Radiology

Technologist-performed Handheld Screening Breast US Imaging: How Is It Performed and What Are the Outcomes to Date?[1]

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Breast density-inform legislation is increasing the need for data on outcomes of tailored screening. Dense parenchyma can mask cancers, and denser tissue is also more likely to develop breast cancer than fatty tissue. Digital mammography is standard for women with dense breasts. Supplemental screening magnetic resonance imaging should be offered to women who meet high-risk criteria. Supplemental screening ultrasonographic (US) imaging may be appropriate in the much larger group of women with dense breasts. Both physician- and technologist-performed screening US imaging increases detection of node-negative invasive breast cancer. To meet anticipated demand in the United States, screening US images will most likely be acquired by trained technologists rather than physicians. While automated US offers standard documentation, there are few data on outcomes. US has been used diagnostically for decades to characterize masses seen by using mammography, but training specific to screening has been lacking. Standard approaches to training and documentation of technologist-performed handheld screening US imaging are needed. This article reviews the current status of technologist-performed handheld screening breast US imaging.

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Since the publication of prospective international multicenter results that validate physician-performed screening breast ultrasonography (US) (1–4), there has been increased interest in implementation strategies. This is particularly pressing because breast-density inform legislation is increasingly widespread. Such legislation requires radiologists to include a qualitative statement of mammographic breast density in the lay letter providing results to patients. Nearly all such legislation also includes language that suggests the patient discuss with her physician whether or not supplemental screening might be considered. The basis for considering supplemental screening is twofold. First, there is a masking effect of dense tissue: noncalcified cancers are often mammographically hidden in areas of dense parenchyma, which results in increase in interval cancer rates (5,6); interval cancers are those that manifest as palpable masses or thicken in the interval between recommended screenings (eg, within 365 days in the United States). Second, there is an elevated risk attributable to extremely dense (compared with fatty) parenchyma of threefold to sixfold (7,8), and this risk may be even greater in fibroglandular tissue that shows moderate to marked background parenchymal enhancement on magnetic resonance (MR) images (9). Some legislation explicitly suggests screening US or MR imaging be performed in women with mammographically heterogeneously dense or extremely dense breasts (collectively, "dense" breasts). In women with dense breasts, mammography should be performed with a digital technique for its improved cancer detection over that of film screen (10).

Essentials

- With intensive training, lesion detection and characterization is equivalent for technologists and physicians in Japan; experience performing at least 100 examinations with supervision has been shown to improve observer performance.
- Standard technique includes transverse and sagittal scanning with a normal examination documented by a minimum of one image from each quadrant and one behind the nipple.
- Findings other than simple cysts should be documented by orthogonal views which include the longest horizontal diameter of the lesion, without and with calipers; a color or power Doppler image is elective and can be helpful.
- Real-time physician rescanning is encouraged for vague abnormalities, particularly during technologist training.
- Incremental cancer detection rate averages 2.5 cancers per 1000 examinations for technologist-performed handheld screening US on the prevalent screen; 13% women are recommended for further testing prior to the next annual screening and one in 22 women is recommended for US-guided biopsy, with only 6.2% of biopsies prompted by US imaging revealing cancer.

Who Merits Supplemental Screening?

High-risk women, including those with known or suspected breast cancer gene (*BRCA*) mutations, lifetime risk of at least 20% (by use of models that predict genetic mutation risk, ie, excluding the Gail model), and women with previous chest radiation therapy at least 8 years earlier and before age 30 years, should be offered annual screening MR beginning at about age 25 years (11). If MR imaging is performed, there is no added benefit to screening US; across 1037 women in four series where MR imaging, mammography, and US were performed, only two cancers were seen only at US imaging (with 31 seen only at MR examination) (12–15). Some high-risk women cannot tolerate MR imaging (because of a pacemaker, aneurysm clip, or severe claustrophobia), and many others may choose not to have MR imaging or be unable to complete it (16); US is a reasonable option for such women. In women with even the highest risk, MR imaging is not cost-effective beyond age 60–70 years, depending on thresholds (17), and alternative supplemental screening may be sought at that time.

At least a third of women over age 50 years and up to half of women in their 40s are at intermediate risk for breast cancer because of dense breasts (18,19). Some of these women may or may not also have additional risk factors, such as a personal history of cancer, some family history of breast cancer, or previous biopsy that showed lobular carcinoma in situ or atypical hyperplasia. While MR imaging may depict additional cancers in women at intermediate risk (20–22), it is very expensive, currently requires intravenous injection of a gadolinium-based contrast agent, and may not be covered by insurance. Because US can depict node-negative invasive breast cancers that are masked on mammography (2–4,23–31), use of annual US screening to supplement mammography can be considered for women with dense breasts, even in the absence of additional risk factors. US imaging can also depict additional cancers in women with scattered fibroglandular tissue (2), though routine screening US has not been advocated in that large group of women. Increased sensitivity of tomosynthesis compared with digital mammography (32) may reduce the supplemental yield of screening US, although further study is needed.

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Abbreviations:
ACR = American College of Radiology
ACRIN = American College of Radiology Imaging Network
ARDMS = Association of Registered Diagnostic Medical Sonographers
ARRT = American Registry of Radiologic Technologists
BI-RADS = Breast Imaging Reporting and Data System
ICDR = incremental cancer detection rate
PPV = positive predictive value

Conflicts of interest are listed at the end of this article.

Why Should Technologists Perform Screening Breast US Imaging?

