Breast imaging for cancer screening: Mammography and ultrasonography

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INTRODUCTION

Screening mammography is the primary imaging modality for early detection of breast cancer because it is the only method of breast imaging that consistently has been found to decrease breast cancer-related mortality. Mammography may detect cancer one and a half to four years before a cancer becomes clinically evident. (See "Screening for breast cancer: Evidence for effectiveness and harms", section on 'Mammography'.)

The prototype of the mammography unit was developed in 1965 [1]. Many technical advances have been made since then to improve the image quality as well as to reduce the radiation dose to the patient. Ongoing technologic advancements, to both enhance mammography and develop other breast imaging modalities, seek to provide earlier diagnosis of breast disease, more accurate assessment of disease extent and treatment response, and improved detection of recurrence.

This topic will review mammography technique, performance capabilities of mammography in particular patient groups, interpretation of a mammogram report, and the use of breast ultrasound as an adjunct to mammography. Newer mammography techniques are also discussed. Issues regarding screening for breast cancer, the role of mammography in individuals with suspected disease, and surveillance for patients with known breast cancer are discussed separately (see "Screening for breast cancer: Strategies and recommendations" and "Clinical features, diagnosis, and staging of newly diagnosed breast cancer" and "Approach to the patient following treatment for breast cancer"). Other imaging

techniques for breast disease are discussed separately. (See "MRI of the breast and emerging technologies".)

In this topic, we will use the term “woman/en” to describe genetic females. However, we recognize that not all people with breasts identify as female, and we encourage the reader to consider transgender and gender nonbinary individuals as part of this larger group.

THE MAMMOGRAPHIC EXAMINATION

A mammogram involves exposing the breast to x-rays, which are both transmitted through the breast tissue as well as scattered to the surrounding tissue. The x-rays are attenuated, based upon the characteristics of the breast tissue, and are then absorbed as latent images on the recording device (figure 1). The latent image is processed and displayed for diagnostic purposes [2].

Routine screening evaluation includes obtaining two views (craniocaudal [CC] and mediolateral oblique [MLO]) of each breast. In the CC view (image 1), the breast is lifted and positioned on the plate and compression is applied from above. In the MLO view (image 2), the breast is compressed and imaged from the side at an oblique angle. Breast positioning is critical. Improper positioning may lead to exclusion of parts of the breast from the field of view, risking nonvisualization of a cancer (image 3).

These two standard views ensure adequate imaging of the relatively mobile inferior and lateral parts and the relatively fixed upper and medial parts of the breast. Obtaining two views for each breast aids in distinguishing overlapping structures from true abnormalities. (See "Diagnostic evaluation of suspected breast cancer", section on 'Diagnostic versus screening mammography'.)

The added benefit of higher cancer detection and lower recall rates with two views outweighs the extra cost and radiation from the second view [3-5]. Studies have shown that 11 to 25 percent of cancers could be missed if only one view was obtained [3,4]. When circumstances dictate that only one view is to be obtained, the MLO view, which images a greater amount of breast tissue compared with the CC view, is preferred.

Breast compression — Adequate breast compression is necessary to obtain good-quality mammograms. Compression increases the image contrast and decreases the radiation dose. Since compression causes homogeneous breast thickness, x-ray penetration is uniform through the tissues. Compression also reduces motion and minimizes superimposition of tissues, improving the diagnostic quality of the study (image 4).

Ideally, compression should be applied until the breast is held firm and immobile. However, some individuals experience pain and discomfort during compression, which can affect

image quality if there is suboptimal compression [6-8]. One way of making the examination more tolerable is to give patients control over the degree of compression [6,9-11]. The utility of patient-controlled compression was evaluated in a study of 109 patients undergoing screening mammography. All individuals were imaged in the same mammography unit. By random assignment, one breast was compressed by the technologist and the other by the patient. Patient-controlled compression was significantly less painful and preserved image quality [10].

Radiation dose — The purpose of screening mammography is to decrease mortality by identifying early-stage breast cancer. The potential benefits of detecting early-stage breast cancer by mammography far outweigh the minimal risks associated with radiation from mammography [12].

The effective radiation dose is often expressed in sievert or millisievert (mSv) units. Sievert units account for relative sensitivities of different tissues and organs exposed to radiation. The effective dose received from a routine screening mammogram is 0.7 mSv, equivalent to the dose received from natural background radiation over three months. (See "Radiation-related risks of imaging".)

It is important to keep the radiation dose as low as possible without compromising image quality. The development of more efficient emulsions and screens in film screen mammography has decreased the dose per exposure [13-15]. Despite technologic improvements, a film screen system does not use all the x-ray photons that pass through the breast. Digital mammography is associated with a lower radiation dose than film screen mammography for the same image quality [16-18].

The radiation dose absorbed by the breast depends upon the breast tissue thickness, with the dose absorbed increasing with the thickness of the breast [18]. Most mammography equipment delivers a mean glandular dose of 0.1 to 0.2 rads (1 to 2 mGy) per exposure. The American College of Radiology recommends that the mean glandular dose exposure for a breast that is 4.2 cm thick should not exceed 0.3 rads (3 mGy) per image.

There is concern that patients with *BRCA1* or *BRCA2* mutations are at increased risk for radiation-induced oncogenesis because of impaired DNA repair mechanisms. The ideal modality and age to start screening for these individuals is reviewed in detail elsewhere. (See "Cancer risks and management of BRCA1/2 carriers without cancer", section on 'Breast cancer screening'.)

Film screen mammography — Film screen mammography has largely been replaced by digital mammography, although the technique is still utilized in some resource limited settings. In film mammography, x-rays pass through the breast tissue and are converted to light by fluorescent screens. This light causes a chemical reaction in the film emulsion that is

processed and displayed as a grayscale image. In a film screen (analog) mammogram, the image is captured, displayed, and archived for storage in a film [2,19].

Digital mammography — There are two main types of digital imaging systems used to acquire digital images: direct radiography (DR), where the image is transmitted directly to the radiologist's workstation, and computed radiography (CR), where a cassette-based removable detector is inserted into an external reading device to generate an image. Most centers in the United States use DR systems; however, across the globe, CR systems are widely used as they represent a less expensive option. Studies comparing CR and DR have shown a lower sensitivity for CR [20,21]. In one study from Ontario, Canada, CR systems were 38 percent less sensitive than screen-film mammography and 21 percent less effective in detection of cancer compared with direct digital systems [20]. CR systems had fewer false positives compared with DR systems, but there was a trend towards a higher interval cancer rate. Based on this data, facilities should consider converting to direct digital systems in order to maximize cancer detection [22].

An example of a suspicious mass on a digital mammogram is shown (image 5).

Full-field digital mammography — Full-field digital mammograms are obtained directly, with digital detectors used in place of film screen systems. The detectors convert the x-ray photons to an electronic signal. This is changed to a digital value with the help of an analog to digital converter.

The digital image is further processed and displayed as a grayscale image [19,23-25]. The digital image can be processed by the computer and displayed in multiple formats. The digital signal can be sent electronically to the viewing station and displayed on high-resolution monitors as a soft copy, or printed on dry laser printers and read on high-luminance viewboxes as a hard copy, similar to film screen mammograms.

Digital mammography has many advantages over film screen mammography [26,27]:

- Greater contrast resolution, especially in dense breasts. Wider dynamic range and higher-contrast resolution enables better visualization of the skin and the peripheral breast tissue [23].
- The ability to postprocess the image by changing the contrast and the brightness and enlarging the image, increasing the ability to detect subtle abnormalities.
- The ability to send images electronically, making remote reading possible (teleradiology). In addition, images can be made available for simultaneous reading at multiple viewing stations, facilitating double reading and expert consultation as needed.

- The ability to store images in optical drives for future reference.
- Lower average radiation dose [25].

Digital mammography also has certain disadvantages compared with film screen mammography:

- Digital images have less spatial resolution compared with film, which in part is compensated by post-processing.
- Higher-resolution display monitors, which are more expensive than standard monitors, are needed to view the high detail and quality of a digital mammographic image.
- Digital systems are expensive, with costs being 1.5 to 4.0 times as much as a film-based system.

Digital versus film screen mammogram — Multiple studies have compared the performance of digital and film screen mammography, and most have found little difference in cancer detection rates [28-37]. The best data come from the randomized Oslo II Study and the Digital Mammographic Imaging Screening Trial (DMIST) study.

- The largest study, DMIST, involved 49,528 asymptomatic women who underwent both film and digital mammography [32]. The overall diagnostic accuracy was similar with the two modalities, but digital mammography was more accurate for premenopausal and perimenopausal women as well as women with dense breasts [32,33]. No differences in performance were found between three different digital systems [38].

  An analysis using the DMIST data found that screening all women age ≥40 years by digital, rather than film, mammography was not cost-effective, with each quality-adjusted life-year (QALY) gained costing USD $331,000 [39]. Targeting screening with digital mammography to individuals ≤50 years of age was cost-effective ($26,500 per QALY gained).

- The Oslo II Study randomly assigned 25,263 women aged 45 to 69 years to either digital or film screen mammography [30,31]. At two years, the rate of breast cancer detection was significantly higher for those assigned to full-field digital mammography compared with film mammography (0.59 and 0.38 percent, respectively) [31]. The positive predictive value was the same for both technologies. Detection rates of invasive cancer were higher with digital mammography but essentially the same for ductal carcinoma in situ (DCIS) [31].

Digital mammography, when available, may detect slightly more breast cancers in individuals <50 years old. However, film mammography remains an acceptable screening modality for all patients. Modeling studies suggest that for United States women aged 50 to

74 years, biennial digital mammography, compared with film mammography, results in significantly increased costs, increased rates of false-positive findings, and no significant decrease in breast cancer death or total mortality [40]. Nevertheless, in the United States in 2016, digital mammography was used in 98 percent of breast imaging centers [41].

Digital breast tomosynthesis (DBT) — For screening, the addition of DBT (also known as 3D mammography) to conventional digital mammography (also known as 2D mammography) increases cancer detection rates and may increase the positive predictive value of the examination; however, studies vary as to the effect of DBT screening on recall rates [42-47].

Tomosynthesis is a modification of digital mammography that uses a moving x-ray source and a digital detector. With DBT, a series of low-dose mammograms is taken at various angles. These two-dimensional images are then used to reconstruct three-dimensional images of the breasts using computer algorithms to generate multiple, thin (usually 1 mm) slices in the same plane as the mammogram [48,49].

Multiple studies have shown increased rates of cancer detection when DBT is added to conventional 2D digital mammography [42-46]. As an example, in a multicenter randomized trial screening 19,560 women aged 45 to 70 years, adding DBT to conventional digital mammography increased the cancer detection rate by 89 percent (8.6 versus 4.5 per 1000; relative risk 1.9, 95% CI 1.3-2.7), with no difference in the recall rate of 3.5 percent [46]. This increase in cancer detection was greater for DCIS and small invasive cancers but not for invasive cancers ≥2 cm. This indicates that adding DBT identifies more smaller invasive cancers without increasing the recall rate.

Multiple studies also reported an overall decrease in the rate of recalls for additional evaluation [45-47,50]. However, one study observed increased rates of false-positive screening results with DBT [44].

DBT increases the radiation dose to the patient when performed in conjunction with a conventional digital mammogram. A combined DBT and digital mammography examination leads to approximately twice the usual radiation dose, and the radiation exposure can be even greater if the patient has dense or thick breasts [46,51,52]. This "double-radiation exposure" still falls below the US Food and Drug Administration (FDA) limits for standard mammography [48,49]. Newer DBT techniques create a synthetic 2D image from the volumetric DBT acquisition, thereby eliminating the need to obtain standard digital mammographic views and thus lowering radiation to levels comparable to or slightly above those of a conventional digital mammogram alone. Synthetic digital mammograms, in lieu of standard digital mammograms, are being more widely adopted with DBT screening [48,49,53]. A meta-analysis found that DBT with synthetic digital mammography had higher cancer detection, higher invasive cancer detection, and lower recall rates compared with DBT with standard digital mammography [54].

The use of DBT in those with dense breasts may improve breast cancer detection rates; this is reviewed separately. (See "Breast density and screening for breast cancer", section on 'Digital breast tomosynthesis' and "Breast density and screening for breast cancer", section on 'Risk stratification for supplemental screening'.)

MAMMOGRAPHY READING

Interpretation of mammographic imaging may be affected by multiple factors, including the timing of the reading by the radiologist (batch or immediate), the number of interpretations (double reading), and the technologic tools available (eg, computer-aided detection, artificial intelligence).

- **Batch reading –** With batch reading, after the four standard views (craniocaudal [CC] and MLO projections of each breast) are obtained and the image quality is approved by the technologist, the patient leaves the center without knowing the results of the study. The study is later interpreted as part of a batch along with other screening mammograms. A radiologist usually reads 30 to 50 mammograms as a batch. Written results are conveyed to the referring clinician as well as provided to the patient. The patient is contacted to return for a diagnostic study if additional imaging is required; at most centers, contacting the patient for additional imaging is done by the radiology department.

  Batch reading offers advantages, as the radiologist is not interrupted during interpretation by discussions with technologists or patients between examinations. Additionally, the patient's prior mammograms are generally made available for comparison during batch interpretation; availability of these prior studies facilitates evaluation of subtle changes and may decrease the number of false-positive results [55-57].

  Immediate (online) reading – In contrast to batch reading, some centers perform immediate ("online") reading where the mammogram is interpreted by a radiologist right after the mammographic views are obtained; the patient waits at the testing facility during interpretation so that additional imaging can be performed at the same visit, if needed. Results are conveyed to the patient after the study is completed. Patients report greater satisfaction with this approach, citing immediate knowledge of their results, having the opportunity to talk to a radiologist on the day of their examination, and experiencing less anxiety and stress associated with having to return for additional evaluation [58,59]. In a randomized trial, patients with false-positive mammograms had less anxiety at three weeks with immediate versus batch reading of screening mammograms [60].

