Breast Imaging Artifacts

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Artifacts appear on breast images for a number of reasons. Radiologic technologists play an important role in identifying artifacts that can help or hinder breast cancer diagnosis and in minimizing artifacts that degrade image quality. This article describes various artifacts that occur in breast imaging, along with their causes. The article focuses on artifacts in mammography, with a heavy emphasis on digital mammography, and on magnetic resonance imaging of the breast. Artifacts in ultrasonography of the breast, digital breast tomosynthesis, and positron emission mammography also are discussed.

After completing this article, the reader should be able to:

- Define imaging artifacts and their effects on breast imaging quality.
- Discuss how artifacts can assist radiologists in characterizing lesions.
- Describe types of artifacts that occur in various breast imaging modalities.
- List factors that contribute to unwanted artifacts in various breast imaging modalities.
- Explain methods to reduce artifacts that interfere with image quality and diagnosis.
- Articulate the role of the radiologic technologist in recognizing and minimizing image artifacts and ensuring image quality.

Breast imaging is becoming a dedicated modality that involves several imaging specialties. A number of imaging tools are available to physicians for evaluating cancer and benign breast disease, and each tool has strengths and weaknesses. Regardless of the imaging equipment used, early detection of breast disease relates directly to how well a radiologist can see abnormalities on images acquired by radiologic technologists. Artifacts that appear on images can interfere with the visibility of abnormalities, reduce overall image quality, and introduce clinical and technical problems in diagnosing breast cancer.

Artifacts are features visible on an image that are not a result of true differences in the breast’s attenuation or that are introduced in error and can interfere with interpretation of a tissue’s structural or functional information. Specific types and characteristics of artifacts vary by modality. Researchers and clinicians cited in the literature classify artifacts using various schemes. For example, some authors distinguish artifacts related to digital mammography detectors as separate from other equipment-related or machine-related artifacts, but other authors categorize all these errors together. A positioning error might be categorized as a technologist-related error, under positioning, or as a patient-related factor. Artifacts can result from technical or patient-related factors or poor equipment calibration. Although most artifacts interfere with image quality, in some incidences, an artifact can help characterize a lesion or finding.

Image quality is essential in breast imaging. Mammograms serve primarily to detect breast cancer, and breast imaging also can be used to stage or further characterize breast lesions. The transition from film-screen to digital mammography has resulted in net health gains for women aged 50 to 74, the population that receives the most benefit from regular screening mammograms.
Radiologic technologists strive for optimal image quality and seek to minimize distractions in images that might lead to false identification of pathology.\textsuperscript{10}

The risk for false-positive results is high, especially with digital mammograms\textsuperscript{11} and among women aged 40 to 49 who have dense breasts.\textsuperscript{13} A study published in 2015 that included data from more than 702,000 women who had mammograms in 2012 revealed that 11.1\% of the women had a false-positive result from a mammogram.\textsuperscript{13} The high rate of false-positive results leads to expensive additional breast imaging studies—an average of $852 for each false-positive mammogram—and adds to problems with overdiagnosis. One study found that 86\% of ductal carcinoma in situ diagnoses never lead to cancer.\textsuperscript{13}

With mammography in particular, the radiologist must be able to see characteristic morphology, details of calcifications, possible breast asymmetry, architectural distortion of breast tissue, and anatomical changes in the breast from prior mammograms to current examinations. The radiologist also needs a diagnostic-quality image to avoid unnecessary repeat and follow-up examinations that introduce additional radiation and patient concerns due to false-positive results.\textsuperscript{10,14}

Because artifacts are not part of breast tissue anatomy or pathology and generally interfere with interpretation, it is critical that radiologic technologists and all breast imaging professionals learn to characterize artifacts on images.\textsuperscript{7} Although most artifacts are related to equipment and technical factors, breast imaging professionals learn to recognize their occurrence, particularly patterns in occurrence, to ensure problems can be corrected quickly. In addition, some artifacts can be prevented by careful attention to patient positioning and exposure factors.\textsuperscript{6,8} Noise and artifacts affect technical and clinical image quality and the probability of optimal display of anatomical detail and relevant pathology.\textsuperscript{10}

**Mammography**

Screening and diagnostic mammography must meet the highest possible quality standards to ensure the modality continues to help reduce breast cancer mortality, and all mammograms conducted in the United States must conform to the Mammography Quality Standards Act (MQSA) regulations.\textsuperscript{15} The evolution to digital mammography is a technological advancement offering many advantages, but digital systems differ from analog equipment in how they acquire, process, and display mammograms. As a result, the causes of artifacts also differ.\textsuperscript{8}

To date, less research has been conducted on identifying digital mammography-related artifacts than on those that occur with film-screen technology. For example, some artifacts specific to film-screen mammography include dust, lint, or hair artifacts that appear as a result of dirty screens; processor roller artifacts caused by dirt on rollers or malfunction of the processor’s pressure or spring tension; static artifacts from conditions such as low humidity; and fogging artifacts, which can occur when light interferes with film processing.\textsuperscript{8,16}

Artifacts common to both analog and digital acquisition methods are related to patients, equipment, or technical factors.

**Patient-related Artifacts**

Patient motion, superimposition of materials on the skin that block visibility of breast parenchyma, and positioning errors are examples of patient-related artifacts. For example, a patient might place her hand on the breast support plate after positioning. Many of these artifacts can be avoided with careful attention to positioning and evaluation of the field of view before image exposure.\textsuperscript{3}

**Blurring From Patient Motion**

Patient motion is one of the most common patient-related artifacts and a common cause of repeat mammograms.\textsuperscript{3} Motion blurring can limit significantly the mammogram’s spatial resolution and image sharpness and obscure microcalcifications.\textsuperscript{10,16} If the radiologic technologist is uncertain whether blurring is related to motion or technical factors, reviewing the exposure information and technical factors used in the examination can help determine whether a long exposure time or improper technique caused blurring instead of patient motion.\textsuperscript{8} For example, magnification examinations require longer exposure times because of smaller focal spots and lower milliamperage (mA) settings for tube current. The amount of blurring is affected by exposure duration, object motion speed, and the degree of magnification used.\textsuperscript{10}
If blurring is caused by patient motion, the radiologic technologist can decrease motion by reminding the patient to remain still during exposure and using appropriate compression. Patient motion is most likely to occur during mediolateral oblique projections because the patient’s breast is not as well supported by the Bucky tray as it is for craniocaudal projections. Increasing compression slightly can decrease breast tissue motion, as can ensuring that compression is consistent during the exposure. The technologist also can use a short exposure time to minimize motion blurring. This can be achieved by increasing peak kilovoltage (kVp) for thick, dense breasts and allowing digital image processing to compensate for losses in contrast up to an extent. The kVp should not be increased to the point that post-processing increases noise or signal-to-noise ratio.

Thin Breast Artifact

The thin breast artifact is exclusive to digital mammography technique. It appears on images of women whose breasts compress to less than 2 cm thick. The paddle edges can appear as opaque outside triangles on the image corners. The artifact most likely occurs because the algorithm processes the paddle edge as the edge of the image. Technologists and radiologists should recognize the artifact and determine whether it appears only when imaging patients who have thin breasts; otherwise, they should check equipment function. The artifact typically does not interfere with image interpretation or necessitate a repeat image.

