Service Breast Cancer Screening Programme in the United Kingdom, what was the most common type of occupational injury in mammographers?
   a. wrist and thumb injuries
   b. shoulder injuries
   c. lower back injuries
   d. eye strain and other vision problems

23. According to an article by Siddiqui, having the lighting fully on or off decreased diagnostic accuracy by approximately ______ %.
   a. 14
   b. 24
   c. 34
   d. 44
24. Which of the following is mentioned by Siddiqui for decreasing eye fatigue?
   a. the 3 Cs
   b. ALARA
   c. fatigue-proofing
   d. the 20/20/20 rule

25. Which of the following is **not** a recommended ergonomic practice for mammographers?
   a. Keep the shoulders relaxed and the arms slightly bent by standing close to the patient.
   b. Keep foot pedals within reach to avoid excessive reaching or straining.
   c. Use securely locked stools or chairs when possible to steady patients during imaging.
   d. Use one hand only to position patients for the CC projection.
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