While technologists routinely perform US of every other body part, breast US has historically been performed primarily by physicians. In the American College of Radiology Imaging Network (ACRIN) 6666 trial of physician-performed screening US, the average time to perform bilateral whole-breast screening US was 19 minutes, ranging up to 90 minutes, and decreasing to an average of 13 minutes by the third round of annual screening (2). These values represent in-room time, including discussion with patients, but do not include the time to generate a report. As of this writing, there is still only one current procedural terminology code for breast US (ie, code 76645), with average Medicare reimbursement of $90 in 2010 (ICD-9 code 793.82, inconclusive mammogram due to dense breasts). Even with the prospect of new codes that recognize the difference between US examination focused on a palpable mass and one performed for screening or extent of disease in a newly diagnosed cancer patient, equipment, room costs, and physician time are financial and logistic disincentives to facilities to offer physician-performed screening breast US imaging. One financially viable model for screening breast US covered by insurance in the United States is for technologists to perform image acquisition. Both handheld and automated approaches exist. Automated approaches require the technologist to be trained to position the patient for standard views and to maintain contact of the transducer with the skin of the breast. With handheld US, the technologist must recognize and document abnormalities while scanning or they will go undetected.

For the last decade and in current workflow, especially in high-volume practices, initial responsibility for diagnostic breast US imaging has been shifting from the physician to the technologist, who will scan, document findings with orthogonal images, and present the images to the interpreting physician. Real-time scanning by the interpreter is encouraged before a final assessment is rendered (33). Although screening was not listed among the indications for breast US imaging until the 2011 revision of the American College of Radiology (ACR) Practice Guideline for the Performance of the Breast US Examination (33), during the preceding years, bilateral whole-breast US imaging became more common in patients with multiple masses and for assessment of extent of disease in women with newly diagnosed cancer (34–36). Many of these examinations are performed by technologists, but interpretation always resides with physicians. Breast screening is a new responsibility for a technologist whose training and experience until now has been largely directed to characterization of mammographic abnormalities or palpable masses.

Operator Dependence

Operator dependence has long been a concern for handheld breast US imaging, whether performed by physicians or technologists. Historically, there was reticence to interpret breast US from static images because of a belief that real-time evaluation was always required. Baker et al (37) reported a series of 152 diagnostic breast US examinations performed at facilities other than Duke and referred for comparison or second opinion, with each of these patients rescanned by physicians. On rescanning the patients, there was a change from the originally recommended patient management for 23 (15.1%) studies. In nine of the 23 (39%) discrepant examinations, the initial imaging facility reported a suspicious finding that was ultimately shown to represent normal fibroglandular tissue. Another five of 23 patients (22%) had examinations that were initially reported as suspicious, but the described abnormalities were subsequently found to represent benign intramammary nodes, extracapsular silicone, or a dilated duct. Three lesions reported as cysts were not, but none of these three was malignant. In two patients with malignant lesions, the initial examination demonstrated suspicious features that had gone unrecognized, and two patients with palpable findings had sonographic imaging correlates that were unrecognized (one cancer and one fibroadenoma). In two other patients, masses documented on US examination did not correlate with the original mammographic finding. The Duke team found that fully 92 (60.5%) cases did not comply with at least one ACR guideline, and 19 of 136 (14.0%) examinations where transducer orientation was indicated recorded only one projection (37), which emphasizes the need for training in standard technique and a minimum of orthogonal documentation of findings.

In studies where the same equipment was used by multiple observers, substantial agreement has been observed for both lesion detection and classification among physicians who perform whole-breast US. In one study, a radiology resident physician and senior attending radiologist performed and interpreted whole-breast US, with κ values for combined mammography and US exceeding those for mammography alone (38). For 11 breast imaging radiologists trained in the ACRIN 6666 technique (1) and qualified as investigators (39), larger lesions were more consistently detected in a day-long experimental session where the same 11 women, each with multiple benign findings, were rescanned by each observer. Specifically, of 407 possible detections of lesions 5 mm or smaller, only 170 (41.8%) were made, while 102 of 110 (92.7%) possible detections were made for lesions larger than 9 mm ($P < .001$) (40). Actual clinical performance of observers has been shown to exceed that seen in experimental situations (41).

Philpotts et al (42) evaluated a consecutive series of 412 technologist-performed screening US examinations, of which 336 (81.5%) were considered negative or benign. For the 76 (18.4%) women with findings, technologists rendered a preliminary assessment and physicians rescanned the patients. Physicians disagreed with the technologists' assessments for five examinations (1% of all studies and 6.6% of those with

findings) (42). Further data that systematically compare interpretations from initial images obtained by the technologist with those after real-time physician rescanning are needed. To facilitate clarity in such an analysis and later review, it is suggested that the technologist take a blank screen image that indicates end of the technologist's exam.

Training for Screening US

At present, the Association of Registered Diagnostic Medical Sonographers (ARDMS) offers clinical certification in diagnostic breast US (43), but there are no requirements or details for screening sonography. The American Registry of Radiologic Technologists (ARRT) requires that members perform 200 breast US examinations within 24 months and participate (eg, explain procedures, verify consent, or set up equipment) in 10 US-guided breast interventional procedures, but again these criteria are not specific to screening (44). Previous series of technologist-performed screening breast US (45–48) have trained either sonographers or mammographic technologists to perform the examination, typically after the technologist has experience in diagnostic breast US ideally at least meeting the requirements of ARDMS or ARRT. Several series have required the first 25 technologist-performed screening US examinations to be performed under supervision of an experienced technologist (47) or radiologist (46). In the Yale program (45), the radiologist routinely rescanned every patient during the first 6 months (ie, about the first 50 cases per technologist), and physicians continue to rescan patients who have findings that require surveillance or biopsy. The International Breast Ultrasound School guidelines are for physicians rather than technologists and are not specific to screening, but recommend the following to achieve accuracy and confidence: performance of a minimum of 500 examinations in a multidisciplinary environment with at least 300 cytologic or histologic correlation cases, and performance of at least 50 interventional procedures with appropriate follow-up (49).