Antiperspirant Artifact

Radiologic technologists who perform mammography are well aware of the need to have patients avoid or remove antiperspirants and skin creams from the axillary area before having a mammogram. Antiperspirants appear on mammograms as high-density particles, which can mimic the appearance of microcalcifications or suggest an unusual lesion. Similarly, some ointments, lotions, dermal tattoos, and powders contain radiopaque elements.

In particular, antiperspirants can include aluminum-based ingredients designed to help block perspiration. Mesurolle et al evaluated types of antiperspirants to determine whether the percentage of aluminum-based complexes contained in the formulas or the mode of application (e.g., roll-on, gel, or solid) affected the appearance of high-density particles on mammograms. The authors found that although the percentage of aluminum complexes did not affect the particles’ appearance, particles from solid antiperspirants mimicked the appearance of microcalcifications more closely than did gels, and roll-on antiperspirants were least like calcifications in appearance.

Staff in breast imaging centers and departments must ensure that they communicate with patients about the need to avoid using or remove residue from antiperspirants or lotions before a mammogram appointment. In addition, technologists should learn to recognize antiperspirant artifacts (see Figure 1) so that they can request that patients thoroughly clean the axillary area and, if appropriate, nearby skin folds, before a repeat examination is performed.

Other Patient-related Artifacts

Skin lesions also can mimic microcalcifications or other abnormalities. Geiser et al reported on the case of a patient who had a yeast infection that caused coarse and flaky skin. The skin lesions appeared as calcification-like artifacts. The artifacts disappeared on a subsequent mammogram after the infection resolved.

Patients sometimes move their head or arms after being positioned by the radiologic technologist, causing rare and unusual artifacts from eyeglasses or the chin. A portion of a patient’s gown also could drop into the field of view after positioning. In addition, clinical devices such as pharmaceutical patches or localization devices can appear in the mammography field of view.

Detector-related Artifacts

Several artifacts can be attributed to problems with the detector in digital mammography. A dedicated electronic detector is used in digital mammography to record the permanent image instead of a film cassette. Detectors absorb x-rays, produce an electronic signal, digitize the signal, and store the image results.

Ghosting Artifacts

Sometimes, a latent image from a prior exposure remains on the detector and is superimposed with a
newly acquired image (see Figure 2). The problem is less common with new detector technology but occurred early in digital mammography, particularly with flat-panel selenium detectors. Detector recalibration and a test image to ensure erasure of the latent image corrects for ghosting with other detectors. Most latent images are caused by low detector temperatures and can be avoided by allowing the detector to warm to the proper temperature (typically 25°C-35°C) before acquiring images.

Gouging Artifacts

Gouging artifacts occur when the compression paddle hits the detector array. This can happen when the array is left unprotected because the breast platform is removed. When the paddle strikes the unprotected array, it causes indentations on the soft material of the array, which appear on the mammogram as circular artifacts (see Figure 3). However, the breast platform should be removed only when performing flat-field quality control tests on certain mammography systems. These tests have different names and procedures, depending on the manufacturer, and likely are performed by the medical physicist. Gouging artifacts can be prevented by ensuring that the detector is replaced when removed and using caution when handling the compression paddle.

Horizontal Line Artifacts

When horizontal lines appear in a digital mammogram, the cause typically is defective pixels (see Figure 4). This artifact is called defective pixel artifact. This is a critical artifact for technologists to identify because the line of dead or defective pixels represents missing diagnostic information. Horizontal lines also can occur because of a readout failure affecting a line
Horizontal line artifacts should be evaluated with imaging of a uniform Plexiglas phantom. If the artifacts persist, the detector should be serviced or replaced. Horizontal lines caused by readout failure might require repeat exposure, but they often are corrected spontaneously by the system.

Dead Pixel Elements

In addition to artifacts from lines of dead or defective pixels, single dead pixels or groups of dead pixels in detectors can cause artifacts in images. Often, artifacts from single pixels or small groups of pixels can be mistaken for microcalcifications because they contrast with the background pixels. If a detector is beginning to fail, several scattered, small groups of dead pixels can mimic scattered or clustered microcalcifications. Although newer detectors fail less easily and are less prone to dead pixel artifacts, repeated false-positive results for microcalcifications could signal a detector problem that requires a phantom test, a call to a service engineer, or detector replacement.

Equipment-related Artifacts

Some artifacts occur because of problems related to mammography film-screen or digital equipment other than the detector. Some of these artifacts are caused by dust or dirt, and others occur because of problems with the grid, filtration tube, or automatic exposure control system.

Dust and Dirt Artifacts

In film-screen mammography, dust and dirt on the cassette can look like microcalcifications. Dust and dirt are suggested by recurrent artifacts in the same location on mammograms acquired with the same cassette. Repeating the mammogram using a different cassette can confirm suspicion of a dust-related artifact, and improving daily and weekly cleaning can minimize their occurrence.

In film-screen or digital mammography, the appearance of dust or dirt on the compression paddle also mimics calcifications and can suggest larger masses. A high-density artifact that is visible on 2 different images.
Compliance Paddle Artifacts

If a mammography department notes that repeated motion artifacts occur on images, particularly from the same equipment, there might be a problem with a compression paddle. At times, the edge of the paddle can be seen as a shadow along the patient’s chest wall. The artifact can be corrected by realigning the paddle. To prevent this artifact, all compression paddles should be checked during annual quality control testing.

Collimator and Grid Artifacts

Grids are used to reduce scatter radiation and maximize subject contrast, although they can contribute to higher dose. In mammography, grids are used in nonmagnification, or contact, projections to reduce noise from scatter. Rarely, grid lines can appear on mammograms as a cross-hatch pattern (see Figure 6). The pattern is caused by the grid being stopped during an image exposure and leaving a shadow. The grid stops as a result of an incorrect grid speed parameter setting. Although radiologic technologists should recognize griddline artifacts, service engineers set grid speeds and should be contacted to correct them. The grid also can be misplaced. If only partially inserted, a vertical bar with alternating black and white lines might appear. Fully engaging the grid corrects this artifact.

Collimator misalignment also occurs infrequently. The misalignment is characterized on a mammogram by a solid vertical white bar against the edge of the image adjacent to the chest wall. The beam must be able to cover the chest wall edge of the receptor. These artifacts are corrected easily by realigning the collimator with the detector.

Noise and Exposure

Full-field digital mammography systems have automatic exposure control, which should compensate for exposure factors and ensure optimal signal-to-noise ratio. Still, patients’ breast anatomy differs. Circumstances such as a thin outer edge of the breast combined with positioning of the photocell too close to the outer edge can lead to misreading of tissue and

Figure 5. Right mediolateral oblique (A) and right lateromedial (B) projections show high-density specks (arrows) resulting from dust on the compression paddle. Dust artifacts can mimic calcifications. Reprinted with permission from Geiser WR, Haygood TM, Santiago L, Stephens T, Thames D, Whitman GJ. Challenges in mammography: part I, artifacts in digital mammography. AJR Am J Roentgenol. 2011;197(6):W1026.
a shorter exposure time than required to produce adequate signal for the entire breast. An underexposed image with low signal-to-noise ratio leads to noise. Noise might look like underexposed pixels on the image or have a “salt-and-pepper” appearance, which is characterized by a light area with scattered dark specks.

Noise can be considered an artifact because it is an unwanted signal variation that affects image quality and can obscure small lesions such as calcifications. Noise affects image resolution and produces a grainy appearance on mammograms. Although some noise can be corrected during postprocessing, it is not recommended because subtle lesions might still be obscured in the underexposed image. Adjusting technique factors by increasing kVp or exposure can correct the underexposure and minimize noise on a mammogram (see Figure 7). Manufacturers continue to research and refine image processing methods to reduce noise on mammograms, particularly to improve the function of computer-aided detection software.