However, online reading has disadvantages. Immediate reading can pose logistical challenges for a radiology practice: a radiologist must be allocated to cover readings during the entirety of every session, and performance of additional mammographic views or a breast ultrasound, when indicated, may result in longer waiting times for prescheduled patients since the screening patient's additional workup must be fit into the schedule. These factors lead to increased cost per examination [61].

A retrospective analysis of 8698 screening mammograms analyzed the rates of recall and cancer detection between immediate and batch interpretation systems [62]. There was no difference in the number of cancers detected between the two groups; however, rates of additional imaging were higher in the group that had immediate reading. The study also found that comparison studies were available less frequently when studies were interpreted immediately following imaging.

- **Double reading** – Double reading refers to review of every screening mammogram by two radiologists. The aim of double reading is to increase the rate of cancer detection. The examination can be interpreted by the two radiologists either independently or interpreted together in consensus. Double reading is standard practice in many European countries [63,64] but not in the United States.

  If readers differ in their interpretation of a mammogram study, institutional protocols differ on how this is adjudicated: patients may be called back for follow-up studies if either reader identifies an abnormality (highest reader recall), a third reader may review the films to determine need for follow-up (arbitration), or a group of radiologists, which may or may not include the original readers, discuss the discordant cases (consensus) [65]. One study found that consensus reading resulted in recall for 45 percent of discordant cases reviewed, with malignancy diagnosed in 11.7 percent of the recalled cases [66]. Review of data collected from over one million screening examinations in women aged 50 to 69 years participating in the Norwegian Breast Cancer Screening Program, where double reading is standard, found that 23.6 percent of the cancers detected (1326 of 5611) were diagnosed in patients who were recalled for discordant interpretations [67]. About 50 percent of the radiologists in this program were dedicated mammography readers.

  Several studies have demonstrated benefit for double reading, but randomized controlled trials have not been performed to evaluate its impact on long-term outcomes. Although not all individual studies have demonstrated an effect on cancer detection rates, a meta-analysis of 17 studies found that cancer detection rates were improved by 10 percent comparing double and single reading (odds ratio [OR] 1.10, 95% CI 1.06-1.14) [68]. In this analysis, 2222 patients would need to be screened by double reading with arbitration for each additional cancer detected. The recall rate for

double reading with arbitration, compared with single reading, was decreased (OR 0.94, 95% CI 0.92-0.96), although the recall rate was increased for double reading without arbitration [68]. In the United States, most often the second reader is solely looking to identify any abnormality that may have been overlooked by the first radiologist, which does lead to increased recall rates and false-positive examinations but greater cancer detection rates [69].

A large trial in the United Kingdom found that vigilance for abnormal mammographic findings did not decrease with time on task [70]. No difference was found in rates of breast cancer detection when the order of mammograms read by the second reader was reversed from the first reading or was the same. The trial also found that batch reading (up to 60 mammograms at a session) improved specificity, with fewer recalls but with the same cancer detection rate as reading mammograms one by one.

Double reading increases radiologist time and therefore the cost per examination. There may also be a delay before the final interpretation can be made. Two studies found that both patients and clinicians preferred delayed batch reading with double reading to immediate reading, once the benefits of double reading were explained [71,72].

- **Computer-aided detection (CAD) –** CAD refers to computer-based technology designed to recognize mammographic patterns and help radiologists identify suspicious areas [73]. CAD reading of digitalized or digital mammograms places marks in areas of concern, most often calcifications, masses, or asymmetries, for special attention during review by the radiologist; on average, four marks are placed per mammogram. The US Food and Drug Administration (FDA) approved CAD in 1998 after several small studies showed the possible usefulness of CAD in increasing cancer detection [74-76]. The use of CAD among United States Medicare patients increased rapidly, from 3.6 percent of mammographies in 2001 to nearly 75 percent in 2008 [77-79]. Surveys of a sample of United States-certified mammography facilities found that the use of CAD by digital mammography facilities was stable at 91 percent from 2008 to 2016 [80].

  CAD has not been shown to improve diagnostic accuracy for screening mammography [77,81-83], and there are no randomized trials that have evaluated the effect of CAD on breast cancer mortality. Results of observational studies on the effectiveness of CAD for mammographic screening interpretation suggest no overall benefit [77,81-84]. Any increase in sensitivity may be offset by a higher recall rate and the potential for overdiagnosis. The increased recall rate with CAD and the costs associated with the equipment likely outweigh possible marginal benefits.

For cancer detection, results using CAD have been less favorable than those with singly read images. In a meta-analysis of 10 studies, CAD did not increase cancer detection compared with singly read mammograms but was associated with more false-positive readings [68]. Similarly, in another study, CAD was not associated with an increase in overall sensitivity but was associated with decreased specificity (OR 0.87, 95% CI 0.85-0.89) and lower positive predictive value (OR 0.89, 0.80-0.99) [85]. There was no increase in diagnosis of invasive breast cancer and no improvement in stage or lymph node status of breast cancer that was detected. Additionally, in an observational study in women aged 67 to 89 years, CAD with screening mammograms was associated with no difference in the incidence of invasive cancer [77]. In retrospective readings of mammograms of patients known to have cancer, CAD sensitivity for lesion identification has ranged from 76 to 94 percent [86-88]. Thus, a radiologist may see an abnormality not detected by CAD and recall a patient for additional studies even in the absence of a CAD finding.

CAD increases the detection of ductal carcinoma in situ (DCIS) because CAD software has increased sensitivity for detection of calcifications [77,89-91]. In an observational study in women aged 67 to 89 years, CAD with screening mammograms was associated with an increased incidence of DCIS (OR 1.17, 95% CI 1.11-1.23) [77]. Since the natural history of DCIS is uncertain, the benefit of early detection and treatment for this condition is unclear and there is potential for over-treatment of preclinical disease. This is of particular concern in older patients with a more limited life expectancy. (See "Breast ductal carcinoma in situ: Epidemiology, clinical manifestations, and diagnosis" and "Ductal carcinoma in situ: Treatment and prognosis" and "Microinvasive breast carcinoma".)

Recall rates were also higher with CAD than with singly read mammograms (OR 1.10, 95% CI 1.08-1.12) in a meta-analysis of 10 studies [68]. In another study, CAD was associated with increased diagnostic testing (diagnostic mammography, breast ultrasonography, or breast biopsy) in women who did not have a subsequent diagnosis of breast cancer [77].

Cancer detection rates for single reading with CAD have been compared with double reading [69,87,89,92-94]. These studies find similar rates of cancer detection for the two models of mammographic interpretation. Recall rates have been reported both as higher [95] and lower [92] for CAD compared with double reading and may depend on how discordant readings were managed with double reading.

Due to the lack of demonstrated benefit, Medicare and other insurers in the United States no longer offer additional reimbursement for the use of CAD in breast cancer screening.

- **Artificial intelligence (AI) –** Interpretation of mammography using AI, where algorithms are developed and continually refined based on deep learning neural networks, may hold more promise than traditional CAD [96-98]. In a study comparing an AI system and previously reviewed digital mammograms interpreted by 101 radiologists, the performance of the AI system was noninferior to that of the average results [99]. However, AI interpretation results were not as good as those of the best radiologists [99]. Several AI algorithms have FDA approval for use in the clinical setting. In one large retrospective study at one institution in the Netherlands, three commercially available AI algorithms performed as well as interpreting radiologists in a screening population [100]. However, further evaluation is required in diverse screening settings to determine the feasibility of using AI for primary or adjunct interpretation of screening mammography [96,97,99].

ABNORMALITIES ON MAMMOGRAPHY

Mammogram abnormalities include masses, calcifications, asymmetries, and architectural distortions. Specific mammographic findings of breast cancer are discussed in detail separately. (See "Diagnostic evaluation of suspected breast cancer".)

- The most specific mammographic feature of invasive breast cancer is a spiculated mass. The positive predictive value of a mass is 81 percent with a spiculated margin and 73 percent with irregular shape (image 6 and image 7) [101-103].

- The density of a noncalcified mass is a significant factor in predicting malignancy. Seventy percent of masses with high density were malignant, and 22 percent of masses with low density were malignant in one study [103].

- Grouped microcalcifications (calcium particles of various size and shape measuring between 0.1 to 1 mm in diameter and numbering more than four to five per cubic centimeter) are seen in approximately 60 percent of cancers detected mammographically (image 8). Histologically, these represent intraductal calcifications in areas of necrotic tumor or calcifications within mucin-secreting tumors.

- Fine pleomorphic and fine linear or fine linear branching microcalcifications (image 9) have a higher predictive value for malignancy than do coarse heterogenous (ie, nonlinear irregular calcifications of varying size and shape) microcalcifications, particularly for high-grade DCIS. However, breast cancers, including DCIS, more often present with the coarse heterogenous or amorphous type of calcifications.

Calcifications that are not suspicious for malignancy and considered benign include vascular and skin calcifications; large, rod-like rim calcifications; coarse dystrophic calcifications (image 10); and round calcifications (image 11).

One prospective study linked findings from 10,641 mammograms performed in 20 facilities over four years with the regional cancer database (Surveillance Epidemiology and End Results [SEER] program) [104]. Focal mass was the most frequent abnormality (56 percent) identified in women found to have breast cancer, followed by calcifications (29 percent). Asymmetry was a frequent reason for additional evaluation (42 percent) but was a finding in only 12 percent of women with breast cancer.

MAMMOGRAPHY QUALITY CONTROL

Variation in mammographic quality and standards of practice throughout the United States led to the development of the mammographic accreditation program by the American College of Radiology in 1987 [105,106]. The Mammography Quality Standards Act (MQSA) was passed in 1992 by Congress [107-109]. The MQSA establishes guidelines for quality control for individual imaging centers and mandates that all United States facilities should be accredited by the American College of Radiology (or Arkansas and Texas Departments of Health for those states, respectively).

THE MAMMOGRAPHY REPORT (BI-RADS)

The Breast Imaging Reporting and Data System (BI-RADS) [110] was developed by the American College of Radiology to standardize the format of a mammography report. BI-RADS has been extended to breast ultrasound and magnetic resonance imaging (MRI) interpretation as well. The use of BI-RADS for standardized reporting helps to guide decision-making and serves as a useful tool in collecting data and auditing individual practices.

Components — The BI-RADS manual describes the organization of the mammography report and the standardized language to use for radiological findings and conclusions [110]. The final diagnostic assessment categories indicate the relative likelihood of a normal, benign, or malignant diagnosis based solely on the imaging findings. One of the seven final assessment categories should be used at the conclusion of each mammogram report (table 1). In the United States, the Food and Drug Administration mandates that all mammography reports include a final BI-RADS assessment category.

The BI-RADS report contains the following elements:

- Indication – The main indication for the study and type of examination (screening versus diagnostic) is stated. Any previous examinations used for comparison are

mentioned in the beginning of the report.

- Overall breast composition (breast density) – All reports have a statement regarding the breast density. Most radiologists use the four categories described in the BI-RADS atlas, based on the proportion of glandular (radiodense) tissue with respect to fatty (radiolucent) tissue. The 2012 fifth edition BI-RADS lexicon assigns breast density based on the presence of any patch of dense tissue [110], whereas earlier editions reported ratios of dense tissue to fatty tissue in quartiles by percent. The BI-RADS classification for breast density is discussed in detail elsewhere. (See "Breast density and screening for breast cancer", section on 'BI-RADS classification'.)

  Briefly, the four main breast density categories are (image 12):

  - A – The breasts are almost entirely fatty
  - B – There are scattered areas of fibroglandular density
  - C – The breasts are heterogeneously dense, which may obscure small masses
  - D – The breasts are extremely dense, which lowers the sensitivity of mammography

- Description of abnormalities/important findings – The main body of the report includes the location and description of any abnormality using standard BI-RADS descriptors. The location of any lesion is described with reference to a quadrant or clock position, and the depth within the breast. The breast is arbitrarily divided into anterior, middle, and posterior depth (figure 2). Each breast is divided into four quadrants: upper-outer, upper-inner, lower-outer, and lower-inner (figure 3). The location can also be indicated using the breast as a clock with nipple in the center (figure 4).

- Comparison to previous examination(s), if appropriate.

- Summary – The report concludes with a pertinent summary stating the most important findings, the final BI-RADS assessment category (as detailed below), and, if a suspicious abnormality is found, what type of management (eg, a biopsy) is indicated.

BI-RADS final assessment categories — The BI-RADS final assessment categories standardize the reporting of mammographic findings and the recommendations for further management (ie, routine screening, short-interval follow-up, or biopsy). Assessments are either incomplete (category 0) or final assessment categories (categories 1 through 6) (table 1) [110]. Of note, BI-RADS categories 3 to 6 are reserved for a diagnostic evaluation and not an initial screening mammogram (ie, screening mammograms should only be given BI-RADS assessments of 0, 1, or 2). It is important to note that the BI-RADS category only refers to the imaging findings and does **not** take clinical findings or presentations into account. Therefore, if the patient has a negative imaging evaluation but has a clinically suspicious lump, a biopsy may still be indicated even though the BI-RADS category is 1 or 2.

BI-RADS assessment categories are as follows:

- BI-RADS 0: Incomplete, need additional imaging evaluation and/or prior mammograms for comparison — This category is used when there is not enough information from the views available to derive a conclusion. This is more commonly used in screening studies, which are interpreted as abnormal when the radiologist is not providing immediate reads.

  Causes for an incomplete evaluation include technical factors such as suboptimal images due to either improper positioning or motion (image 13), a questionable lesion not fully evaluated on the standard screening views, or unavailability of prior mammograms to confirm stability of a possible focal or diffuse abnormality. The patient is asked to return for additional mammographic views and/or an ultrasound, or prior mammograms are required.

- BI-RADS 1: Negative – This is a completely negative examination (image 1 and image 2). The woman should continue with screening mammography and clinical breast examination based on current screening guidelines.

- BI-RADS 2: Benign – Benign masses such as fibroadenomas (image 14) or cysts (image 15), or benign vascular or parenchymal calcifications (image 10) may be reported. There is no concern for malignancy and no further action needs to be taken. The rationale in reporting these findings is to document benignity and to prevent unnecessary evaluation. Routine follow-up is recommended.