In Japan, technologists and physicians who plan to offer screening breast US imaging attend a 2-day, 16-hour course, including live scanning and review of movies of breast US examinations (where they are asked to identify abnormalities). They also receive training in documentation and complete training and testing in interpretation of still images (50). Results of tests from 422 physicians and 415 technologists showed significantly better or similar performance by technologists than by physicians on all tasks: sensitivity for lesion detection on video review was greater for technologists than for physicians (85.9% vs 84.0%, respectively; $P = .037$), but not different on still images (95.8% vs 95.9%, respectively; $P = .75$). Specificity on still images was higher for technologists than for physicians (86.6% vs 85.1%, respectively; $P = .026$) but not different for video specificity (80.3% vs 79.4%, respectively; $P = .35$) (50). Both technologist and physician observers with experience in fewer than 100 breast US examinations showed worse performance, and physicians who were not radiologists or breast surgeons showed worse performance as well (50). Clinically, the technologist renders a preliminary assessment for the examination, which is then reviewed by the interpreting physician together with orthogonal images of findings with and without calipers, and with a single Doppler image. Cine loops are performed in about 5% of cases (31). Interpretation of screening US examination is performed in batch mode (after the patient has left the facility) (31,51). Formal training programs leading to certification, such as that reported by Tohno et al (50) in Japan, are essential as technologist-performed US screening becomes the major method of providing this service to women with dense breasts of intermediate risk in the United States.

At the institutions of both authors, whole-breast US is performed for screening women with dense breasts, extent of disease examinations in patients who are ineligible for MR imaging (or whose breast surgeons prefer their patients not to have MR imaging), and diagnostic purposes (ie, follow-up of multiple solid masses). At one of the author's (W.A.B.) facilities, where over 91 000 screening mammographic examinations and 9600 breast US examinations are performed annually, mammographic or sonographic technologists who perform screening US examinations are required to perform the following: (*a*) review the experience of Stavros et al (52) in description of benign and suspicious features on US; (*b*) review the Breast Imaging Reporting and Data System (BI-RADS) US (53) atlas, terminology, and definitions; *(c)* complete the training quiz of 70 proven cases (including 25 cancers) used for ACRIN 6666 investigators (39); and (*d*) demonstrate knowledge of US physics and terminology. Each technologist-in-training is then teamed for a minimum of 2 months with a senior technologist who has at least 2 years of experience in diagnostic breast US imaging, including whole-breast US imaging, until at least 100 cases have been supervised, including both screening and diagnostic cases, the latter with feedback from the radiologist who routinely rescans the patient. Before independently performing screening, the technologist must document experience scanning at least three of each of the following entities: cysts, complicated cysts, fibroadenomas, intraductal masses, sebaceous cysts, lipomas, mastitis or abscess, skin thickening (>2 mm) and observe at least 10 US-guided breast interventions. Technologists who perform any breast US imaging must meet ARRT certification requirements for diagnostic breast US within 1 year of training. We perform interpretation in batch mode and provide feedback to our technologists on a regular basis, including biopsy results. Malignancies seen at US imaging are routinely reviewed with available technologists.

At the other author's (E.B.M.) site, over 80 000 multimodality breast imaging procedures are performed annually,

including over 13 000 US examinations. All 10 US technologists (sonographers) perform both screening and diagnostic US examinations and are subspecialty certified for breast US by either the ARRT or ARDMS. For the first 3 months, new sonographers are mentored and supervised by senior sonographers. If the technologists do not pass the breast US certifying examination within 1 year after joining the staff, they must resign. At both authors' sites, technologists are supervised by physicians and receive feedback regarding technique, image quality, documentation, and results of biopsies performed on abnormalities found on screening examinations.

Technique and Documentation

The technologist should verify clinical history, including prior surgical scars or masses known to be benign by prior biopsy, and these should be noted on a history or results form. Parenchymal scars can usually be easily recognized on US scans and extend to the overlying skin incision; scars should be documented if visible sonographically, to allow comparison to subsequent examinations, and annotated (below the image) as "scar." Echogenic clips are often seen within biopsied masses. It should be verified that the patient also had a current screening mammogram (or one 6 months before if an alternating 6-month mammogram–US imaging strategy is used), and that her breast parenchyma is dense on her most recent mammogram (at least by report) because there is no role for US screening in patients with fatty breasts. While variability exists among and within radiologists to distinguish heterogeneously dense breasts from scattered fibroglandular tissue (54), the distinction is not critical for patients with moderate scattered fibroglandular tissue who may also benefit from supplemental screening US imaging. In the ACRIN 6666 trial, the supplemental yield of screening US was not different in breasts visually estimated as 26%–40% dense versus those estimated as more than 80% dense (55). Indeed, in the BI-RADS fifth edition (56), breasts that are heterogeneously dense in only one quadrant are recommended to be considered heterogeneously dense, as in the ACRIN 6666 protocol. It may be that targeted US imaging of dense portions of the breasts would be as effective as whole-breast US imaging in such patients, but such an approach requires validation.