Field Inhomogeneity

When conducting weekly quality control tests with a phantom, a radiologic technologist might note an inhomogeneous field on the image. This inhomogeneity is caused by a detector that is not warmed to the recommended temperature.

Postacquisition Artifacts

Some artifacts specific to digital mammography occur after the image is acquired because of image processing or storage. Other artifacts are specific to the manufacturer’s software.

Processing Artifacts

Digital mammography uses an electronic system and sophisticated software algorithms to process and record images. The algorithms support the ability to manipulate differences in contrast on images. Processing artifacts typically occur because the software system’s algorithm fails to compensate for differences in exposure. For example, rapid changes in breast tissue thickness can occur in women with breasts that are thick despite compression. These artifacts can appear as a “breast within a breast” but do not interfere with diagnostic evaluation of the image.

Large breasts or breasts with implants also can cause the software algorithm to lose the edge of the breast.
The processing algorithms in digital mammography typically analyze individual pixels in comparison with surrounding pixels, and if the software fails to detect the edge of the breast, edges might have a jagged appearance. Choi et al found that loss of edge occurred in up to 19% of mammogram studies, making it the second most common software-related artifact after high-density artifacts, although loss of edge was found only in systems with direct detectors. Repositioning sometimes can correct for loss of edge, but recurrence of the artifact could require adjustment to the processing algorithm.

Processing artifacts often appear as high-density regions and vary in shape depending on the cause. Spot-compression projections of high-density objects can cause a pixel dropout artifact in processing. The pixel dropout results from the effect of the spot compression paddle on the image processing software’s algorithm. This occurs because a highly dense object such as a biopsy clip overlies dense breast tissue. The physical density of the object causes significantly lower exposure to detector elements directly below the objects, leading to low signal-to-noise ratio. Other processing artifacts can appear as dark lines, such as a halo effect around objects (eg, ports). A dark halo also can appear around nipple markers if the skin line processing parameter is not set correctly.

If the processing artifact is caused by a difference in gains among groups of pixels, the artifact can appear as vertical bars with lower exposure than the rest of the image. These bars might appear in areas of very high or very low exposure.

Image Storage

Other postacquisition artifacts can be seen after images are stored. These might occur if the picture archiving and communication system (PACS) improperly reconstructs the image or fails to read Digital Imaging and Communications in Medicine (DICOM) header information correctly. Without correct DICOM

Figure 7. A. Left craniocaudal projection with visible calcification (arrow) seen through hematoma. B. Noise on magnified left craniocaudal projection obscures calcification (circle). Noise makes the image appear to have many underexposed pixels, resulting in a grainy appearance. This projection should be repeated at higher kilovoltage peak and with an exposure compensation setting of +2. A higher exposure compensation setting will cause the automated exposure control system to increase the required exposure by about 30%, lowering noise in the image and improving contrast. The automated exposure control for this system normally would compensate for the difference in the required exposure for a magnification view. However, with the hematoma in this patient, the automated exposure control system did not compensate properly, and the technologist was required to intervene. Reprinted with permission from Geiser WR, Haygood TM, Santiago L, Stephens T, Thames D, Whitman GJ. Challenges in mammography: part I, artifacts in digital mammography. AJR Am J Roentgenol. 2011;197(6):W1026.
information, the system cannot read the parameters needed to display the stored image correctly.19

Processing parameters must appropriately match techniques used to acquire a mammogram to ensure image quality. Breast imaging centers must ensure that all image processing software used for storage and display of mammograms is appropriate for the images acquired for their respective digital mammography systems and that they meet DICOM and other applicable processing standards. This includes using object descriptor types specific “for processing” image data that display diagnostic-quality mammograms for interpretation.10 Radiologic technologists also should check all images sent to the PACS after completing studies to ensure that data is recorded correctly before deleting the original image.19

Ultrasonography

Breast sonography is used for several indications in diagnostic imaging of the breast and to guide breast biopsies.24 Ultrasonography always has been helpful for characterizing solid masses and differentiating between solid and cystic lesions in the breast.2 Ultrasonography is essential to imaging morphology of internal tissues, but it is less helpful for quantifying the properties of tissues.9 Elastography techniques have added qualitative tissue information.9

Ultrasonography has become increasingly important in helping to characterize suspicious breast lesions and in imaging women who are pregnant or have dense breasts and lesions obscured on mammograms.9,24 The ability of the interpreting physician to characterize masses is highly dependent on the technical factors of the sonographic study and resulting image quality.24

As with mammography, image quality is important to optimize diagnostic certainty for interpreting physicians and to help determine tissue composition for diagnosis.25,26 High-resolution ultrasonography now is the standard of care to optimize image quality24 but can increase artifacts from reverberation and other causes. Some lesions, such as complicated cysts, contribute to false-positive results.25 Although some artifacts can interfere with the quality of sonograms, other artifacts contribute to the interpreting physician’s ability to distinguish tissue characteristics and suspicious findings.26,27

Beam Artifacts

Artifacts that can occur in ultrasonography include grating lobes and side lobes. In ultrasonography, the main beam exits the transducer at approximately the same width as the transducer but begins to narrow as it approaches the focal zone. Eventually, the beam diverges, and the side and grating lobes are types of off-axis energy that occur on the outer edges of the bow-tie shaped beam. Beam-width artifact occurs when the widening distal beam becomes larger than the transducer’s width. This causes detectable echoes from some reflective structures or tissues. Adjusting the focal zone to better cover the area of interest can minimize beam-width artifact.26

Attenuation Artifacts

In breast B-mode imaging, attenuation artifacts can be used to analyze tissue composition. An attenuation artifact is caused when the beam strikes a structure with low attenuation. The amplitude of the beam within areas of the imaging field that are deeper than the weakly attenuating structure is greater than the amplitude at the structure’s depth. A bright band extends from the object with weak attenuation. This helps to characterize the type of tissue encountered in relation to knowledge of attenuation of typical anatomy in the area (see Figure 8). Frequency also affects attenuation.26

Mirror-Image Artifacts

Some artifacts in ultrasonography are caused by reverberations or multiple beams. The mirror-image artifact occurs when the primary beam strikes an oblique interface first, before encountering the expected reflective structures. The reflecting echoes from the deeper structures strike the back of the closer interface, and then bounce off the deep reflective surface again before returning to the transducer.26

Nakagami Statistical Model

Use of the Nakagami statistical model has been investigated as a method to provide more information for tissue characterization in B-mode imaging. The model relies on ultrasonic backscatter signals from tissue to produce scatterer properties that help characterize lesions. However, the method is affected by
a noise-induced artifact that can alter how well the Nakagami imaging method detects differences in concentration of scatter. The artifact is produced by noise in anechoic areas of tissue. Because anechoic areas have no scatterers, the only signals these areas receive are noise. The noise interferes with the Nakagami calculations. The model also produces a type of artifact known as parameter ambiguity, which is caused by beam divergence. Signals received from the far field of the equipment’s transducer might be interpreted by the model as beam divergence or as tissue properties.4

Tsue and Tsai analyzed the artifacts caused by the Nakagami algorithm and found that some were related to the system and others to tissue characteristics or imaging angle.4 Specifically, some factors that cause artifacts in B-mode imaging also can cause artifacts in Nakagami images. Artifact-inducing factors include side lobes, cross-talk, and mirror-image.4