- BI-RADS 3: Probably benign – This category is used when there is a finding that does not have characteristic benign features, but the likelihood of malignancy is less than 2 percent. Examples of lesions in this category would include a focal asymmetry (image 16), a group of round calcifications, or a circumscribed mass that is detected on a baseline screening examination.

  These types of findings are followed at shorter intervals than the routine one- or two-year screening interval to assess for stability. Generally, the lesion is followed with diagnostic mammography and/or ultrasound at 6- to 12-month intervals for up to three years [111-113]. Follow-up at shorter intervals may be requested for close surveillance of a lesion that is not clearly benign. At any of these interval follow-ups, the lesion could be downgraded (BI-RADS 2) if it declares itself as clearly benign, or upgraded (BI-RADS 4 or 5) if there is a change with sufficient concern for malignancy.

- BI-RADS 4: Suspicious – This category implies that there is a lesion with suspicious features for malignancy (image 8). The chance that the imaging finding is a cancer ranges between 2 and 94 percent. The degree of suspicion or worry for malignancy varies both with the lesion and with the interpreter.

The BI-RADS 4 category is very broad, and the findings are compatible with both ductal carcinoma in situ (DCIS) and invasive breast cancer. Subdivisions of this category were introduced to convey the level of concern, so the patient and their clinician can make an informed decision regarding management. These subcategories are:

- BI-RADS 4A – Chance of malignancy 2 to 9 percent
- BI-RADS 4B – Chance of malignancy 10 to 49 percent
- BI-RADS 4C – Chance of malignancy 50 to 94 percent

- BI-RADS 5: Highly suggestive of malignancy – Lesions which have classic worrisome imaging features such as spiculations (image 6 and image 7), pleomorphic calcifications (image 9), and skin retraction are placed in this category. The suspicion for malignancy is 95 to 100 percent.

- BI-RADS 6: Known, biopsy-proven malignancy – This includes patients with established biopsy-proven cancers that have yet to be surgically excised who present for further imaging to either evaluate the contralateral breast or assess response to neoadjuvant chemotherapy, or who present for a second opinion with interpretation of outside imaging studies.

Clinical decision-making

A positive mammography report — All reports with BI-RADS 0, 4, or 5 need further intervention. In most institutions, the clinician is contacted to convey the need for biopsy, and both the clinician and patient are contacted to convey the need for further imaging.

In addition, a BI-RADS designation of 4C or 5 indicates that a malignant diagnosis is strongly suspected and that a possible rebiopsy is needed if the pathology tissue sample is initially interpreted as benign.

A negative mammography report — If there is a clinical suspicion for malignancy, a negative mammogram should **not** deter further evaluation (image 17). The false-negative rate of screening mammography has been reported between 10 to 30 percent, with the false-negative rate being highest in those with markedly dense breast tissue [63-65].

Up to 15 percent of cancers detected on clinical breast examination are not visible on diagnostic mammography [64,66,68]. The addition of ultrasound decreases the false-negative rate but still does not exclude the presence of breast cancer [68]. In the setting of a negative imaging evaluation (mammography plus ultrasound), the chance of malignancy ranges between 0 and 3 percent [114,115]. The evaluation of a palpable breast mass is reviewed elsewhere. (See "Diagnostic evaluation of suspected breast cancer", section on 'Palpable breast mass'.)

VARIABLES AFFECTING SCREENING ACCURACY

A number of other factors related to characteristics of the patient (eg, breast density or low body mass index [BMI]) or the interpreting radiologist (eg, volume of readings and years of experience) may affect the accuracy of screening. Patient race does not appear to affect the accuracy of mammography [116,117].

Breast density — Increased breast density impairs the ability to detect abnormalities on mammography and increases the risk for breast cancer. The Breast Imaging Reporting and Data System (BI-RADS) guidelines for mammogram interpretation recommend that breast density be reported in a sentence in every mammogram report [118]. Determination of breast density, the effect of breast density on the risk of breast cancer, and supplemental screening considerations for patients with increased breast density are discussed separately. (See "Breast density and screening for breast cancer", section on 'Breast density and primary screening for breast cancer'.)

Radiologist — In addition to intra- and interrater variability among radiologists in mammographic breast density assessment, the ability to accurately interpret mammograms differs between radiologists [119,120]. Most studies suggest that accuracy is greater for radiologists who interpret a high volume of screening and diagnostic mammograms [121-127].

A study of the performance of 124 United States radiologists in interpreting 469,512 screening mammograms found that less experienced radiologists had higher sensitivity for breast cancer but also higher recall rates and lower specificity [124]. In this study, greater radiologist experience was associated with lower sensitivity (more false-negative studies) but higher specificity (fewer false-positive studies).

Compared with the United States, mammogram recall rates in the United Kingdom and many other countries are lower, with similar invasive cancer detection rates [128,129].

Prior studies — Comparing a mammogram with one taken previously, especially one taken a year previously, can improve specificity [130,131].

Body habitus — Mammography may have lower sensitivity in thin individuals. In a multivariate analysis from a 12-month prospective study of 122,355 women ages 50 to 64, mammography had a lower sensitivity in those with a BMI below 25 (86 versus 91 percent) [132].

SCREENING VERSUS DIAGNOSTIC MAMMOGRAPHY

Mammographic views and subsequent procedures may differ, depending on whether the examination is ordered for screening (asymptomatic individual) or for diagnostic purposes (workup of a breast complaint or an abnormal finding).

Screening mammogram — A screening mammogram is performed in a patient with no clinical symptoms or complaints. The purpose of the study is to decrease morbidity and mortality by detection of early stage and therefore treatable breast cancer. Although earlier detection does not necessarily ensure cure, screening mammography is the best modality currently available to detect clinically occult breast cancer [133-137].

Two standard views are obtained of each breast. Additional views, such as anterior compression, cleavage view (image 18), or an exaggerated craniocaudal (XCCL) view (image 19), may be obtained to maximize imaging of all breast tissue [138].

Diagnostic mammogram — Diagnostic mammography is performed in patients who present with breast complaints or have an abnormal clinical examination as well as in those who have abnormal screening mammography. Patients with specific breast symptoms, such as a palpable lump, nipple discharge, or focal pain, should undergo diagnostic mammography.

Abnormalities on mammography include masses, calcifications, architectural distortions, and asymmetries. The abnormality could be related to technical factors such as motion, improper positioning, or artifacts (image 13). Alternatively, the finding might represent benign or malignant breast disease. Even when the abnormality seen on a screening mammogram is very suspicious for malignancy, additional evaluation is usually indicated to determine the extent of the lesion and to assess for the presence of any additional findings [139]. Availability of the abnormal screening mammogram at the time of diagnostic examination is crucial in ensuring that the appropriate diagnostic workup is performed. This is particularly important when the screening mammogram is performed at a different institution or practice.

The diagnostic examination is always supervised by a radiologist. The views obtained are tailored to evaluate a specific abnormality, with the adjunctive use of digital breast tomosynthesis (DBT) and ultrasound if needed in order to make an accurate diagnosis. The radiologist interprets the images and conveys the findings and recommendations directly to the patient at the time of the examination.

A focal spot compression view, one type of additional view, is performed by applying focal compression to the area of interest in the breast using a small compression paddle. This view is helpful to further evaluate an area of asymmetry or a mass seen on screening mammography (image 20). Spot compression and tangential views of a palpable abnormality have been shown to detect cancers not seen on traditional views [140]. In

addition, DBT can be applied to any diagnostic mammographic view to aid in evaluation of focal findings.

A focal magnification view is performed to further characterize the morphology of calcifications and the margins of a mass. The size, distribution, and morphology of calcifications are seen best on magnification views (image 21). In addition, magnification views can provide details regarding margins of masses.

A 90 degree lateral view is a true lateral view of the breast. The x-ray beam can travel from either the medial (mediolateral) or the lateral (lateromedial) side of the breast. This view is a direct orthogonal view to the craniocaudal (CC) projection and is useful in triangulating lesions. A delayed lateral view is often performed in evaluating calcifications. The breast is held in compression for up to two minutes and the image is obtained after the two-minute "delay." This view may help in confirming the presence of a benign pattern of calcifications, called milk of calcium deposition, associated with benign breast microcysts.

Other views that may be obtained in a diagnostic workup are tangential views, to further evaluate a palpable area or to confirm that calcifications are dermal in etiology, and rolled CC views. Rolled views are helpful in confirming that a finding seen only on one of the conventional views represents a true or three-dimensional lesion. For the rolled view, the patient is positioned similar to the view that depicted the original lesion. The technologist places their hands on either side of the breast and "rolls" the breast tissue (medial and lateral for the CC view; superior and inferior for the mediolateral oblique [MLO] view). Compression is applied to keep the breast tissues rolled and the image is obtained. The direction of the roll (medial, lateral, superior, or inferior) is documented on the image. If the lesion is "real," the radiologist can use these images to determine the location of the lesion, thereby facilitating performance of a targeted diagnostic ultrasound.

Surveillance mammogram — In patients who have a history of breast cancer, surveillance mammograms after the initial diagnosis and treatment are based on individual breast center practices. In some centers, surveillance mammograms are performed annually as diagnostic mammograms for three to five years after surgery, with a radiologist onsite who can interpret the study at the time of the evaluation and determine if further views or tests are indicated. In other centers, they are performed as a routine screening mammogram. Strategies for breast imaging following breast cancer diagnosis and treatment are reviewed in detail elsewhere. (See "Approach to the patient following treatment for breast cancer", section on 'Breast imaging'.)

ROLE OF ULTRASOUND

Ultrasound is not typically used in the routine screening for breast cancer. (See "Screening for breast cancer: Strategies and recommendations", section on 'Other imaging modalities'.)

Although whole-breast ultrasound screening may detect additional early-stage breast cancers that are mammographically occult, particularly in those with dense breast tissue, the additional screening test carries a substantial risk for false-positive results, leading to patient anxiety, breast biopsies with benign results, and follow-up imaging. In one large cohort study that included more than 3000 women who underwent mammography and same-day ultrasonography and more than 15,176 matched controls who underwent mammography alone, the benefits of adding same-day ultrasonography to screening mammography did not outweigh harms [141]. Women who underwent both studies compared with those who underwent mammography alone had similar cancer detections rates (5.4 versus 5.5 per 1000) and similar interval cancer rates (1.5 versus 1.9 per 1000) but higher false-positive biopsy rates (52 versus 22 per 1000). The positive predictive value of biopsy recommendation was also lower in patients undergoing both studies (9.5 versus 21.4 percent).

The benefits and harms of using whole-breast ultrasound as an adjunct to mammography for screening individuals with dense breasts are discussed separately. (See "Breast density and screening for breast cancer", section on 'Whole-breast ultrasound screening'.)

Ultrasonography is commonly used for diagnostic follow-up of an abnormality seen on screening mammography to clarify features of a potential lesion. (See "Diagnostic evaluation of suspected breast cancer", section on 'Breast ultrasound'.)

OTHER BREAST IMAGING TECHNIQUES

Other breast imaging techniques have been studied but are not recommended for screening the general (average-risk) population.

Magnetic resonance imaging (MRI) — MRI of the breast and indications for its use are described separately. (See "MRI of the breast and emerging technologies".)

Functional breast imaging techniques — Positron emission mammography (PEM) and breast specific gamma imaging (BSGI) are functional breast imaging techniques and are discussed separately. (See "MRI of the breast and emerging technologies", section on 'Nuclear breast imaging'.)

SOCIETY GUIDELINE LINKS

Links to society and government-sponsored guidelines from selected countries and regions around the world are provided separately. (See "Society guideline links: Screening for breast

cancer".)

INFORMATION FOR PATIENTS

UpToDate offers two types of patient education materials, "The Basics" and "Beyond the Basics." The Basics patient education pieces are written in plain language, at the 5th to 6th grade reading level, and they answer the four or five key questions a patient might have about a given condition. These articles are best for patients who want a general overview and who prefer short, easy-to-read materials. Beyond the Basics patient education pieces are longer, more sophisticated, and more detailed. These articles are written at the 10th to 12th grade reading level and are best for patients who want in-depth information and are comfortable with some medical jargon.

Here are the patient education articles that are relevant to this topic. We encourage you to print or e-mail these topics to your patients. (You can also locate patient education articles on a variety of subjects by searching on "patient info" and the keyword(s) of interest.)

- Basics topic (see "Patient education: Breast cancer screening (The Basics)")
- Beyond the Basics topics (see "Patient education: Common breast problems (Beyond the Basics)" and "Patient education: Breast cancer screening (Beyond the Basics)")

SUMMARY AND RECOMMENDATIONS

- Screening mammography is the only breast imaging modality that consistently has been found to decrease breast cancer-related deaths. Routine evaluation includes obtaining two views (craniocaudal [CC] and mediolateral oblique [MLO]) of each breast. (See 'Introduction' above and 'The mammographic examination' above.)
- Breast compression improves image quality. Patient-controlled compression may minimize discomfort. (See 'Breast compression' above.)
- The effective radiation dose received from a routine screening mammogram is equivalent to the dose received from natural background radiation over three months. Individuals with *BRCA1* or *BRCA2* mutations may be at somewhat greater risk for radiation-induced cancer. (See 'Radiation dose' above.)
- Digital mammography, compared with film mammography, improves image quality and facilitates interpretation but may not significantly impact overall cancer detection rates. Both technologies represent acceptable screening modalities for all patients.

Digital mammography may offer a small screening advantage in those younger than 50 years old and those with dense breasts.

- Digital breast tomosynthesis (DBT, also known as 3D mammography) may increase cancer detection rates and the positive predictive value of screening examinations compared with digital mammography. (See 'Digital versus film screen mammogram' above and 'Digital breast tomosynthesis (DBT)' above.)

- Computer-aided detection (CAD) has not been demonstrated to improve mortality rates from breast cancer screening. CAD is associated with lower overall accuracy, may increase patient recall rates, and may increase the potential for overdiagnosis. (See 'Mammography reading' above.)