The recommended technique for handheld breast US is the same for physicians and technologists. High-frequency linear transducers are used for breast US imaging, with a maximum frequency of at least 12 MHz and often up to 18 MHz (57). The patient is positioned with the ipsilateral arm raised, supine for the inner breast and supine oblique, with a wedge or other support behind her for the outer breast so that the tissue of interest is parallel to the chest wall while the patient is scanned. The field of view should be set so that the pectoralis muscle is at the deepest aspect of the image, not including the lung. In the ACRIN 6666 trial, 94% of breasts were less than 4-cm thick (1). Rarely, the field of view may need to be transiently increased to demonstrate posterior features of a deep lesion. Gain should be set so that fat is medium gray throughout the image, with the time-gain compensation curve gradually increasing with increasing depth. A wide focal zone or range of zones can be used on most current equipment without slowing the frame rate below the minimum necessary for the visual perception of continuous display, but real-time adjustment of the focal zone is still necessary for optimal assessment of deep or superficial lesions; the focal zone should be centered at or just deep to the lesion. Even the best transducers are not focused well until a depth of at least 7 mm is reached, and a standoff pad or glob of gel is used with superficial lesions so that the lesion is placed within the optimal focal range of the transducer. Spatial compounding is standard on current equipment and improves margin definition, though posterior features are less conspicuous.

All series to date have used quadrant-by-quadrant scanning and documentation, including scanning behind the nipple. Transverse and sagittal survey scanning is preferred, and it was used in ACRIN 6666 (58). Radial (ie, clock hands) and antiradial (orthogonal to radial) survey scanning can be performed, though radial scanning causes extensive rescanning of tissue closer to the nipple and may diminish scanning of more peripheral tissue. In a normal examination, a minimum of one image of each quadrant and that is one behind the nipple should be obtained (1) (Table 1). Images are labeled with the clock-face location, transducer orientation, and distance from the nipple in centimeters. Distance can be estimated by using the length of the transducer's footprint (usually 3.8, 5, or 5.5 cm) as calibration. Typically, a 30-minute appointment is allotted for the examination, but 45 minutes may be needed during technologist training.

Findings other than simple cysts should be documented with a minimum of two orthogonal views that include the longest diameter of the lesion (eg, radial and antiradial or transverse and sagittal), with and without calipers. This is the same standard used for US documentation of findings in any other body part evaluated sonographically, the ACR Breast Ultrasound Practice Guideline (33), and the ACR Breast Ultrasound Accreditation Program (59). When multiple simple cysts are present, representative images can be obtained of the largest cysts (eg, the largest in each quadrant). Complicated cysts (ie, oval or round circumscribed mass with an imperceptible wall and homogeneous low-level echoes) merit documentation as in Table 1, but can often be dismissed as benign findings when observed in the company of simple cysts or when internal echoes are mobile or a fluid-debris level is seen without evidence of an intracystic mass (60). Optionally, a power or color Doppler image (with presets set to low flow) can be included as standard for lesions other than simple cysts (Fig 1) (33). Both simple and complicated cysts lack internal vascularity. It is important to follow such a standard approach to all

Table 1

Summary of Recommended Technique and Documentation for Handheld Screening Breast US Performed by Technologists or Physicians

Parameter	Technique or Documentation
Survey scanning	Transverse and sagittal, ipsilateral arm raised, supine oblique position for outer breast, supine for inner breast, using linear array transducer with maximum frequency of at least 12 MHz, up to 18 MHz. Field of view set so that pectoral muscle is at deep aspect of image (not including lung). Gain set so that fat (eg, subcutaneous fat*) is medium gray throughout image. Focal zones may need adjustment while scanning to be centered at any findings
Image labeling	Annotation should be below the image, not placed on the image itself. Labeling should include: laterality (right or left), clock-face location, distance from nipple (in cm), and transducer orientation
Negative examination	Representative image of each quadrant and one behind the nipple
Simple cysts	Single image of largest cyst each quadrant, in longest diameter (often radial), without calipers
Complicated cysts with debris or clustered microcysts	When multiple, bilateral, in company of simple cysts, single images of largest complicated cyst or clustered microcysts each quadrant without calipers; when solitary or diagnostic uncertainty, document as for solid masses
Solid or complex cystic and solid mass	Image along longest axis of mass (usually radial), with and without calipers; orthogonal image (usually antiradial) with and without calipers; optional image by using color or power Doppler
Scar	If visible sonographically, include an image showing extension to overlying skin scar and include "scar" in label beneath the image; orthogonal image recommended

* Fat and, in particular, subcutaneous fat serves as the referent for "isoechoic" (59); hypoechoic masses are less echogenic (darker gray) than fat and hyperechoic masses are more echogenic (whiter) than fat.

findings so that the technologist is not placed in the position of distinguishing benign from suspicious findings while performing a scan. This also parallels mammographic imaging, where two views are routinely obtained for screening. Final responsibility for interpretation lies with the physician.

When obtained by experienced technologists, these images are usually sufficient to allow batch interpretation of screening US and render a final assessment of 1, negative; 2, benign; 3, probably benign; 4, suspicious; or 5, highly suggestive of malignancy. Real-time assessment, which may be conveyed to the interpreting physician as a cine loop, is most critical when there is a question of whether a finding is normal or not, such as the following: distinguishing an isoechoic mass from a fat lobule or distinguishing refractive shadowing at the edges of fat lobules (Fig 2) from a hypoechoic mass. These types of artifacts can be reduced by increasing the pressure while performing a scan or changing the angle of insonation or patient position slightly without veering from the area of interest. Facilities must determine standard approaches to notifying patients and scheduling biopsies if BI-RADS category 4 or 5 assessments are made directly from screening examinations interpreted in batch mode. BI-RADS 0 (incomplete, needs additional imaging) should be used rarely, only when the patient needs to return on a separate date for further imaging evaluation prior to rendering a final assessment, possibly to include further mammographic or other imaging evaluation. To date, a BI-RADS category 0 assessment was used in only 50 of 16676 (0.3%) of women in technologist-performed screening US studies (45–48).