**Elastography**

Elastography, which measures the stiffness of tissue, has emerged as an additional feature of breast ultrasonography to help physicians characterize lesions with objective information.9,24 As the sound waves move through breast tissue, the speed at which they attenuate depends on tissue stiffness, which facilitates a quantitative measurement of the stiffness or hardness of tissue. Interpreting physicians can compare relative stiffness of a suspicious lesion to surrounding tissue or simply use elasticity measurements to identify tissue or organs.9,28 This assessment has been added to the Breast Imaging and Data Reporting System (BI-RADS) Atlas.24

Artifacts can occur in elastography as a result of technical problems, but others might indicate diagnostic information.9 For example, noise can occur following substantial precompression. The noise is displayed in a pattern of several moving areas, much like a worm. Reducing precompression eliminates the artifact.9

The sliding artifact can appear as a white ring or several waves that surround a lesion if the mass moves in and out of the imaging plane during acquisition. The sonographer can correct the sliding artifact by repositioning the patient so that the lesion is better located within the imaging plane, or by asking the patient to hold her breath. Using less compression also can correct the sliding artifact. Most lesions affected by the sliding artifact are benign and move freely.9

The aliasing artifact appears on elastography images as a blue-red-green pattern and can be used to help distinguish masses. Cho et al examined more than 1100 breast

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**Figure 8. Use of attenuation artifacts to analyze the composition of tissue.** A. This transverse ultrasound image of the breast shows a small hypoechoic nodule with increased through transmission (arrow). The nodule was stable over a 2-year period in a patient with multiple cystic breast lesions. B. A transverse ultrasound image of the breast showing a small hypoechoic nodule with posterior shadowing (arrow). The lesion was pathologically proved breast cancer. Reprinted with permission from Feldman MK, Katyal S, Blackwood MS. US artifacts. Radiographics. 2009;29(4):1188.
lesions on ultrasonography with elastography. A total of 13 lesions displayed the blue-red-green aliasing artifact. All of the women who had the lesion had heterogeneously dense breasts. Each lesion discovery was followed up with biopsy, and the lesions disappeared as soon as the biopsy needle was fired into the lesion (see Figure 9). The authors reported that all of the lesions were confirmed as benign on biopsy and suggested that the aliasing artifact could be used to help distinguish complex cysts from solid breast masses using elastography.

The bull’s eye artifact is another example of an elastography artifact unique to a particular lesion and therefore useful in diagnosis. Because cysts are filled with fluid, and fluid moves, the cyst appears as a dark lesion with a central white area and a white area posterior to the cyst. The artifact also is known as the bull’s-eye cyst and is considered highly predictive for fluid-filled cysts. Solid components appear as hard areas, which display as dotted white lines. Shear-wave elasticity imaging is an elastography technique that applies a push pulse to tissue to produce a shear wave perpendicular to the equipment’s beam. Sampling techniques are used to calculate the speed of the shear through tissues, which determines strain and a quantitative measurement of lesion stiffness. The shear wave might not propagate normally in extremely hard lesions, such as invasive malignancies. However, the waves also do not propagate through simple cysts. No results or color coding appear for the area of the image containing the hard mass, but a red halo appears around the hard tissue of a malignant mass, helping to differentiate a malignant lesion from a simple cyst on shear wave imaging.

Franchi-Abela et al reported on use of artifacts in distinguishing nodules with elastography through comparative analysis of an ultrasound elastography phantom made up of a homogenous medium containing 8 spheres with varying degrees of hardness. The authors cautioned that manufacturers have developed a range of techniques for analysis, which can complicate reliance on parameters such as elastography artifacts to characterize tissue. Their phantom analysis demonstrated that simple measurement to determine whether a nodule is present and its relative stiffness compared with surrounding tissues is reliable, but that determining more complex ratios between regions is less reliable. The authors found in 2013 that qualitative analysis methods varied among equipment depending on manufacturer, and that analysis based on shear wave techniques was particularly variable. They cautioned that interpretation should include clinical findings and that characterization of lesions based on findings reported in the literature should be based only on reports using the same elastography system and transducer frequency.

**Power Doppler Vocal Fremitus**

Power Doppler vocal fremitus is a power acoustic Doppler method of ultrasonography used to help
diagnose breast hamartomas.\textsuperscript{27} A hamartoma is a benign mass formed from local tissue. In the breast, hamartomas typically are made up of lobules, ducts, fat, and other mesenchymal tissue.\textsuperscript{29} Assessing the fat content with mammography can help diagnose hamartomas, but on sonograms, the benign lesions typically appear in various patterns of heterogeneous tissue with internal echoes, making them difficult to diagnose.\textsuperscript{27}

Power Doppler vocal fremitus imaging manipulates artifacts to help distinguish benign lesions from malignant ones. The technique has been used when options such as elastography are not available to display characteristics that distinguish between benign and malignant lesions. Examples of characteristics are vibrational defects in microcalcifications that distinguish fibroadenomas from malignant lesions, which do not differ significantly from those that can be observed with conventional B-mode imaging. However, hamartomas do not form true capsules. According to Yildiz et al, hamartomas display vibrational artifacts throughout the lesion and surrounding tissue at the same depth, which differs from other benign and malignant masses, making them stand out with power Doppler vocal fremitus imaging.\textsuperscript{27}

**Automated Whole-Breast Ultrasonography**

Ultrasonography improves screening of women with dense breast tissue who have high risk of breast cancer and cannot have magnetic resonance (MR) scans, and it could improve screening for women at intermediate risk.\textsuperscript{30} Whole-breast ultrasonography has been discussed as an adjunct screening modality for women with dense breast tissue, but its use has not been widely adopted, partly because of a high false-positive rate, and partly because of logistics associated with implementing the technology.\textsuperscript{31} Recent advances in technology could overcome some of the limitations of whole-breast ultrasonography by automating image capture.\textsuperscript{31}

Although the equipment used to acquire automated whole-breast sonograms uses a transducer roughly the size of a mammography compression paddle, the image processing technology is similar to that of conventional breast ultrasonography. A drawback to the automated technology is the introduction of artifacts during automated data acquisition that either contribute to false-positive results or obscure pathology. Primarily, a shadowing artifact occurs in the subareolar region. Manufacturers have been working to reduce the severity of the artifact caused by the nipple and have achieved some success.\textsuperscript{31}

**Magnetic Resonance Imaging**

Breast MR imaging plays an important role in screening for and diagnosing breast disease. With contrast enhancement, the modality is a sensitive screening method for women with breast augmentation and some patients at high risk for the disease, including those with a family history of breast cancer.\textsuperscript{12,32} Dynamic contrast-enhanced MR imaging helps to characterize and stage breast lesions and at times assists physicians in monitoring treatment response. Success is highly dependent on careful selection of technique, proper patient positioning, and lack of artifacts in the images.\textsuperscript{33,34}

Technical artifacts and artifacts related to patients can simulate pathology, obscure a lesion, or interfere with physicians’ interpretation of images.\textsuperscript{7,34} To achieve diagnostic-quality and sensitive images, the equipment must have high spatial and temporal resolution, an open and dedicated breast surface coil, and simultaneous bilateral imaging.\textsuperscript{12,32} A large field of view and numerous technical factors involved in bilateral breast imaging lead to challenges in ensuring image quality. Manufacturers have designed specific pulse sequences for their systems that help optimize image quality and minimize artifacts.\textsuperscript{7} Patient comfort also is important to reduce motion artifacts.\textsuperscript{12}