- Diagnostic mammograms are performed to evaluate breast abnormalities (symptoms, clinical findings, or follow-up of abnormal screening mammograms) and are distinguished from screening mammograms. Additional views are obtained with diagnostic mammograms and these are performed when a radiologist is immediately available for review of the study, especially as patients may also need a diagnostic breast ultrasound to complete the evaluation. (See 'Screening versus diagnostic mammography' above.)

- The Breast Imaging Reporting and Data System (BI-RADS) standardizes reporting for mammography and ultrasonography and helps to guide decision-making. It also serves as a useful tool in data collection and audit functions. The summary of a BI-RADS report specifies findings as incomplete or as one of six final assessment categories (table 1). A negative mammogram should **not** deter further intervention if there is clinical suspicion for malignancy. (See 'Mammography quality control' above.)

- Ultrasound is not typically used in the routine screening for breast cancer. Although whole-breast ultrasound screening may detect additional early-stage breast cancers that are mammographically occult, particularly in patients with dense breast tissue, the additional ultrasound screening test carries a substantial risk for false-positive results, leading to patient anxiety, breast biopsies with benign results, and follow-up imaging. (See 'Role of ultrasound' above.)

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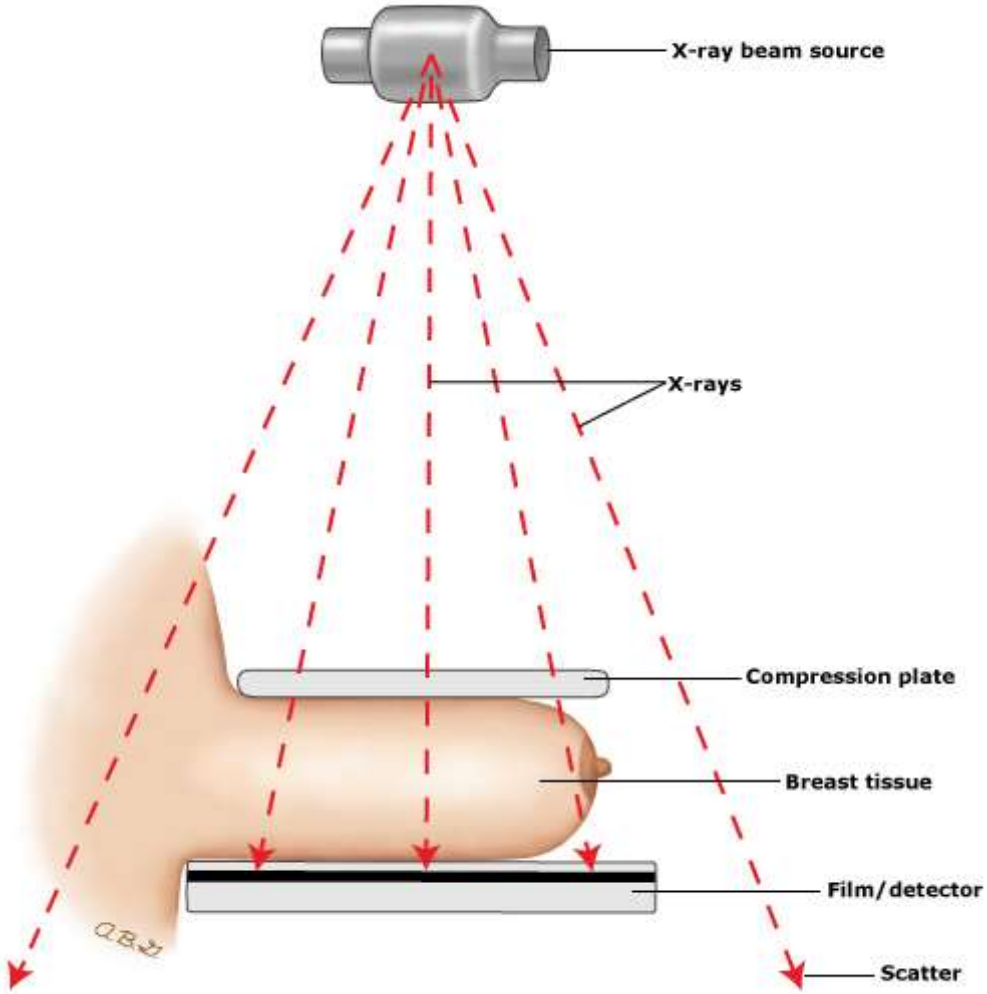
Topic 7561 Version 53.0

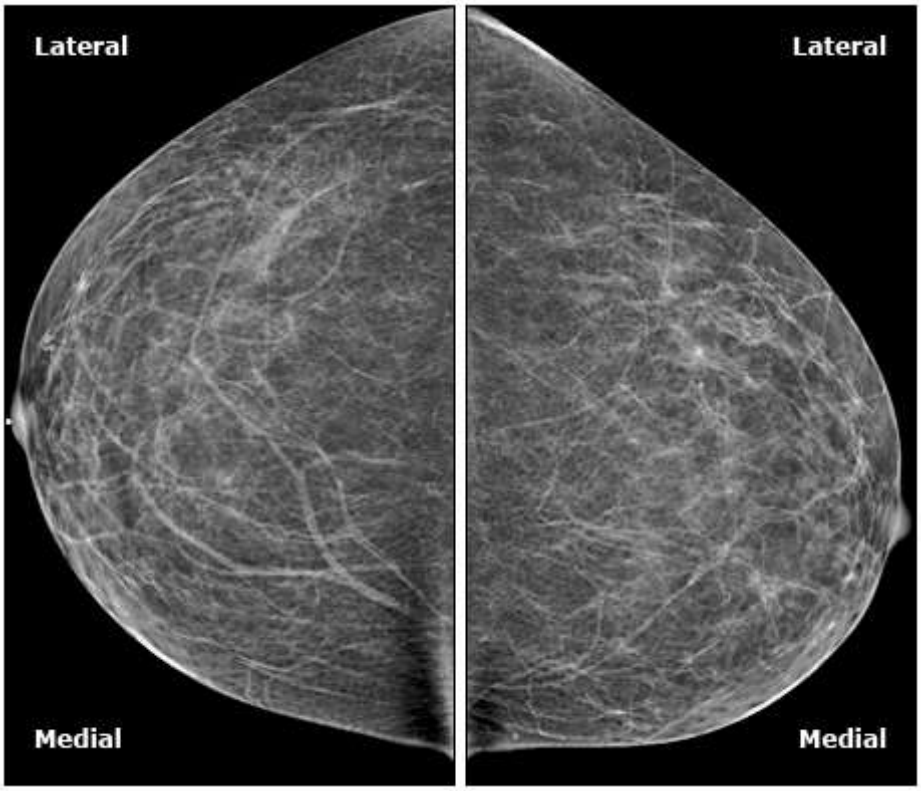
GRAPHICS

Schematic diagram of a mammogram



Graphic 51636 Version 2.0

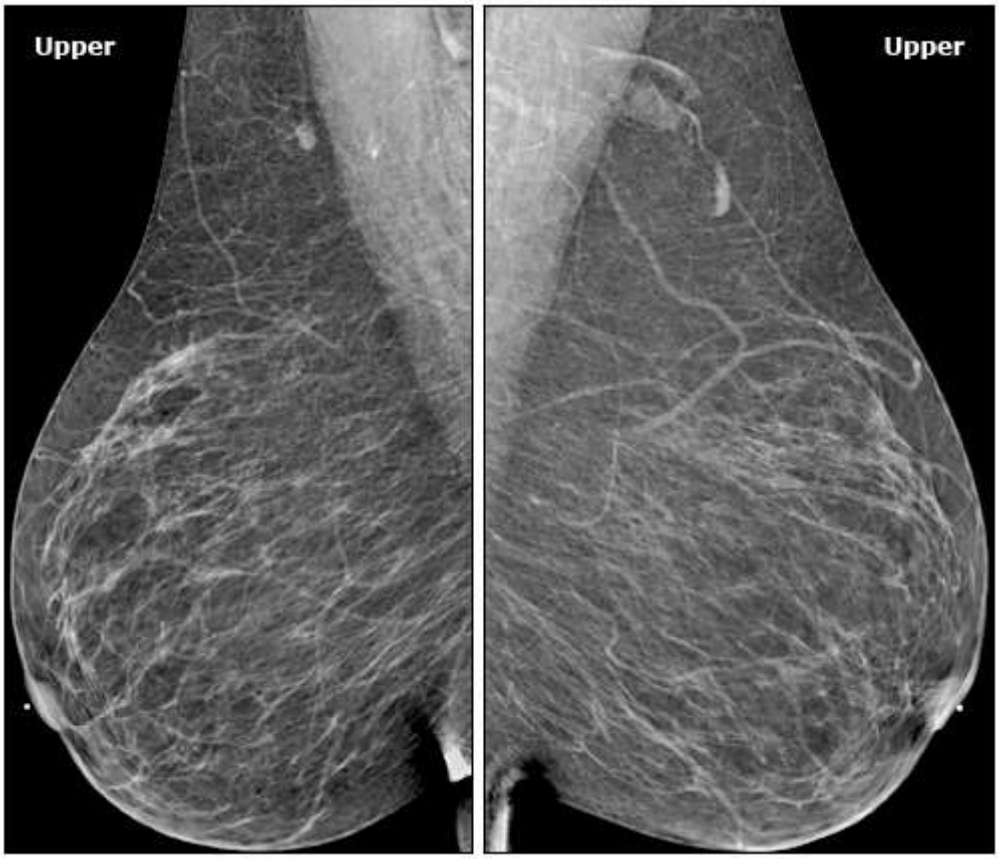
Normal CC (craniocaudal) views of both breasts



By convention, the mammograms of both breasts are viewed as mirror images. The upper half represents the lateral or outer aspect of the breast and the lower half represents the medial or inner aspect of the breast. The nipples are in profile and normal fat is visible between the edge of the film and the glandular tissue.

Graphic 65703 Version 3.0

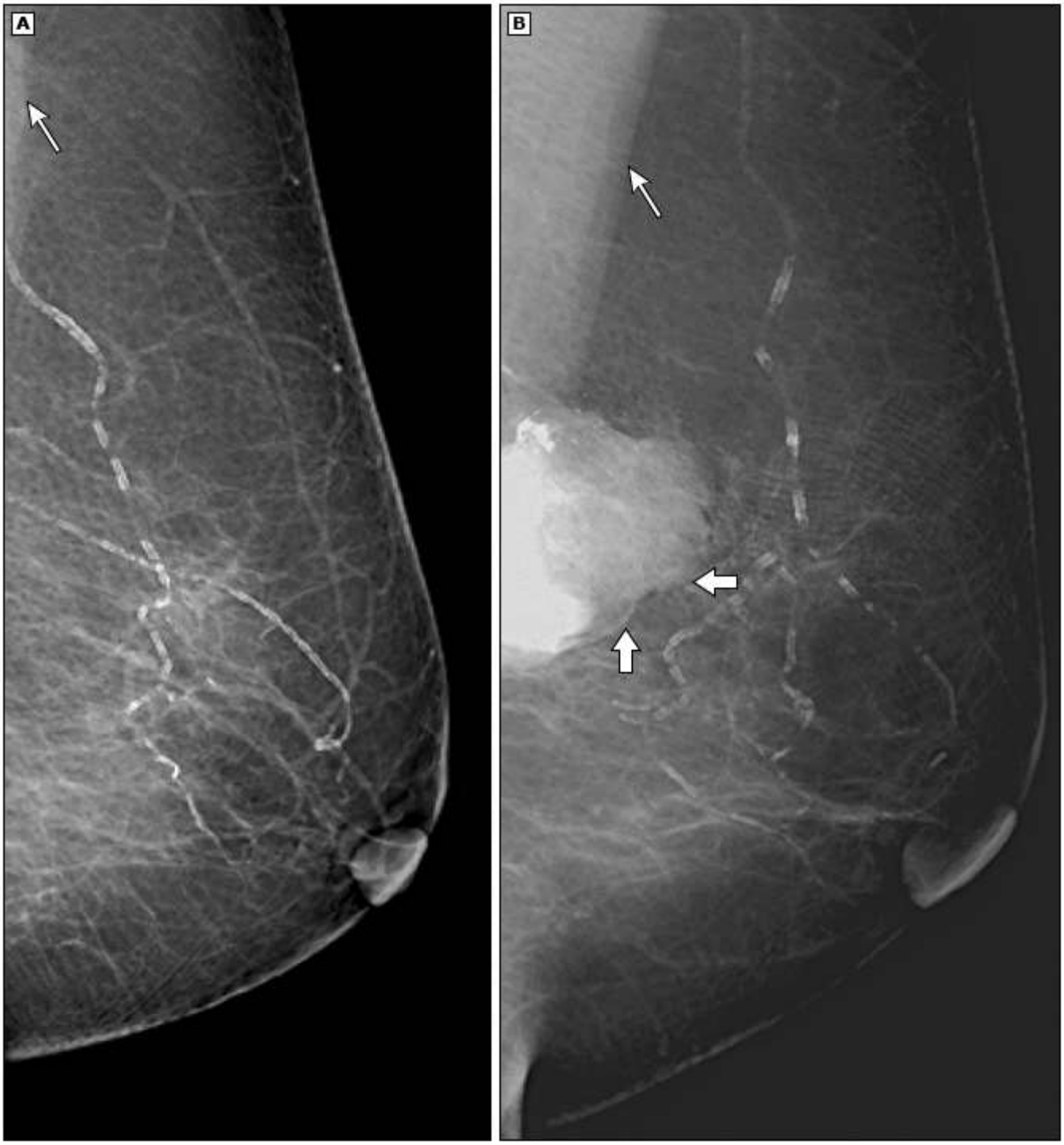
Normal MLO (mediolateral oblique) view of both breasts



By convention, the mammograms of both breasts are viewed as mirror images. The pectoralis muscle is seen at least till the level of the nipple. The top portion of the image represents the upper half of the breast and the bottom portion of the image represents the lower half of the breast.