Screening US is meant to supplement, not replace, screening mammography. A screening US examination should be interpreted together with the most recent screening mammogram (Figs 2, 3), ideally with one integrated impression and overall BI-RADS assessment for the patient (61). When performed the same day, and if both studies are interpreted by the same breast radiologist, one integrated report can be issued for both the mammogram and US. For billing and audit purposes, it is important to create separate paragraphs in the report that detail the results of each modality, and to audit outcomes by modality (ie, to distinguish recalls prompted only by mammography, those prompted only by US, those prompted by both, and those avoided after integration of mammographic and US findings). If it is not practicable for a facility's workflow or physician scheduling to have the same breast imager interpret both the mammograms and screening US for a given patient, the US report should refer to mammographic findings, if any. Determining correspondence of mammographic and sonographic findings requires careful attention to lesion size, appearance, depth, and surrounding tissue (ie, fatty or echogenic [dense] parenchyma) and may occasionally require diagnostic workup with placement of a metallic marker over the sonographic abnormality with repeat mammographic views in the area of concern (62). Isoechoic cancers can be difficult to distinguish from fat lobules, particularly in the absence of echogenic rim or effects on surrounding tissue, and may be overrepresented among false negative cancers on US.

Figure 1

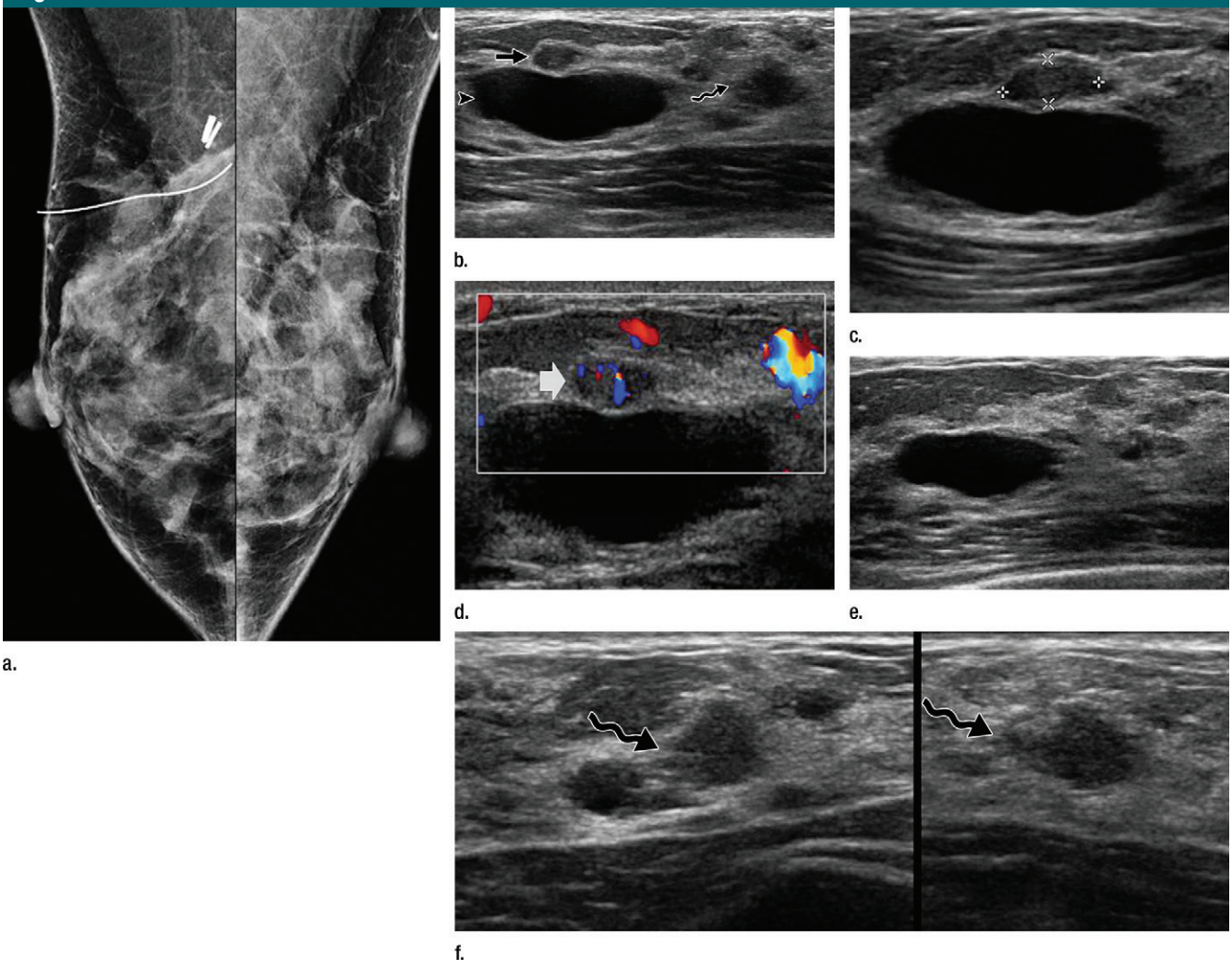

Figure 1: Images in a 48-year-old woman who 13 months earlier had atypical ductal hyperplasia at excisional biopsy of right-breast calcifications. **(a)** Bilateral digital mediolateral oblique mammograms show heterogeneously dense fibroglandular tissue that could obscure detection of small masses. Scar is marked by a wire in the upper area of the right breast. No suspicious findings are seen. **(b)** Transverse US image in the 12-o'clock position in the right breast from technologist-performed examination (L 17–5 MHz) shows simple cyst (arrowhead) with possible isoechoic oval mass (straight arrow) just anterior to it and possible irregular isoechoic mass just medially at 2:00 as well (curved arrow). **(c)** The technologist obtained an orthogonal (sagittal) image of the 12:00 area. Calipers obscure margin evaluation of the possible oval mass: images should be obtained without and with calipers. **(d)** Transverse color Doppler image at 12:00 shows internal vascularity within the oval isoechoic mass (arrow). Biopsy was recommended because this was new compared with **(e)** prior year transverse US same area, which shows only the cyst. **(f)** Radial and antiradial US images of the 2:00 right breast confirm an irregular isoechoic 0.5 cm mass with indistinct margins (arrows), suspicious, BI-RADS category 4b. Histopathologic analysis of the 12:00 mass showed low nuclear grade ductal carcinoma in situ and, of the 2:00 mass, grade 2 invasive ductal carcinoma with ductal carcinoma in situ, estrogen receptor and progesterone receptor positive, human epidermal growth factor receptor 2 negative, Ki-67 proliferation index 7%. Sentinel node biopsy was negative at mastectomy, and the invasive tumor measured 0.6 cm. Multifocal ductal carcinoma in situ was confirmed. Cancers seen only at screening US often lack posterior features or effects on the surrounding tissue, as in this case.

Over the 3 years of US screening, cysts were seen in 1255 (47.1%) of all 2662 participants in the ACRIN 6666 trial, and 516 of 793 (65.1%) of premenopausal women and 537 of 1363 (39.4%) postmenopausal women had cysts on at least one screening US examination. Complicated cysts were seen in 376 (14.1%) of women (60). Among 2172 women with two breasts, 1372 (63.2%) women in the ACRIN 6666 trial had at least one finding reported other than a simple cyst (63), which indicates the importance of avoiding excessive follow-up or biopsy of common benign findings. Nearly 20% (745 of 2662) of ACRIN 6666 participants had a finding that was proba-