**Patient-related Artifacts**

Careful positioning can help reduce patient-related artifacts and improve MR image quality.\textsuperscript{7,34} Appropriate positioning for breast MR should maximize the area of breast tissue imaged, minimize skin folds and deformed breast tissue, and result in homogeneous fat suppression on images.\textsuperscript{34} Improper positioning can lead to breast tissue outside the coil and asymmetry or artifacts that cause diagnostic mistakes related to improper display of the axillary area.\textsuperscript{33}

One of the first considerations in positioning patients for breast MR is compression and placement of the breast within the dedicated coil. Positioning begins with proper coil setup. Disposable linen covers are optimal; cloth linens can lead to artifacts because they often
contain starch. Cloth such as sheets and towels also can cause skin-fold artifacts from pressure lines on the patient’s skin. Skin-fold artifacts from pressure lines or positioning problems appear as inhomogeneity on localizer images, and on all subsequent contrast-enhanced images, unless corrected.34

Open coils are preferable to closed ones because they provide a space for the technologist to adjust the breast for optimal positioning. The technologist can help guide the breast into the coil by placing one hand on the patient’s back as the patient lowers herself into the coil. The technologist can use her other hand to pull the breast down and toward the patient’s feet to eliminate skin folds (see Figure 10). After positioning, the technologist can visually check the breast to ensure that it is centered in the coil, and then repeat the positioning adjustment and visual check of the other breast.34

When the breast is located too far superiorly in relation to the coil, decoupling artifacts can be seen superiorly. The decoupling artifacts are from decoupling mechanisms, which are circuits activated by diodes in the coil. Decoupling causes signal variations and distortion in the image. Placing a thin pad between the patient’s body and the coil can minimize decoupling artifacts.34

Inhomogeneous fat suppression also can occur when the patient is positioned superiorly in the coil. The inconsistent fat suppression should be recognized in localizer images and the patient’s position moved more to the coil’s center to correct uneven fat suppression. If the breasts are positioned so that they are pointing medially instead of straight down, fat suppression also is inhomogeneous because of compressed medial tissue.43 Ensuring that medial tissue is pulled away from the sternum laterally and checking the nipple position on localizer images can prevent artifacts from poor medial positioning.43

Yeh et al used fat saturation pads to enhance images affected by inhomogeneous fat suppression.44 By placing the pad between the patient and the coil, the air-tissue interface at the patient’s neck is eliminated, and the magnetic field becomes more uniform. The authors reported that the pad is similar in magnetic susceptibility to human tissue and that it can be used at tissue-air interfaces along the chest wall or other regions and to correct poor fat suppression superiorly, inferiorly, and posteriorly.34

Patients who have large breasts present additional challenges for optimizing image quality and minimizing artifacts. If a breast is too large for the coil, breast parenchyma becomes crowded, producing skin folds and uneven distribution of contrast material in the breast. Some patients might require large coils for breast MR imaging.34 If the breast is compressed excessively, usually as a result of poor positioning, changes in signal intensity occur at the outer edges of the coil. These signal changes from overcompression typically are hyperintense. The hyperintensity artifacts, also called near-field artifacts, occur at the site of the tissue contact or compression (see Figure 11). The hyperintense region can mimic an enhancing lesion and lead to a false-positive...
result. For example, the nipple of a patient who has large breasts might flatten on the coil’s anterior surface.\textsuperscript{7,35}

Placing the patient’s arms at her sides can help relax pectoralis muscles and cause breast tissue to rest more deeply in the coil.\textsuperscript{7} However, some artifacts or other imaging problems can be introduced with this patient position vs having the arms over the head, such as shoulder or arm tissue wrap. It also can be helpful to use a pad to elevate the patient away from the coil.\textsuperscript{34}

Motion artifacts typically blur the image, and might be called ghosting artifacts because of the brighter moving tissues. Motion artifacts occur during phase encoding, regardless of motion direction.\textsuperscript{7} Motion-related artifacts usually are the result of patient movement, and are not caused by breathing or cardiac motion.\textsuperscript{35} The breast coil supports the patient’s sternum, lateral chest, and areas above and below the pendent breasts. As a result, motion related to breathing or heartbeat affects tissues that are posterior to the breasts.\textsuperscript{35}

Comfortable positioning, thorough and clear patient instructions, and a scan time of no more than 20 minutes help reduce patient motion artifacts.\textsuperscript{35} Yitta et al reported that placing patients in the prone position with a feet-first entry into the magnet bore can decrease claustrophobia and related patient motion.\textsuperscript{7}

**Metal-related Artifacts**

Some metal objects pose a safety hazard and introduce unwanted susceptibility artifacts in breast MR imaging. Susceptibility is the object’s tendency to be magnetized. Various metals have differing susceptibility, which affects the signal loss and resulting artifact.\textsuperscript{36} Artifact appearance also is affected by the object’s shape, size, orientation, and position, as well as imaging techniques and parameters.\textsuperscript{37} Usually, metal susceptibility artifacts appear as signal voids, bright spots, or signal distortion of tissue.\textsuperscript{33}

Because breast MR often is used as a follow-up examination for patients who have had breast cancer treatment, metallic devices in or on the patient are a concern (see Figure 12).\textsuperscript{7,37} The most common metallic objects encountered in patients who have MR breast imaging are surgical clips, biopsy markers, and biopsy needles.\textsuperscript{36,37} Patients also might have ports for delivering chemotherapy drugs that are positioned near the breasts and that contain metal components. Other devices include pacemakers and orthopedic fixation devices located in the shoulder or spine.\textsuperscript{36}

Susceptibility artifacts are helpful to the extent that they can help locate a biopsy marker, for example, but metal devices can cause a number of artifacts that interfere with imaging, such as local field inhomogeneity, and can obscure malignancy.\textsuperscript{7,36,37} Common mechanisms of metal artifacts include\textsuperscript{36}:

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**Figure 11.** This 38-year-old woman has a strong family history of breast cancer. A. TI-weighted contrast-enhanced fat-suppressed axial magnetic resonance (MR) image of breasts shows distortion of the right lateral breast (arrows) resulting in a near-field hyperintense artifact that could be misinterpreted as an enhancing lesion. This is caused by the breast being compressed against the lateral coil. Notice that the left breast is appropriately positioned. B. The 3-D image shows flattening of the lateral right breast. Reprinted with permission from Yitta S, Joe BN, Wisner DJ, Price ER, Hylton NM. Recognizing artifacts and optimizing breast MRI at 1.5 and 3 T. AJR Am J Roentgenol. 2013;200(6):W676.
Fat-suppression failure — this occurs when the static field shift is either similar to or greater than the shift between water and fat. Conventional fat-saturation techniques that selectively reduce signals from fat fail to suppress fat or could mistakenly suppress water when metal is present in the field.

T2* dephasing — the signal in a voxel becomes incoherent because of spatially varying resonance frequency. Minimizing dephasing time with spin-echo sequences is one approach to reducing T2* dephasing from metal objects.

Geometric distortion — when the signal is displaced in proportion to shifts in frequency, the image can have geometric distortion. If the frequency shifts vary spatially across the image, the displacements occur in different parts of the image and distort the appearance of the metallic object. Careful selection of pulse sequence and parameters can reduce artifacts caused by metal objects and to correlate susceptibility artifacts on images to metal devices in the patient.