Graphic 75940 Version 4.0

Importance of correct positioning

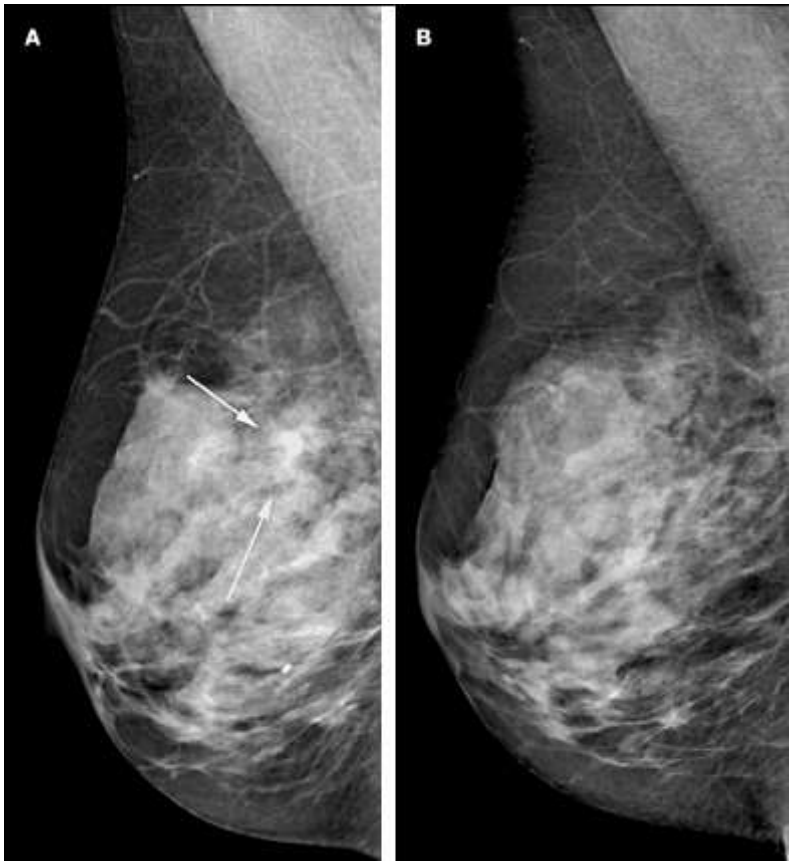


Both figures show the MLO view of the left breast. In Panel A, the posterior breast tissues are not included. The pectoralis muscle (arrows) is barely visible. Upon better positioning of the same breast (Panel B), the large irregular mass (thick arrows) becomes obvious.

MLO: mediolateral oblique.

Graphic 75653 Version 4.0

Importance of breast compression

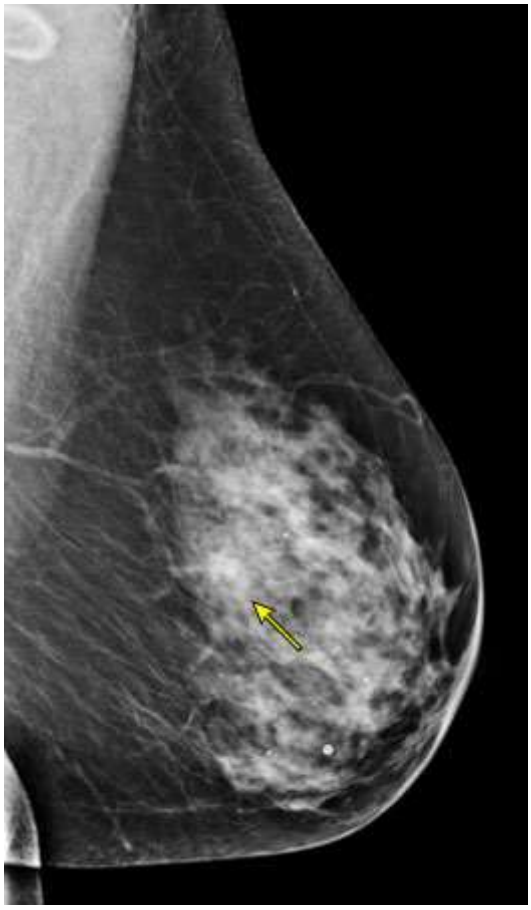


MLO view obtained with inadequate compression (Panel A), raises the question of an irregular asymmetry (arrows). On repeat imaging (Panel B) with better compression, the breast parenchyma is better visualized, with no underlying abnormality. Breast compression minimizes superimposition of tissues and decreases patient motion, thereby improving the diagnostic quality of the study.

MLO: mediolateral oblique.

Graphic 74381 Version 4.0

Breast cancer on mammography

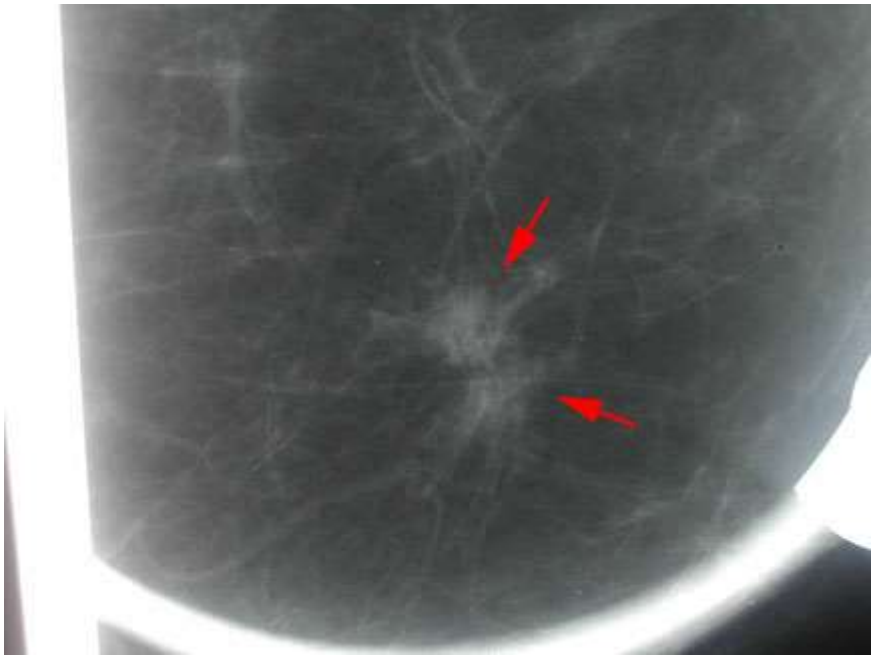


The arrow identifies a suspicious mass in the left inner upper breast in a 54-year-old woman with heterogeneously dense breast tissue. Biopsy revealed invasive carcinoma.

Courtesy of Phoebe Freer, MD and Priscilla Slanetz, MD, MPH, FACR.

Graphic 107389 Version 1.0

Mammogram spiculated mass

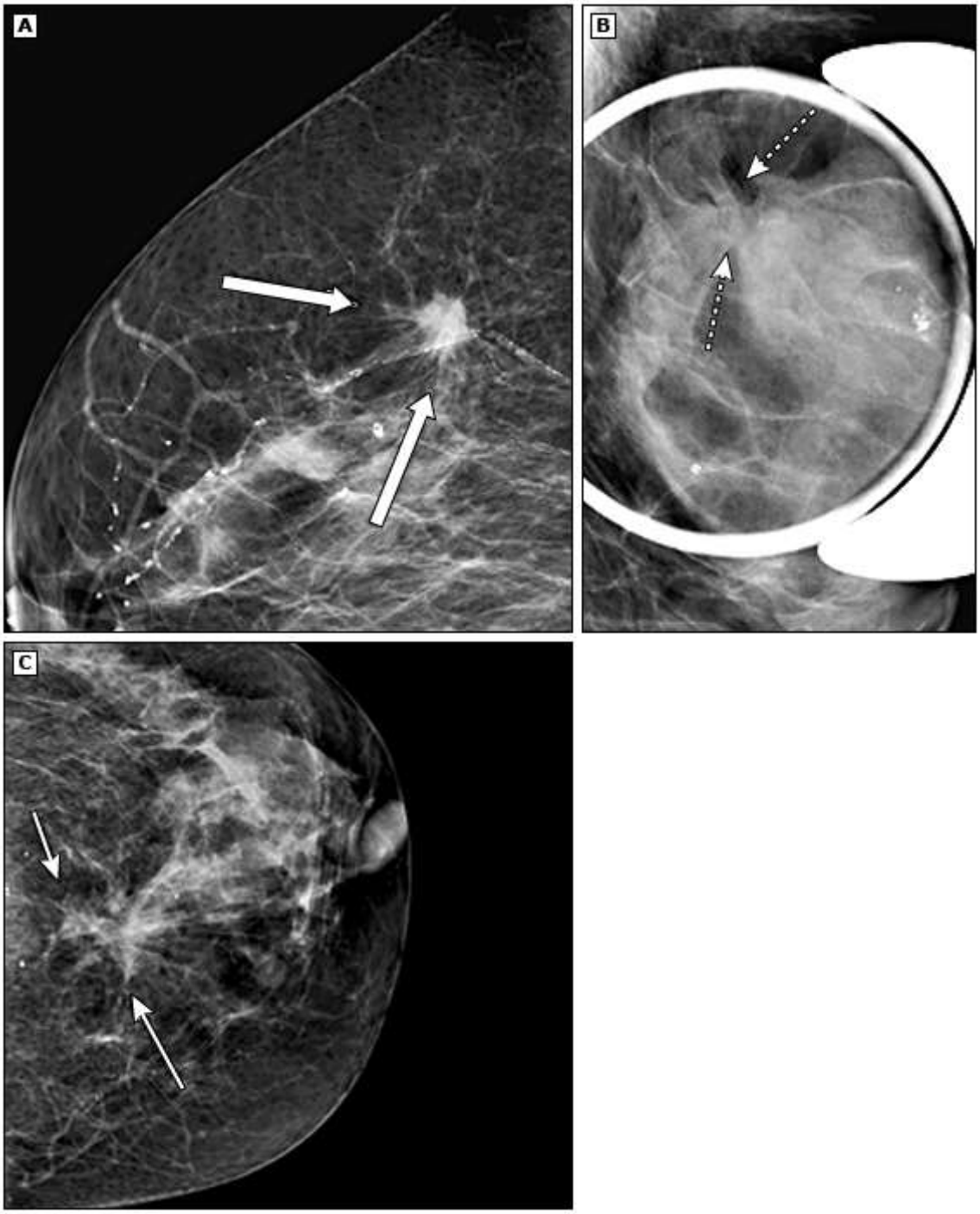


Spot magnification view of a mammogram showing 2 small adjacent interconnected spiculated masses (red arrows). Pathology revealed tubular carcinoma. Tubular carcinoma characteristically appears spiculated on mammogram and is often associated with satellite lesions.

Courtesy of Lisa E Esserman, MD.

Graphic 57593 Version 3.0

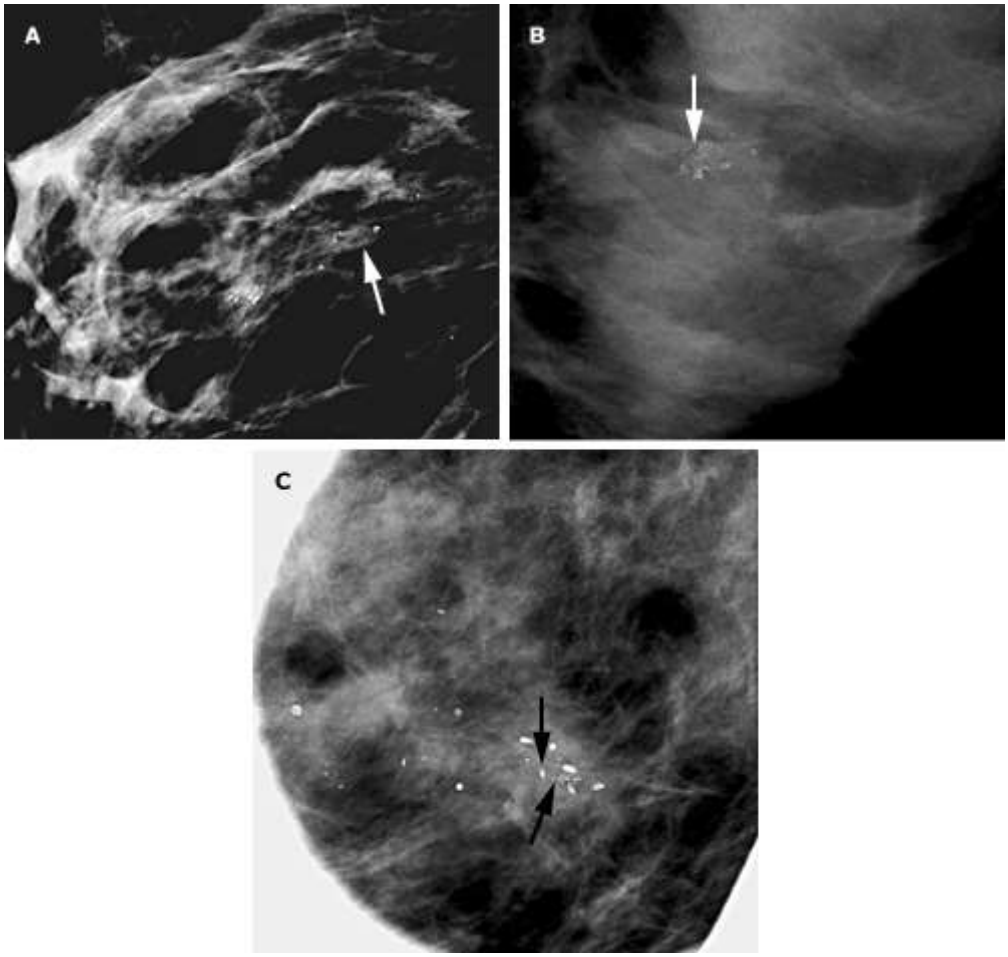
Suspicious mass



Spiculation from invasive ductal carcinoma in 3 different cases. In Panel A, an irregular mass with spiculated margins is seen (thick arrows). In Panel B, the cancer is not seen as a mass, but extensive distortion (dashed arrows) is seen. In Panel C, an indistinct mass is seen with spiculations extending far beyond the mass (arrows).