Figure 2

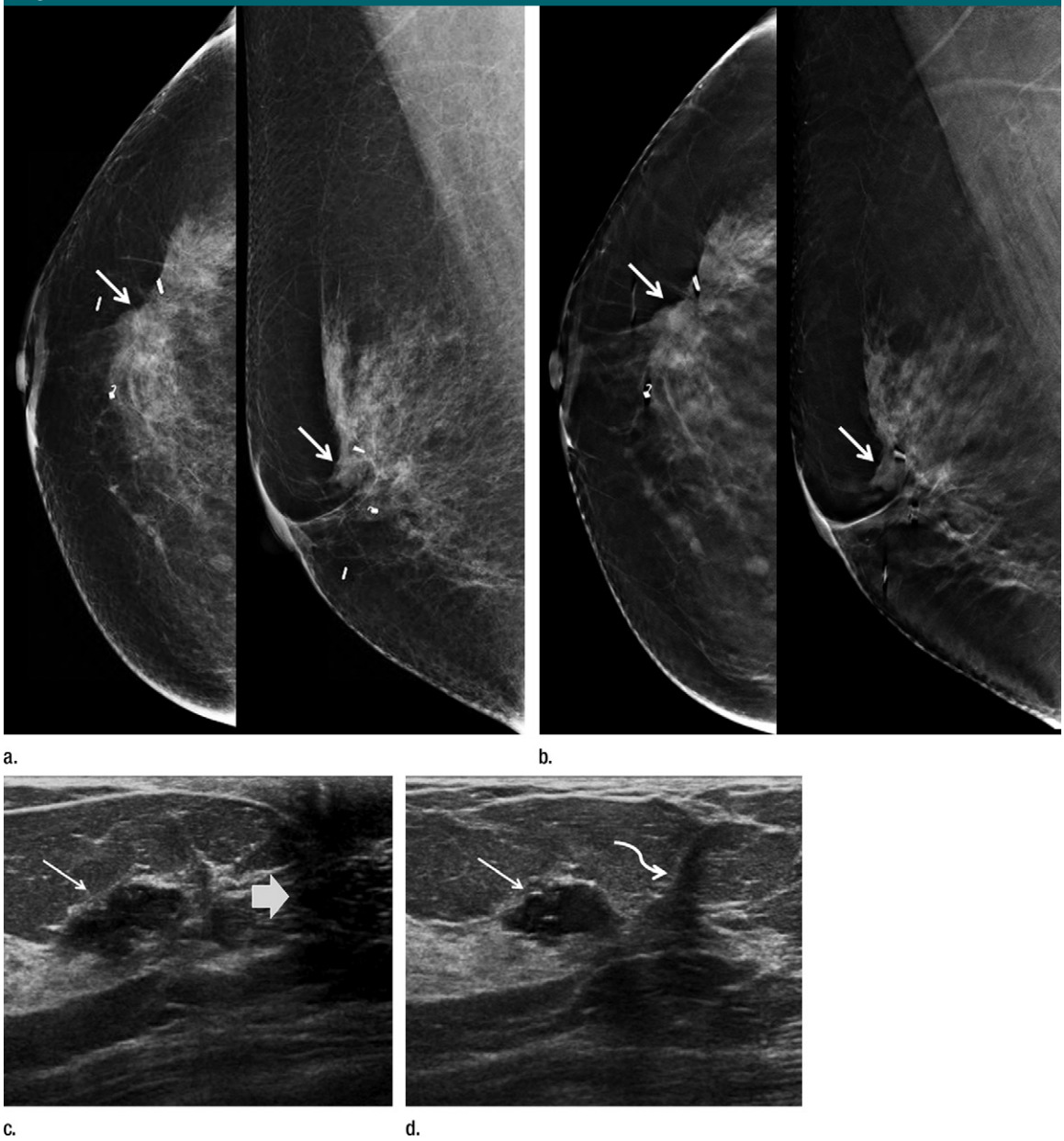

Figure 2: Images in a 56-year-old woman who 7 years ago had excision of atypical ductal hyperplasia on the right side. **(a)** Digital right craniocaudal and mediolateral oblique mammograms show moderate scattered fibroglandular tissue with vague nodularity in subareolar outer right breast (arrows). Clips denote prior benign biopsy sites. **(b)** One-millimeter digital craniocaudal and mediolateral oblique tomosynthesis images obtained in combination with the standard mammogram more clearly show a mass (arrows). **(c)** Transverse US image (L17–5 MHz) of 9:00 right breast shows a microlobulated partially circumscribed, partially indistinctly marginated mass (thin arrow) with no posterior features, which corresponds to the mass depicted by using mammography and tomosynthesis, but which is now recognized as suspicious, BI-RADS category 4b. Posterior shadowing is seen from the nipple (thick arrow), a normal appearance; scanning behind the nipple can require changing the angle of insonation to reduce shadowing. **(d)** Sagittal US image confirms the suspicious mass (straight arrow). Refractive edge shadowing is seen from fat lobules (curved arrow). US-guided core biopsy and excision of the mass showed a 0.5-cm nuclear grade-2 ductal carcinoma in situ, estrogen receptor and progesterone receptor negative.

Figure 3

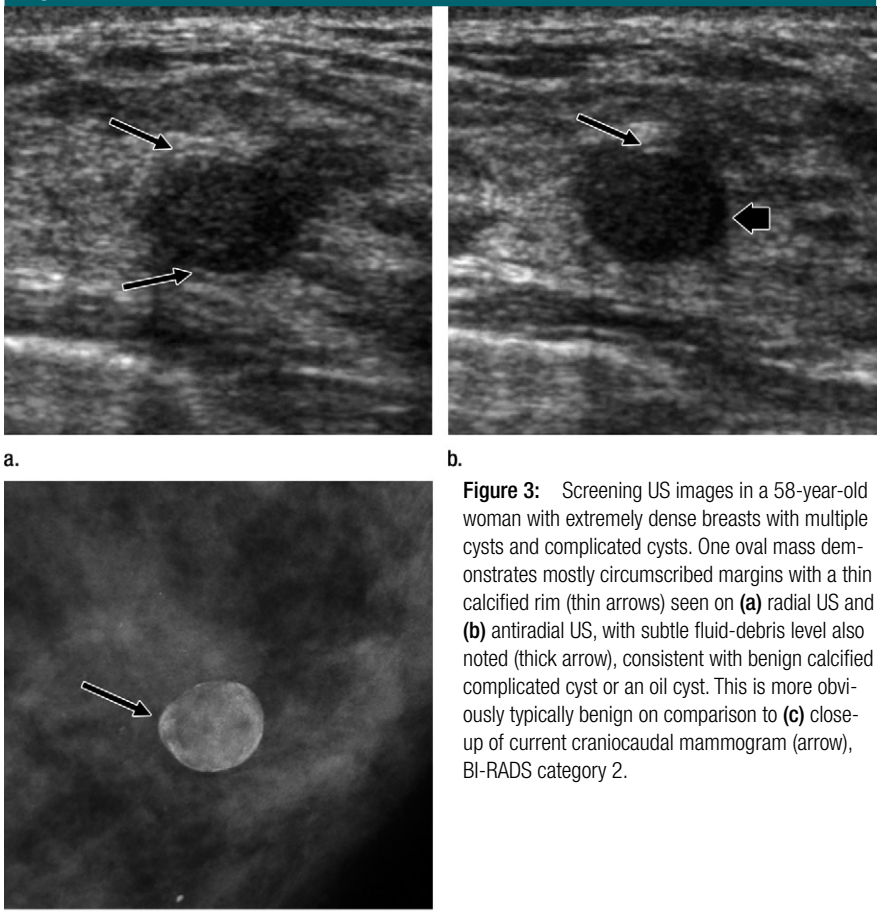

Figure 3: Screening US images in a 58-year-old woman with extremely dense breasts with multiple cysts and complicated cysts. One oval mass demonstrates mostly circumscribed margins with a thin calcified rim (thin arrows) seen on **(a)** radial US and **(b)** antiradial US, with subtle fluid-debris level also noted (thick arrow), consistent with benign calcified complicated cyst or an oil cyst. This is more obviously typically benign on comparison to **(c)** close-up of current craniocaudal mammogram (arrow), BI-RADS category 2.