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Technical Artifacts

Although inhomogeneous fat saturation can result from poor positioning or the challenges of large breasts, it has other causes. This artifact also is called chemical shift artifact because of the difference in resonance frequency between water and fat. Conventional fat-saturation techniques that selectively reduce signals from fat fail to suppress fat or could mistakenly suppress water when metal is present in the field.

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frequencies of water and fat. It is a frequent artifact found in breast MR imaging, especially in patients who have breast implants.\(^3\) Fat-suppression techniques are used often in breast MR because fat is hyperintense on T1-weighted images and can obscure enhancing lesions. Chemically selective fat-suppression techniques use a suppression pulse below the water peak to suppress fat frequencies. If the center frequency is tuned incorrectly, water suppression occurs instead, and leads to inhomogeneous fat suppression (see Figure 13). The technologist can minimize water suppression artifacts by simultaneously setting the center frequency accurately and positioning shim volumes correctly. Shim volume settings are manufacturer specific.\(^7\)

Aliasing artifacts are the display of anatomical structures in areas that differ from their actual locations in the body. They occur because of excitation of tissues outside the field of view and are more likely to occur with incorrect field-of-view selection.\(^9\) The aliasing is caused by superimposition of the excited tissue from outside the field of view onto the image.\(^7,33\) Aliasing also is called phase wrap or wraparound artifact because it occurs during the phase-encoding direction.\(^7\)

Incorrectly selecting section, or slice, thickness can affect temporal resolution and signal-to-noise ratio. Overly thin sections reduce the factors, and selecting sections that are too thick increases risk of partial volume artifacts.\(^3\)

Misregistration artifacts can occur often in fat-saturation images. If movement of the patient occurs between the sequences acquired before contrast injection and after the contrast-enhanced images are acquired, a small offset in images occurs and can create focal areas of false image enhancement on subtraction images.\(^7,33\)

Artifacts also can occur from loss of bolus during gadolinium contrast injection. In postprocessing, the software might incorrectly assess the kinetic pattern of

\(\text{Figure 13. A 32-year-old woman with strong family history of breast cancer underwent } 1.5\text{-T breast MR imaging. A. The unenhanced fat-suppressed T1-weighted image shows inhomogeneous fat saturation. Troubleshooting determined the corresponding shim volume for the breast was too small and failed to cover much of the breast (drawing). B. The repeat unenhanced fat-suppressed T1-weighted image after adjustment of shim volumes shows homogeneous fat suppression. Shim volumes have been enlarged and now cover the entirety of each breast (drawing). Note that shim volume configuration is a vendor-specific feature. In this case, there are separate shim volumes for each breast. Reprinted with permission from Yitta S, Joe BN, Wisner DJ, Price ER, Hylton NM. Recognizing artifacts and optimizing breast MRI at 1.5 and 3 T. AJR Am J Roentgenol. 2013;200(6):W680.}\)
breast lesion enhancement, which can cause the physician to misinterpret the image.\textsuperscript{35}

\textbf{Breast Augmentation Imaging Artifacts}

MR imaging provides excellent spatial resolution for imaging of breast implants.\textsuperscript{36} When mammography of women with silicone or saline implants is difficult to perform, MR imaging with contrast is the preferred method. MR without contrast also can be used to assess integrity of silicone implants.\textsuperscript{37} The excellent sensitivity of MR for augmented breast imaging is attributed to MR’s ability to acquire images in which only silicone contributes to the displayed signal. This is particularly beneficial in determining whether silicone implants have ruptured and extravasated gel.\textsuperscript{38}

MR sequences such as water and silicone suppression are used to evaluate implants and distinguish problems such as extracapsular rupture from disease pathologies or artifacts. Implants have various characteristics on MR images, depending on the implant type. Typically, a silicone implant’s fibrous capsule is displayed as a T2-hypointense line around the implant.\textsuperscript{39}

Free silicone injections, which are liquid silicone injections not contained in an implant, are displayed as multiple, nonenhancing T1-hypointense and T2-hyperintense masses that produce artifacts. The silicone masses and artifacts interfere with sensitivity on mammograms and ultrasonography. On MR images, a ghosting artifact from movement can mimic the indication of a subcapsular line. In addition, inhomogeneity, or chemical shift artifact, can occur at the interface of silicone and soft tissue. The artifact can mimic encapsulation.\textsuperscript{38}

Kim et al evaluated the image quality and diagnostic performance for detecting implant rupture of 3 MR imaging techniques.\textsuperscript{39} The authors found that STIR with iterative decomposition of silicone and water using least-squares approximation (STIR IDEAL) was equal to or better than water-saturation STIR imaging in quality, and better than Dixon techniques in all categories. However, STIR IDEAL imaging produced more artifacts than STIR techniques. Specifically, when measuring image quality for each technique’s diagnostic quality in implant integrity evaluation, water-saturation STIR produced faint artifacts that did not affect interpretation. STIR IDEAL produced slightly more artifacts, but the artifacts also did not significantly affect interpretation. In the Dixon technique, discernible artifacts were displayed that interfered with interpretation. The Dixon technique included swap artifacts, motion artifacts from the lung and heart, and metallic susceptibility artifacts more often than the other 2 techniques.\textsuperscript{39}

Tissue expanders are used for breast reconstruction. They are balloon implants filled with increasing amounts of saline over a period of weeks through a port. Many of the injection ports are not MR compatible and produce significant susceptibility artifacts.\textsuperscript{38}

\textbf{Diffusion-Weighted Imaging}

As MR techniques continue to advance, a new consideration for breast MR is diffusion-weighted imaging (DWI), and use of DWI sequences has become increasingly common.\textsuperscript{1,40} Diffusion is molecule movement from random thermal motion. Adding strong gradient pulses sensitizes the motion, causing signal attenuation in normal tissue with free random motion, but high signal in areas with restricted diffusion. DWI has been used often to diagnose stroke, and it can help differentiate benign from malignant breast lesions because of the different attenuation of solid and cystic areas.\textsuperscript{41}

The DWI technique could reduce total scan time and eliminate the need for gadolinium contrast and resulting adverse effects in some patients.\textsuperscript{1} In addition, it can provide morphological information on breast tissue.\textsuperscript{42} The suggested protocol would involve acquiring unenhanced DWI images along with T2-weighted anatomical images, saving time for breast imaging centers and costs for patients and payers.\textsuperscript{1}

DWI is highly sensitive to several types of artifacts, however. In particular, studies have found that motion, magnetic susceptibility, and chemical shift artifacts could interfere with measurement of the apparent diffusion coefficient, which can indicate malignancy. The apparent diffusion coefficient is lower in malignant tissue than in benign lesions or normal breast tissue. Artifacts on DWI images also can distort image display.\textsuperscript{43}

Use of single-shot echo-planar imaging (EPI) with DWI offers high speed and sensitivity in acquiring breast images, but artifacts have continued to produce
Breast Imaging Artifacts

problems with several clinical methods and use of higher-strength magnets. Artifacts common to single-shot EPI DWI are T2* blurring, ghosting, and insufficient fat suppression.

At times, artifacts and noise from EPI sequences have led to images that cannot be used. Dong et al proposed use of reduced field-of-view (rFOV) DWI sequences to eliminate artifacts and improve image quality. The method uses 2-D radiofrequency to excite small areas within the region of interest, and it has been used in spine and brain mapping. In 12 scans, rFOV DWI resulted in fewer artifacts from lung and heart motion. The authors reported that previous studies also have shown that the technique led to better image resolution and fewer susceptibility and chemical shift artifacts.