Graphic 77782 Version 5.0

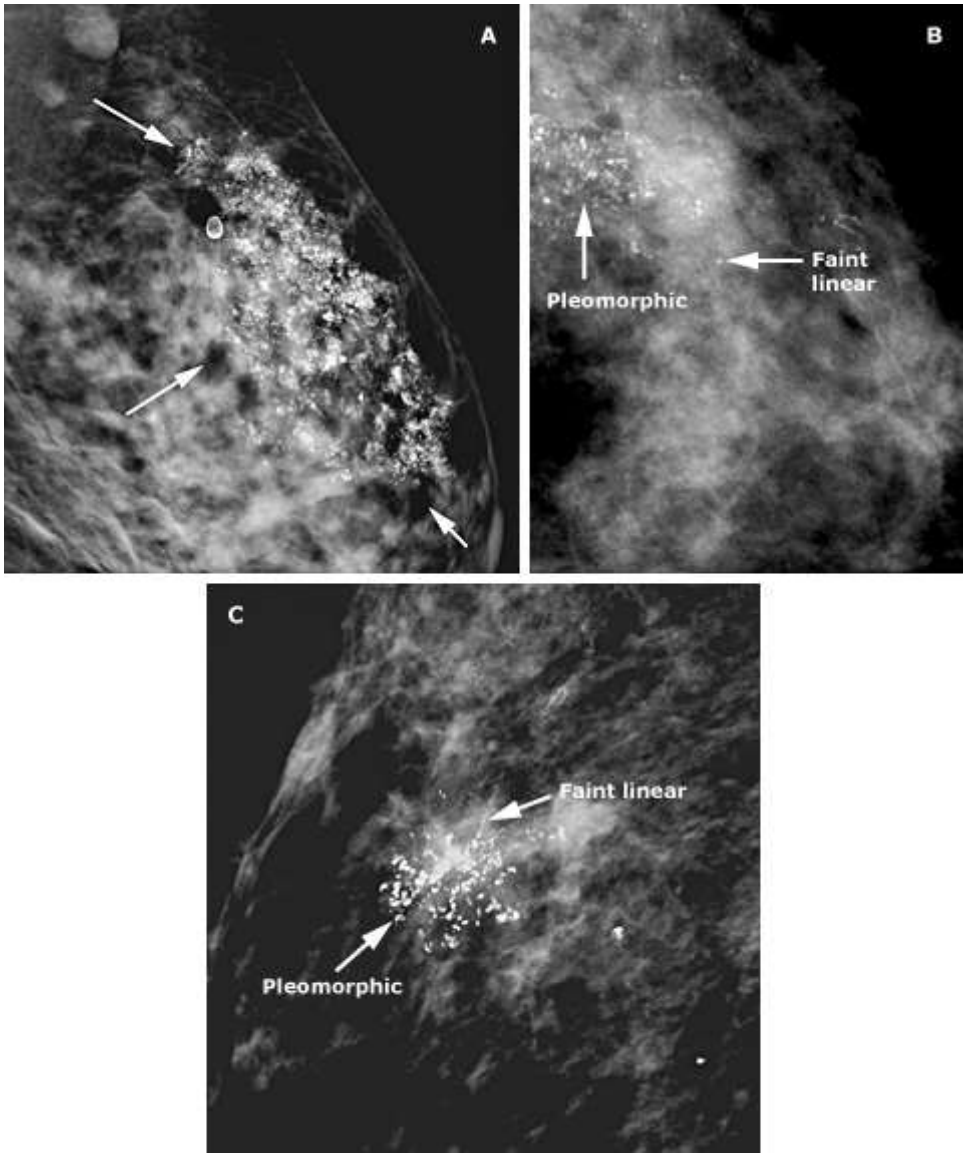
Suspicious calcifications



Grouped microcalcifications in 3 different cases. A loose group of coarse heterogenous calcifications is seen in Panel A (arrow). A small cluster of amorphous calcifications is seen in a background of dense breast parenchyma in Panel B (arrow). Fine pleomorphic calcifications are seen in between coarse larger calcifications in Panel C (arrows).

Graphic 62953 Version 5.0

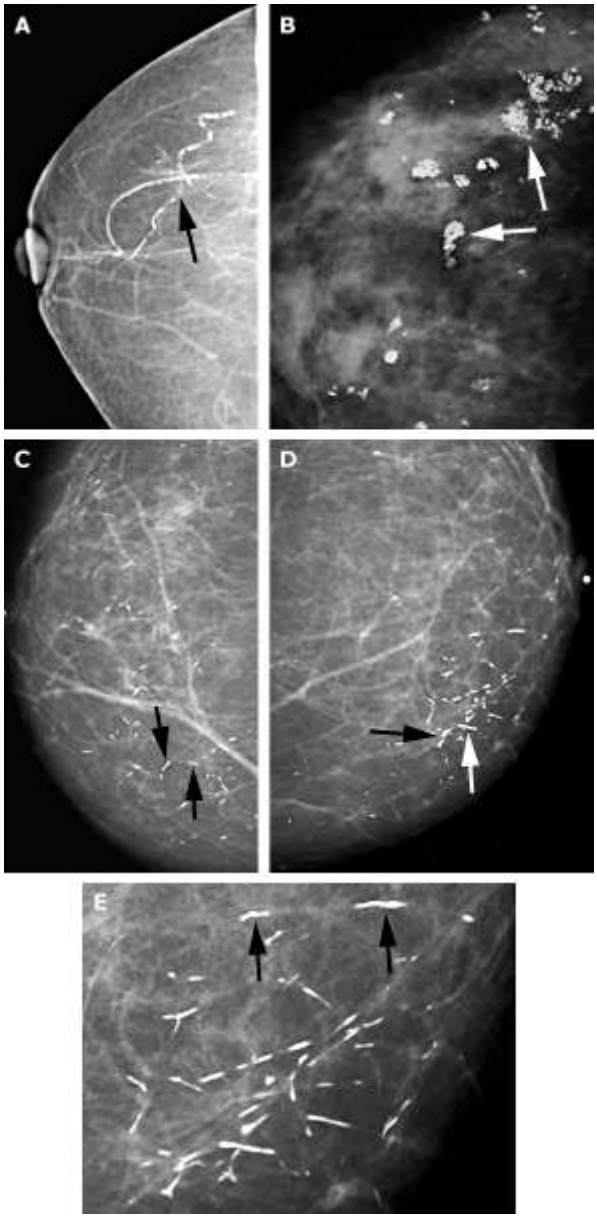
Pleomorphic calcifications (suspicious)



3 different cases of suspicious calcifications (arrows): segmental coarse heterogenous distribution (Panel A); and faint, with some grouped linear branching and fine pleomorphic calcifications (Panels B and C).

Graphic 73616 Version 3.0

Benign patterns of calcifications

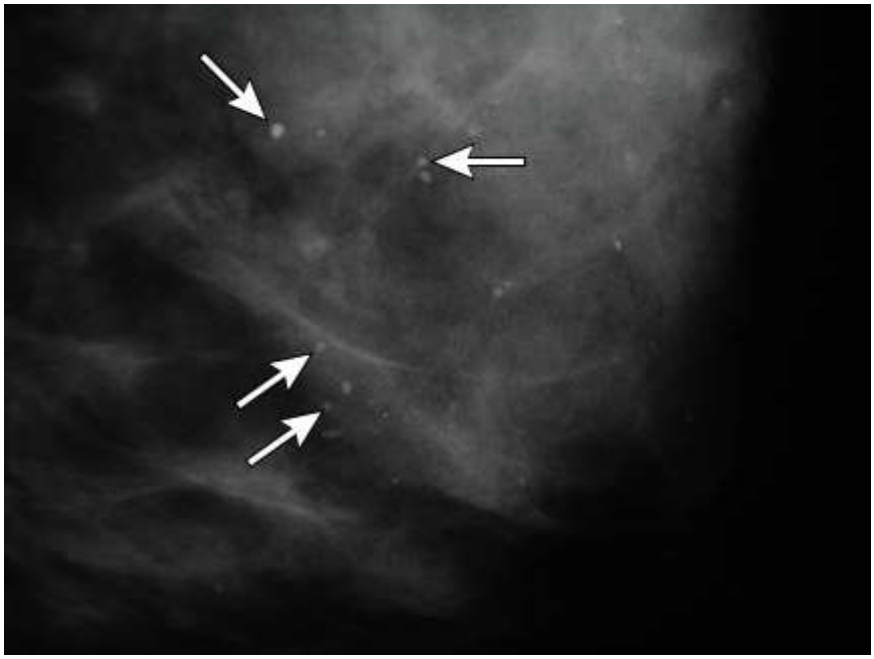


Benign patterns of calcifications (arrows) in 3 patients. Vascular calcifications are seen in the lateral aspect of the breast on a CC mammogram (Panel A). Multiple coarse "popcorn" calcifications are characteristic features of calcifying fibroadenomas (Panel B). Bilateral, benign, large, rod-like secretory calcifications are seen in CC views of both breasts (Panels C and D). The rod shape is better seen on the magnification view (Panel E).

CC: craniocaudal.

Graphic 75088 Version 4.0

Round mammographic calcifications



Magnified medial lateral oblique mammogram showing scattered, well-defined, round calcifications (arrows) that can be characterized as benign. These findings are benign and would be described as BI-RADS 2.

BI-RADS: Breast Imaging Reporting and Data System.

Courtesy of Lisa E Esserman, MD.

Graphic 52281 Version 6.0

BI-RADS assessment categories

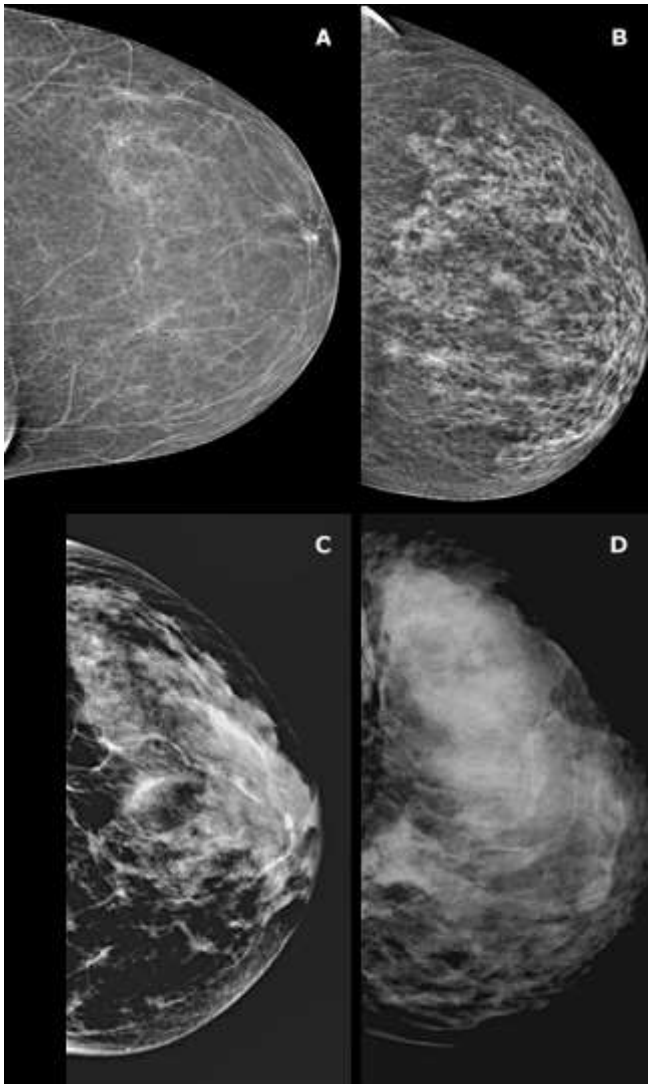
Assessment	Management	Likelihood of cancer
Category 0: Incomplete – Need additional imaging evaluation and/or prior mammograms for comparison	Recall for additional imaging and/or comparison with prior examination(s)	N/A
Category 1: Negative	Routine mammography screening	Essentially 0% likelihood of malignancy
Category 2: Benign	Routine mammography screening	Essentially 0% likelihood of malignancy
Category 3: Probably benign	Short-interval (6-month) follow-up or continued surveillance mammography	>0 but ≤2% likelihood of malignancy
Category 4: Suspicious	Tissue diagnosis*	>2 but <95% likelihood of malignancy
Category 4A: Low suspicion for malignancy		>2 to ≤10% likelihood of malignancy
Category 4B: Moderate suspicion for malignancy		>10 to ≤50% likelihood of malignancy
Category 4C: High suspicion for malignancy		>50 to <95% likelihood of malignancy
Category 5: Highly suggestive of malignancy	Tissue diagnosis*	≥95% likelihood of malignancy
Category 6: Known biopsy-proven malignancy	Surgical excision when clinically appropriate	N/A

BI-RADS: Breast Imaging-Reporting and Data System.

* Practice guidelines recommend biopsy for all BI-RADS 4 and 5 lesions. If there are clinical factors (eg, age, comorbidities, etc) for which the patient, in consultation with the clinician, chooses to defer biopsy, the reasoning should be documented in the medical record.