bly benign, detailed in Barr et al (64), and including isolated circumscribed benign-appearing masses and probable fat necrosis (Fig 4), with 0.8% (six of 745) of such BI-RADS category 3 lesions malignant in ACRIN 6666 (64). Across four other series, a 0.7 malignancy rate (10 of 1337) has been observed for nonpalpable BI-RADS category 3 lesions seen on US scans (in conjunction with mammography) (65–68). In the ACRIN 6666 protocol, only one malignancy was identified among BI-RADS 3 lesions because of suspicious changes at 6-month follow-up, and all of the cancers identified because of change at 12 months or less were node negative (64). Because BI-RADS category 3 findings are common on screening US (up to 20% of women) and the malignancy rate is less than 1%, 12-month follow-up may be reasonable, and such findings certainly should not undergo initial biopsy. Complex cystic and solid masses include intracystic masses, cystic masses with thick (≥0.5 mm) wall and/or thick (≥0.5 mm) septations, and predominantly solid masses with cystic components, are suspicious and merit biopsy (60,69). Importantly, cancers detected with supplemental US have been reported more likely than cancers first seen by using mammography to be oval or round, circumscribed, lack an echogenic rim and other effects on surrounding tissue, and to show no posterior features or enhancement (68,70). This emphasizes the importance of careful technique and documentation to avoid misclassification.