Bogner et al proposed use of DWI with parallel imaging and readout-segmented EPI to reduce artifacts. The authors evaluated use of the technique for assessing breast lesions with 7T MR imaging and found that it reduced blurring and geometric distortion.

Other Breast Imaging Modalities

Breast imaging professionals might encounter artifacts in other breast imaging situations, including the use of any breast imaging modality for biopsy guidance, and in modalities used to monitor or stage breast cancer, along with new technology.

Digital Breast Tomosynthesis

Digital breast tomosynthesis (DBT) is an extension of digital mammography that provides 3-D formatting, or tomographic planes of the breast, to eliminate problems caused by overlapping breast tissue. This relatively new breast imaging modality acquires a series of step-and-shoot or continuous images as the x-ray tube moves in a limited-angle arc around the patient.

DBT provides limited views, and its reconstructions can include a number of artifacts. Many of these artifacts are out of plane and interfere significantly with image interpretation. Examples include:

- Streak artifacts – large objects appear to shift and fade as the interpreter scrolls through adjacent slices, and those with high contrast produce streaks that overlap and converge toward a slice that displays a true calcification.
- Truncation artifact – also called truncated projection artifact, this common DBT artifact is caused by the detector’s and beam’s finite size. At large angles, the field of view might not cover the entire volume of an imaged breast. The artifact appears as bright horizontal lines and a bright area. The artifact can occur along the breast boundary as a result of truncated projections, or breast projections that are recorded in some images and cover one area of the detector in some projection angles, but not in others.
- Cupping artifact – this artifact is displayed as a roll-off of attenuation in the direction of the DBT scan and occurs between an object’s edge and center. The cupping artifact is caused by scatter radiation and beam hardening.

Several reconstruction methods and algorithms have been evaluated to improve DBT image quality and reduce artifacts. Among these are a breast boundary detection method that would help reduce peripheral artifacts (see Figure 14).

Positron Emission Mammography

Positron emission tomography (PET) uses high-resolution molecular imaging technology and fluorodeoxyglucose F 18 (FDG-18) to provide images with areas of increased FDG uptake that indicate malignancy and detect biologic changes in vivo. Dedicated PET scanners with limited angle geometry for mammography could provide geometric flexibility and detector separation; however, the limited angles produce additional artifacts. Lee et al reported that use of time-of-flight information included in image reconstruction could reduce artifacts in scanners with limited angle geometry.

PET-computed tomography (PET-CT) can be used to stage breast cancer, monitor treatment or a patient’s response to therapy, or detect recurrence in a patient with a history of breast cancer. With PET-CT, artifacts can occur when CT is used for attenuation correction of
Artifacts that can lead to confusion for the interpreting physician, who must determine whether they are caused by FDG uptake, include:

- Respiratory artifact – PET acquires images throughout several stages of the breathing cycle, but CT acquires images during a single phase. This leads to mismatches in CT and PET data.
- High CT attenuation material artifact – some breast implants have metallic parts, which are associated with high Hounsfield units. The system must account for the high attenuation of these parts in relation to PET data. The physician can compare images with and without attenuation correction to determine whether the apparent FDG concentration is actual or from a high-attenuation artifact.

- Truncation artifact – the field of view in CT is 50 cm, and the PET field of view is 70 cm. Some large patients have anatomy that extends beyond the CT field of view, which results in PET data with no corresponding CT data, underestimating standard uptake values in the regions and resulting in artifacts.

Dedicated Computed Tomography

Use of dedicated breast CT was introduced in 2012 and is still in the demonstration stage. The modality aims to provide low-dose CT scans that result in high-resolution images with high sensitivity and specificity. Scanners in development are reported to use no compression and result in images with no superimposition of breast tissue.

Cupping artifacts have been reported in early development of dedicated breast CT systems and processing algorithms. The cupping artifacts, which are the result of intensity bias, have led to significant problems with tissue classification. The artifacts occur most often because of scattered x-rays being included in the breast CT projections and concentrating in the center of the breast. Yang et al adopted a bias correction method that reduced cupping artifacts and improved overall quality of breast CT images.

The Role of the Technologist

A range of artifacts can be caused by technical, processing, or patient-related factors. Rapid identification of artifacts is an important consideration for radiologic technologists who perform breast imaging. Some artifacts are caused by technical and equipment errors that require a medical physicist or service engineer to correct. In fact, the medical physicist is responsible for annual quality control tests on mammography equipment that evaluate uniformity of screen speed, screen artifacts, and system artifacts. Although correction of some artifacts might be beyond the scope of the technologist’s practice, the technologist is the first member of the team to spot repeated artifacts. In addition, many
artifacts can be prevented with correct and careful attention to patient positioning.33

According to Yeh et al, inadequate positioning is the most common reason mammography centers fail to achieve mammography accreditation from the American College of Radiology.14 In mammography in particular, compression and positioning contribute to image quality, and accurate positioning eliminates most artifacts. Radiologic technologists must learn to recognize artifacts attributable to poor positioning and consider positioning concerns and anatomy beyond the breast, such as the patient’s body habitus.14,56 It also is important to note arm and hand position to minimize superimposition of the chin, glasses, or other anatomy or objects.3,56 For example, the patient’s hair can create a swirling pattern on a mammogram and lead to a repeat projection.3

The technologist should take time to check for hair that might be in the field of view before acquiring an image. Technologists should learn which clinical items cause artifacts that obscure pathology or significantly interfere with diagnosis for various modalities. For example, the technologist might have to move or remove tape, catheter tubing draped across the field of view, or pharmaceutical patches (see Figure 15). Some items that cause artifacts must be present in or on the patient. For example, a biopsy clip might be left in place even though it can cause a susceptibility artifact.3,56,19 Some breast imaging centers routinely use scar and mole markers as part of the procedure.57 Use of a marker can help ensure that the mole or other skin lesion remains noted after compression compared with the use of a diagram. The American College of Radiology states that breast imaging facilities should adopt policies that require consistent use of one shape of radiopaque marker for skin lesions and another shape for palpable lesions. In addition, the type of lesion should be permanently annotated on the image or described in the mammography report.18

Other technologist responsibilities regarding artifact reduction include following institutional policies and industry standards regarding technical factor or technique and sequence selection when acquiring breast images, preserving cleanliness in all breast imaging patient and processing areas, and communicating appropriately with patients so that they cooperate and remain still to prevent motion artifacts. Technologists, radiologists, and medical physicists must work together to discuss and address causes of artifacts, particularly those that occur repeatedly and might be the result of poor procedures or faulty equipment or software programs.3,7,8,33

As breast imaging becomes a dedicated imaging modality,1 having dedicated breast imaging technologists can improve consistency and quality of medical images. Positioning is similar across the modalities, and technologists with knowledge and experience in breast-specific imaging often have a clearer understanding of patient factors that affect positioning.34

Conclusion

Artifacts contribute to image degradation and affect diagnosis of breast disease. Understanding how artifacts affect image interpretation and eliminating

Figure 15. Right craniocaudal projection with scar marker. Tape (arrows) holding the scar marker in place is visible. This might obscure underlying disease. Reprinted with permission from Geiser WR, Haygood TM, Santiago L, Stephens T, Thames D, Whitman GJ. Challenges in mammography: part I, artifacts in digital mammography. AJR Am J Roentgenol. 2011;197(6):W1028.
those caused by technical, patient, positioning, and processing errors can improve detection of breast cancer. Ultimately, efforts to minimize artifacts that obscure pathology, confound interpretation, or lead to repeat or follow-up imaging can improve imaging efficiency and effectiveness.