Graphic 100197 Version 10.0

Varying patterns of normal breast density

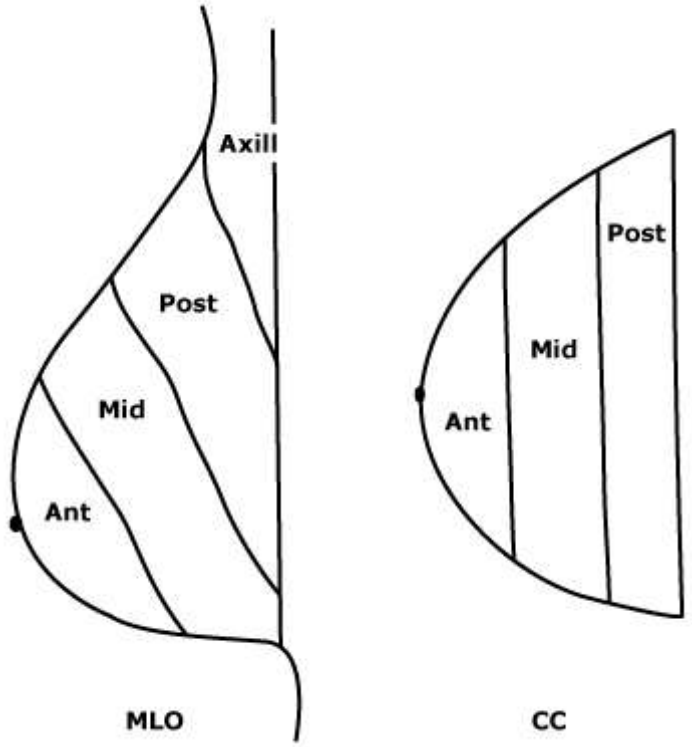


The mammographic breast density results from varying proportions of fat, connective tissue, and ductal and lobular elements. The mammogram report should mention the density pattern using the standard BI-RADS classification into predominantly fatty (Panel A), scattered fibroglandular (Panel B), heterogenous (Panel C) or dense (Panel D) breast tissue.

BI-RADS: Breast Imaging Reporting and Data System.

Graphic 52305 Version 6.0

Lesion location

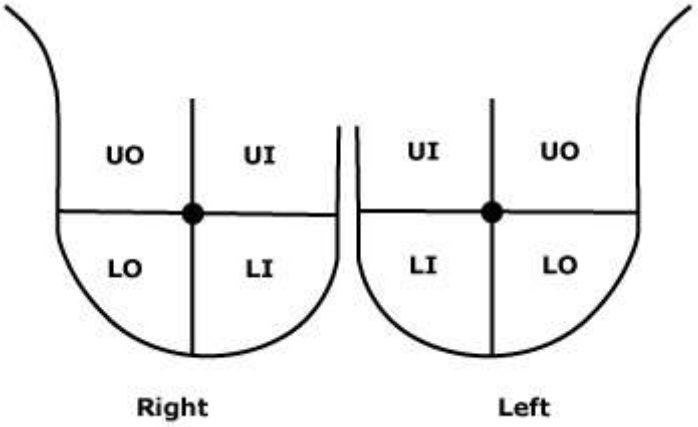


Schematic representation of CC and MLO views. The breast is divided into anterior, middle and posterior depths to aid lesion localization.

CC: craniocaudal; MLO: mediolateral oblique; ant: anterior; mid: middle; post: posterior; axill: axillary.

Graphic 80647 Version 2.0

Breast quadrants

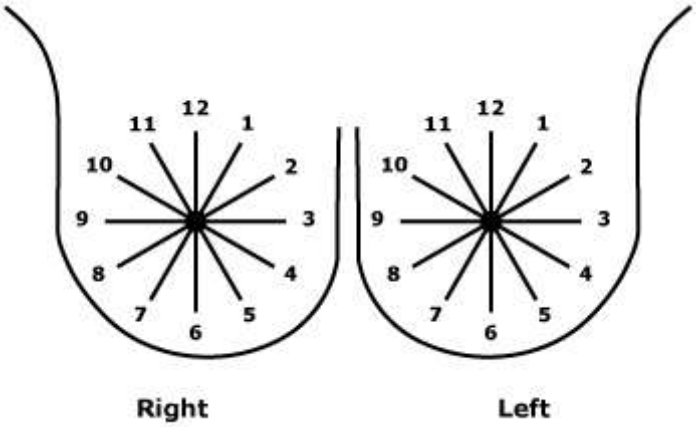


The breasts are divided into 4 quadrants with the nipple as the center.

UO: upper outer; UI: upper inner; LO: lower outer; LI: lower inner.

Graphic 72001 Version 2.0

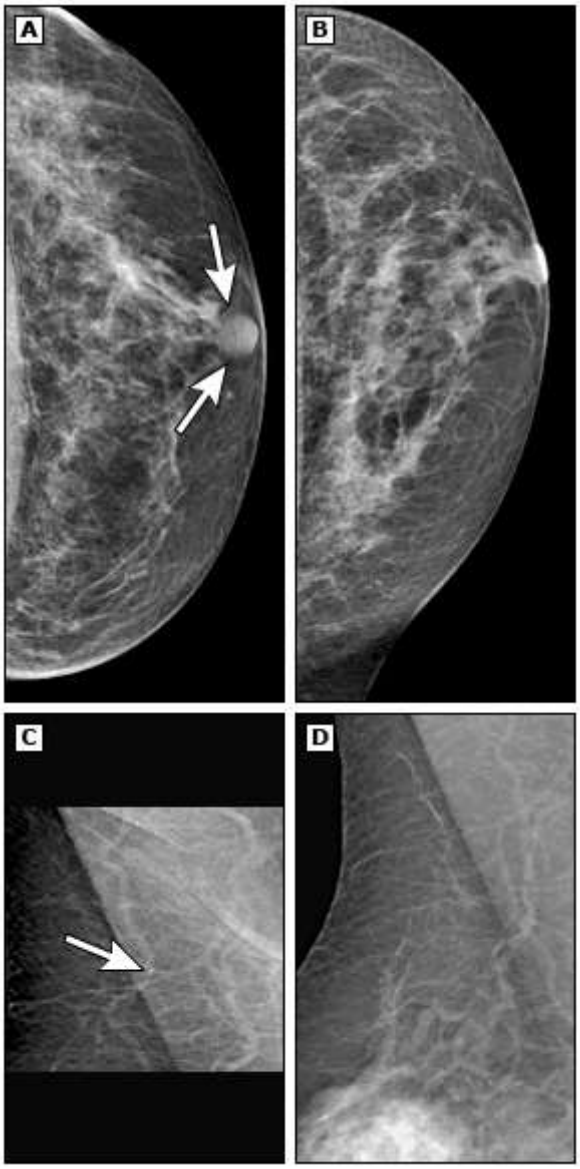
Clock position in locating a lesion



The location can also be indicated as a clock position. Each breast is divided into clock positions with the nipple as the center.

Graphic 60065 Version 1.0

Technical factors leading to additional imaging

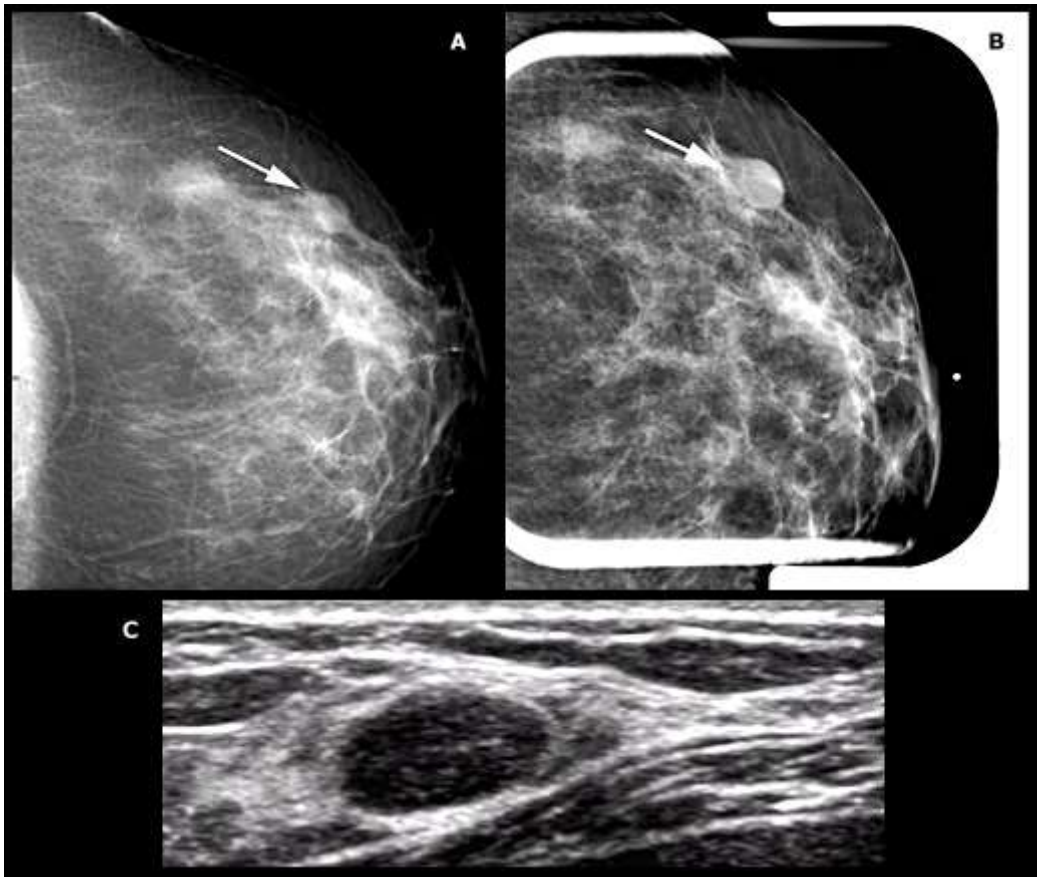


On a standard CC view performed during routine screening mammogram, the nipple (arrows) can appear as a nodule (Panel A) if not properly positioned, leading to additional workup. When the CC view of the same breast is repeated with the nipple in profile (Panel B), it becomes clear that there is no lesion. Similarly, deodorant may appear as very faint radiodensities. This is usually seen in the axillary portion of the breast on the MLO view, mimicking microcalcifications (Panel C, arrow). A repeat MLO view (Panel D) after washing the axilla shows normal appearance.

CC: craniocaudal; MLO: mediolateral oblique.

Graphic 66345 Version 4.0

Benign solid mass on mammogram and ultrasound

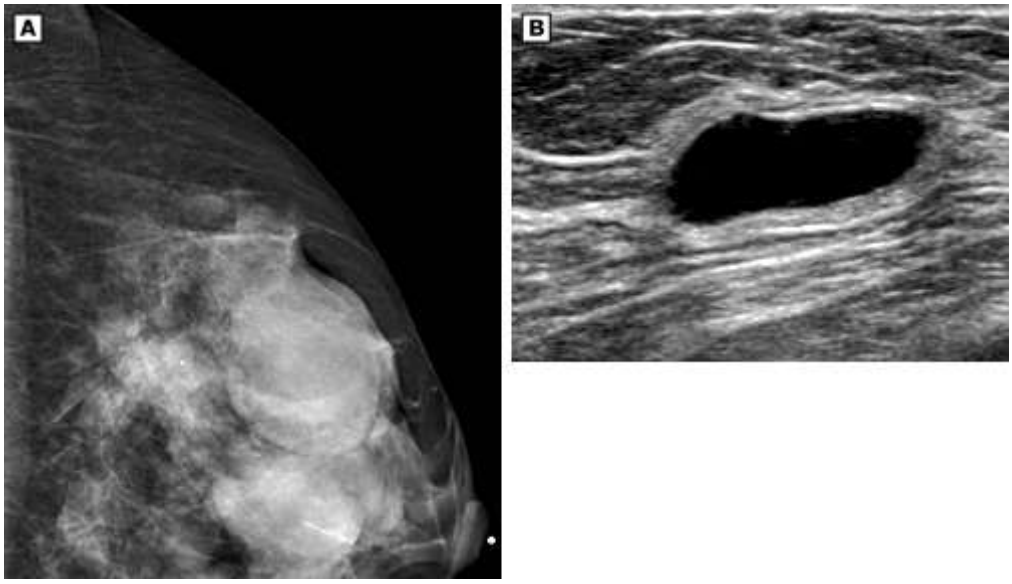


A well-defined oval mass (arrow) is seen in the lateral aspect of the breast on CC and spot CC views (Panels A and B). On ultrasound (Panel C), it has benign features and is consistent with a fibroadenoma.

CC: craniocaudal.

Graphic 54203 Version 3.0

Benign breast cysts

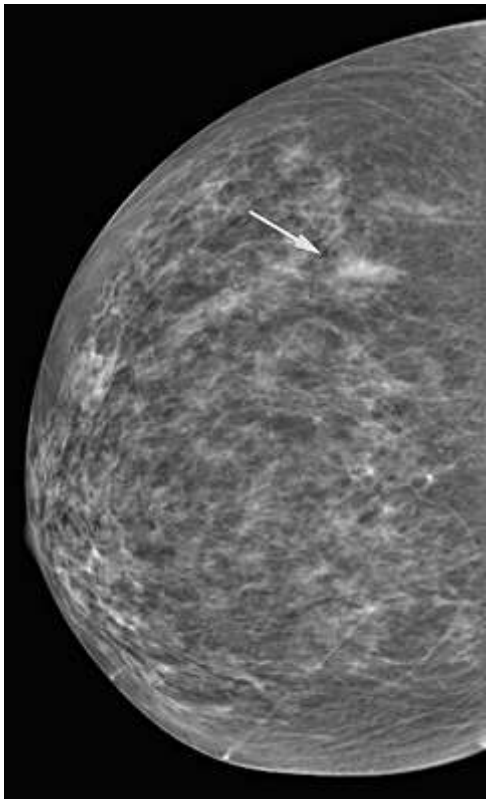


Multiple circumscribed oval and round masses seen on CC mammogram (A). Simple cyst is seen on ultrasound (B), confirming the benign nature of the mammographic mass.

CC: craniocaudal.

Graphic 63321 Version 4.0

Parenchymal asymmetry

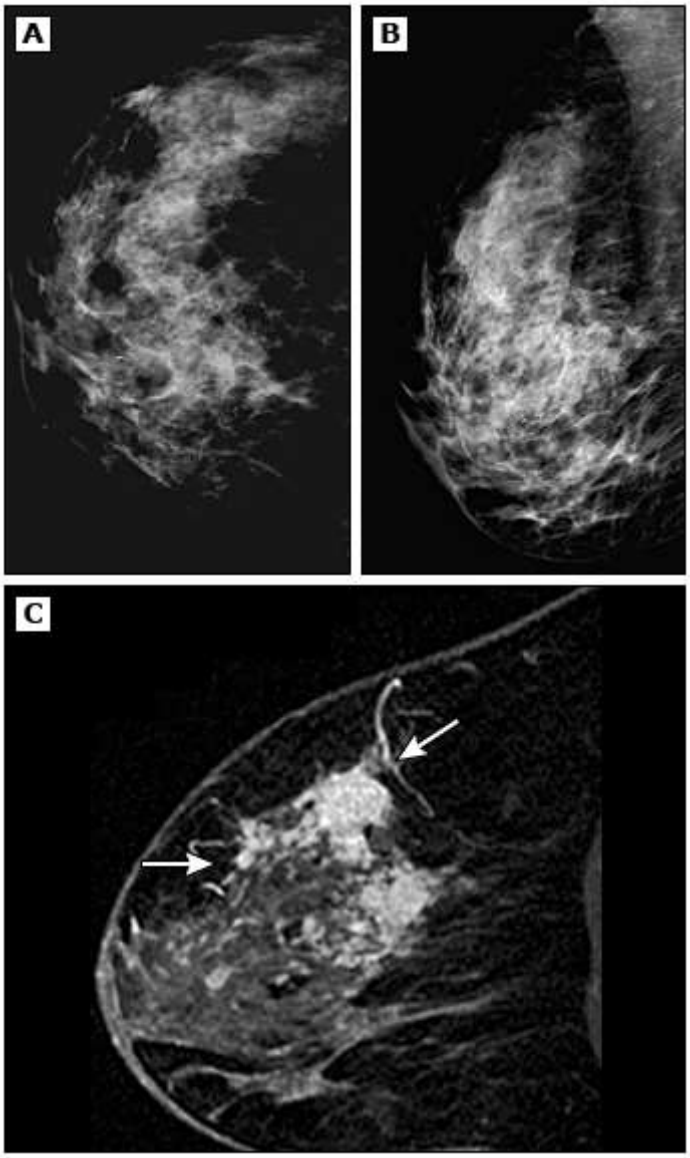


An asymmetry (arrow) is seen in the lateral aspect of the breast on the CC view. Additional evaluation with diagnostic mammography and ultrasound did not reveal a suspicious finding.

CC: craniocaudal.

Graphic 71340 Version 6.0

Mammographically occult breast cancer

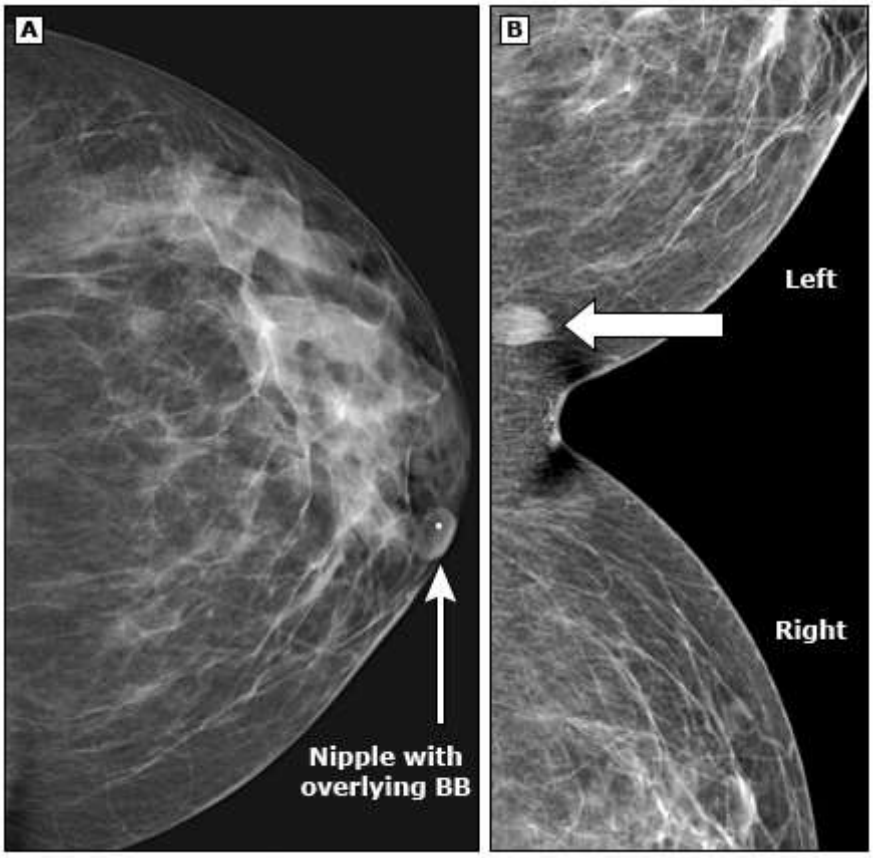


A dense breast can obscure a cancer. CC and MLO views (panels A and B) in a woman with a palpable breast lump show dense breast parenchyma. No discrete mass or calcifications are seen. A sagittal post contrast MR image (panel C) in the same breast shows multiple enhancing masses (arrows) involving the upper half of the breast worrisome for malignancy. Ultrasound-guided biopsy revealed invasive ductal cancer. If there is a clinical suspicion for cancer, a negative mammogram should not stop further intervention.

CC: craniocaudal; MLO: mediolateral oblique; MR: magnetic resonance.

Graphic 54454 Version 8.0

Cleavage view

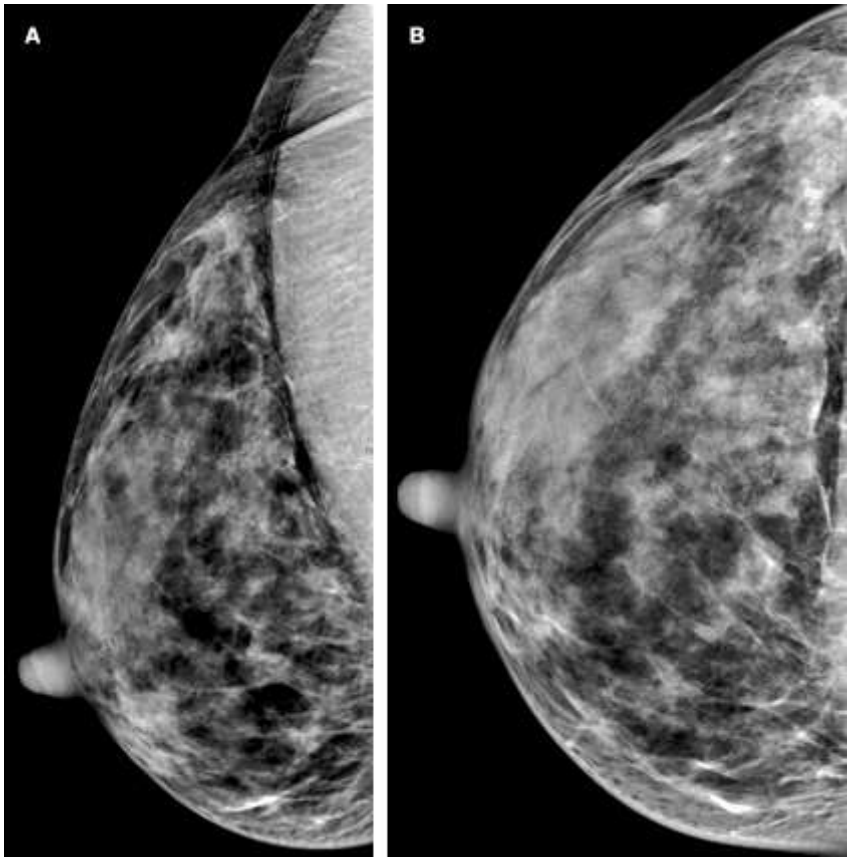


Cleavage views of both breasts may be obtained to adequately image the medial tissues. On the original CC view (Panel A), a small mass in the medial aspect of the left breast is not seen, and the normal nipple, with an overlying BB, is demonstrated (thin arrow). The mass is well seen on the cleavage view (Panel B, thick arrow).

CC: craniocaudal.

Graphic 57051 Version 5.0

Exaggerated craniocaudal view

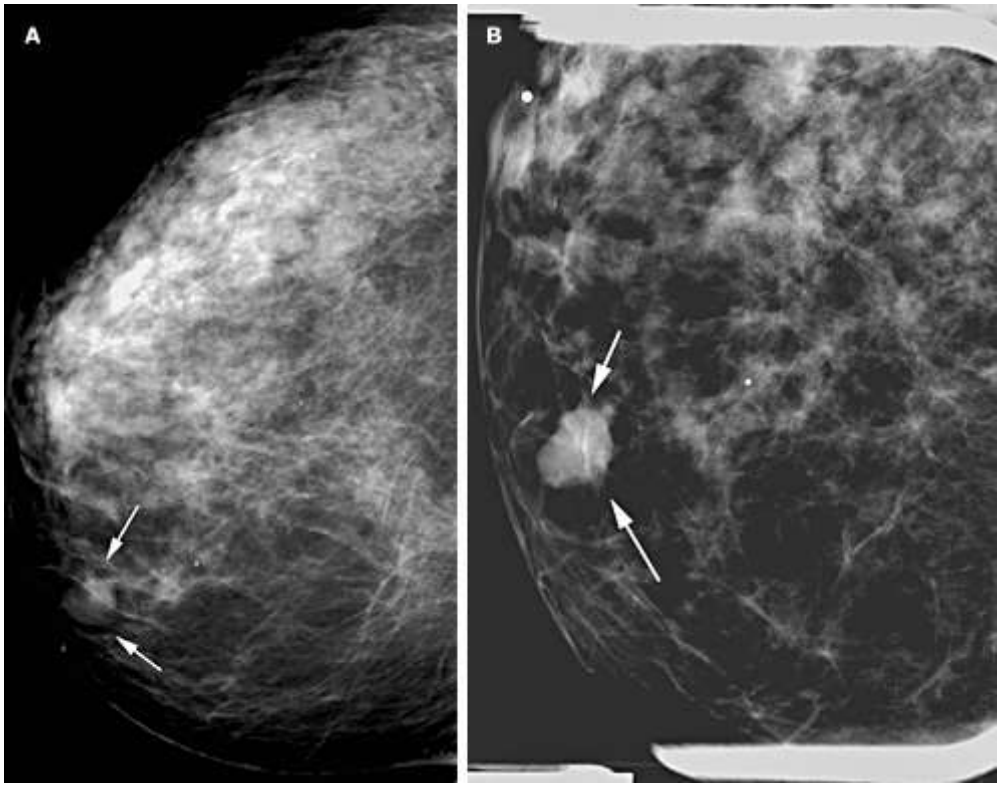


The XCCL view (Panel A) includes the more posterior and lateral breast tissue than the standard CC view (Panel B).

XCCL: exaggerated craniocaudal; CC: craniocaudal.

Graphic 76637 Version 3.0

Value of spot compression

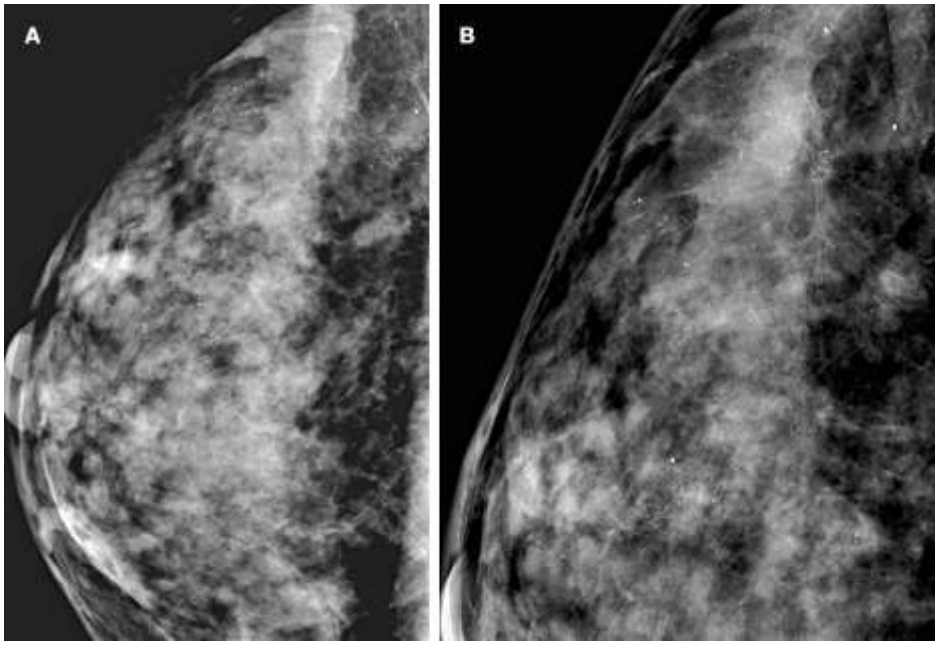


There is suggestion of a mass (arrows), obscured by surrounding breast parenchyma, in the medial aspect of the breast on the CC view (Panel A). The margins, shape, and density are better evaluated with spot compression (Panel B).

CC: craniocaudal.

Graphic 78340 Version 3.0

Magnification view



The routine CC view (Panel A) shows calcifications in the lateral aspect of the breast. The size, shape, and distribution of these calcifications are better seen on magnification view (Panel B). The pleomorphic appearance and segmental distribution of numerous calcifications oriented towards the nipple is a classic appearance of ductal carcinoma in situ.

CC: craniocaudal.

Contributor Disclosures

Priscilla J Slanetz, MD, MPH, FACR Other Financial Interest: Endomag [reviewed 53 cases for pre-FDA study]. All of the relevant financial relationships listed have been mitigated. **Christoph I Lee, MD, MS** Consultant/Advisory Boards: GRAIL [Cancer screening]. Other Financial Interest: McGraw-Hill [Textbook royalties]; Oxford University Press [Textbook royalties]. All of the relevant financial relationships listed have been mitigated. **Joann G Elmore, MD, MPH** No relevant financial relationship(s) with ineligible companies to disclose. **Gary J Whitman, MD** Consultant/Advisory Boards: Siemens [Digital mammography, tomosynthesis, breast cancer]. All of the relevant financial relationships listed have been mitigated. **Jane Givens, MD, MSCE** No relevant financial relationship(s) with ineligible companies to disclose.

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