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1. Artifacts that appear on breast images can:
   1. interfere with the visibility of abnormalities.
   2. reduce image quality.
   3. introduce clinical problems in diagnosing breast cancer.

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

2. A study including data from 702,000 women who had mammograms in 2012 revealed that 11.1% of women had ______ a mammogram.

   a. positioning errors leading to artifacts on
   b. technical errors on
   c. false-negative results from
   d. false-positive results from

3. All of the following are common patient-related artifacts that cause repeat mammograms except:
   a. mirror-image.
   b. thin breast.
   c. antiperspirant.
   d. blurring.

4. When the mammography paddle edges appear as opaque outside triangles on the image corners, the artifact most likely is caused by:
   a. overcompression.
   b. patient motion.
   c. thin breasts.
   d. poor positioning.

5. In a study of antiperspirant artifacts found on mammography, roll-on antiperspirants were most like calcifications in appearance.
   a. true
   b. false
6. Ghosting artifacts in digital mammography are caused by:
   a. patient motion.
   b. superimposition of adipose tissue.
   c. a latent image from a prior exposure on the detector.
   d. overheating of the detector.

7. The typical cause of horizontal lines on a digital mammogram is (are):
   a. not allowing the detector to warm before imaging.
   b. defective pixels.
   c. poor compression.
   d. dust or dirt on the compression paddle.

8. A high-density artifact that is visible on 2 different mammography images in the same area of the detector most likely is caused by:
   a. defective pixels.
   b. a readout failure.
   c. a dirty compression paddle.
   d. automatic exposure control failure.

9. The appearance of a cross-hatch pattern on a contact mammogram could indicate:
   a. a problem with the compression paddle.
   b. grid lines.
   c. dead or defective pixels.
   d. collimator misalignment.

10. Which of the following statements is false about noise on mammograms?
    a. Noise is caused by an underexposed image with low signal-to-noise ratio.
    b. Noise has a grainy appearance.
    c. It is not recommended to correct noise during postprocessing.
    d. Noise has no effect on image quality.

11. The “breast within a breast” artifact occurs in:
    a. film-screen mammography only.
    b. women who have thin breasts.
    c. women with breasts that are thick despite compression.
    d. breasts that are overcompressed.

12. Spot-compression projections of high-density objects can cause a ______ artifact in processing.
    a. pixel dropout
    b. circular
    c. dark halo
    d. vertical bar

13. Postacquisition artifacts can be seen after images are stored when:
    1. the picture archiving and communication system (PACS) improperly reconstructs the image.
    2. the PACS fails to read Digital Imaging and Communications in Medicine (DICOM) header information correctly.
    3. processing parameters match techniques used to acquire a mammogram.
    a. 1 and 2
    b. 1 and 3
    c. 2 and 3
    d. 1, 2, and 3

14. Types of off-axis energy that occur on the outer edges of the bow-tie shaped ultrasound beam are called:
    1. grating lobes.
    2. attenuation artifacts.
    3. side lobes.
    a. 1 and 2
    b. 1 and 3
    c. 2 and 3
    d. 1, 2, and 3

continued on next page
Directed Reading Quiz

15. When an ultrasound beam strikes an oblique interface and reflecting echoes from deeper structures strike the back of the closer interface before returning to the transducer, it leads to ______ artifacts.
   a. grating lobe
   b. attenuation
   c. mirror-image
   d. scatterer

16. In elastography, a white ring or several waves surrounding a lesion are known as the ______ artifact.
   a. bull’s eye
   b. ghosting
   c. sliding
   d. wormlike

17. Which of the following statements is true regarding the aliasing artifact in elastography?
   a. The artifact appears as a dark lesion with a central white area.
   b. It is less likely to appear in women who have dense breasts.
   c. It tends to hide pathology more than any other ultrasonographic artifact.
   d. The artifact can help distinguish complex cysts from solid breast masses.

18. In shear wave elasticity imaging, a malignant mass can be differentiated from a cystic one by the presence of:
   a. color coding on the harder malignant mass.
   b. a red halo around the malignant mass.
   c. propagation of waves through the cyst.
   d. a white halo around the cyst.

19. Which of the following is false about hamartomas?
   a. They are benign masses.
   b. They form true capsules.
   c. They appear in various patterns of heterogeneous tissue with internal echoes on sonograms.
   d. Doppler vocal fremitus imaging is useful for identifying them.

20. A drawback to automated whole-breast ultrasonography is:
   a. high false-negative rates.
   b. aliasing artifacts in the axillary region.
   c. shadowing artifacts in the subareolar region.
   d. artifacts caused by superimposition of adipose tissue.

21. Cloth linens are preferred to disposable ones for breast magnetic resonance (MR) imaging.
   a. true
   b. false

22. Positioning a patient too far superiorly in relation to the MR breast coil can result in:
   1. decoupling artifacts.
   2. hyperintensity artifacts.
   3. inhomogeneous fat suppression.
   a. 1 and 2
   b. 1 and 3
   c. 2 and 3
   d. 1, 2, and 3

23. When the nipple of a patient with large breasts is flattened against the MR breast coil’s anterior surface, it can cause a ______ artifact.
   a. hyperintensity
   b. motion
   c. skin-fold
   d. far-field

24. Metal susceptibility artifacts on MR images usually appear as:
   1. signal voids.
   2. bright spots.
   3. signal distortion of tissue.
   a. 1 and 2
   b. 1 and 3
   c. 2 and 3
   d. 1, 2, and 3

continued on next page
25. A drawback to short T1 inversion recovery sequences in breast MR imaging is:
   a. the sequences cannot be used for fat suppression.
   b. it tends to increase metal susceptibility artifacts.
   c. the method reduces signal-to-noise ratio.
   d. it causes larger artifacts from metal implants than other methods.

26. When using fat suppression techniques, the technologist can minimize water suppression artifacts by ______ and simultaneously ______ .
   a. selecting thick sections; accurately setting center frequency
   b. setting the center frequency accurately; positioning shim volumes correctly
   c. positioning shim volumes correctly; selecting thick sections
   d. selecting thin sections; setting the upper frequency correctly

27. Artifacts common to single-shot echo-planar diffusion-weighted imaging include:
   1. T2* blurring.
   2. ghosting.
   3. insufficient fat suppression.
   a. 1 and 2
   b. 1 and 3
   c. 2 and 3
   d. 1, 2, and 3

28. An artifact common in digital breast tomosynthesis and caused by the finite size of the beam and detector is known as ______ artifact.
   a. streak
   b. staircase
   c. truncation
   d. cupping

29. Respiratory artifacts occur in positron emission tomography-computed tomography (PET-CT) because:
   a. the technology is still in its infancy.
   b. the examination takes too long for breath-holding.
   c. PET acquires images in several breathing phases, but CT in a single phase.
   d. of the limited field of view for lung expansion on CT units.

30. According to Yeh et al, ______ is the most common reason that mammography centers fail to achieve mammography accreditation.
   a. inadequate positioning
   b. presence of artifacts on sample images
   c. poor recordkeeping
   d. failure to complete annual artifact tests