Auditing Technologist-performed Screening US

An approach to documenting and auditing screening breast US has been proposed by Sickles and D'Orsi (71) in the 2013 edition of BI-RADS. The new version of BI-RADS proposes that a technologist obtain no more than a single image of any finding and that findings of concern be rescanned in real time by the physician. The act of documenting an orthogonal image, or Doppler, or any other additional US image (such as elastography) is proposed to constitute a positive test, while rescanning without any documentation does not.

We have a different approach. For audit purposes, we recommend that a so-called negative screening US examination is one for which the assessment is negative (BI-RADS category 1) or benign (BI-RADS category 2) after integration with mammography. This includes simple cysts for which aspiration is recommended for symptomatic relief, but not complicated cysts recommended for aspiration due to diagnostic uncertainty. As in all published studies of technologist-performed US to date, and as in the ACRIN 6666 protocol, we also include as negative for audit purposes examinations with findings assessed as negative or benign, which have been fully documented with orthogonal views and possibly a Doppler image. The question of whether real-time physician re-evaluation should be considered a recall (BI-RADS category 0, incomplete, needs additional imaging) for screening audit purposes is debatable; since physician rescanning is encouraged while technologists are being trained, it is typically not considered a recall if it is performed as part of the initial imaging visit when the final assessment is BI-RADS category 1 or 2. From the patient perspective, real-time physician scanning would certainly be a recall if performed on a different day, even if the final assessment is BI-RADS category 1 or 2. A true-negative US examination, as for mammography, is one where no cancer is diagnosed within the screening interval, typically 365

Figure 4

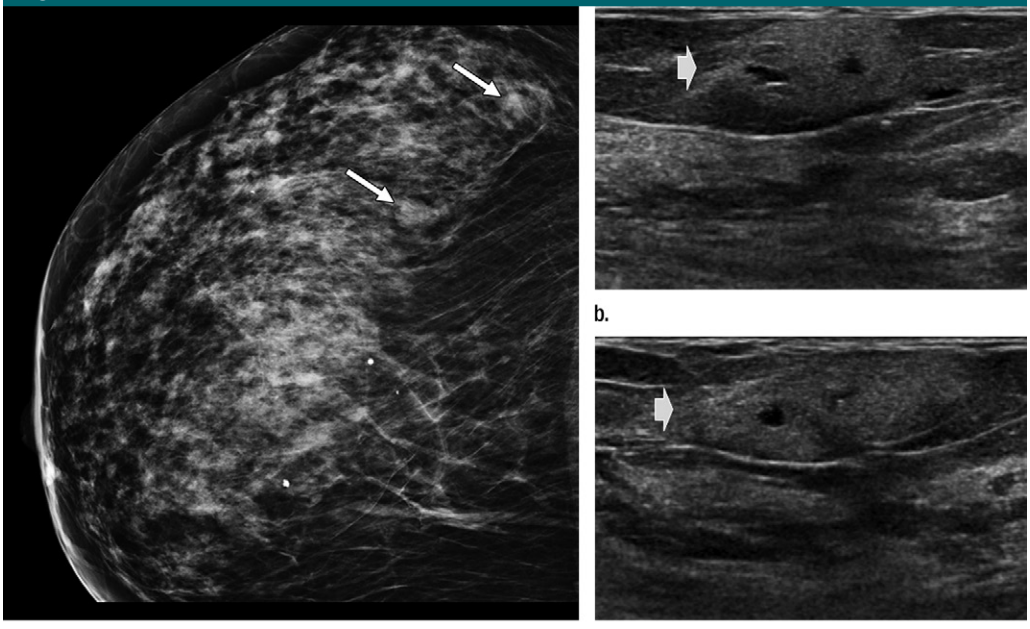

Figure 4: Images in a 70-year-old woman undergoing US for follow-up of two nodules in the posterior upper outer right breast seen on **(a)** craniocaudal mammogram (arrows) that proved to be cysts (not shown). In view of her heterogeneously dense parenchyma, whole-breast screening US was also performed, which revealed an incidental ovoid predominantly hyperechoic mass with cystic spaces within it, seen on **(b)** radial and **(c)** antiradial US images. The mass (arrow in **b** and **c**) is located within the subcutaneous fat, close to the nipple in the 9:00 axis. Close inspection of the skin revealed a subtle bruise and the patient was undergoing treatment with enoxaparin sodium (Lovenox; Sanofi, Bridgewater, NJ) and warfarin. US findings are typical of fat necrosis. With the proper history, as in this case, the finding can be dismissed as benign, BI-RADS category 2. Absent such history, 3-month follow-up US can be performed and should show decrease or resolution of the echogenic edema and associated fluid collections.

days in the United States. As for mammography in the BI-RADS fifth edition (56), a recommendation for anything other than routine screening should be considered a positive test for audit of screening US outcomes (ie, recalls include BI-RADS category 0, 3, 4, and 5 assessments, and all of these are considered positive screening tests). A true-positive US examination is one where cancer is diagnosed within the screening interval (in the United States, within 365 days) after positive imaging (Fig 5).

Technologist-performed Screening US Outcomes: Cancer Detection

Table 2 summarizes outcomes to date from technologist-performed US imaging in the United States (45–48), including only results after a negative screening mammogram with dense breasts. Women with a personal history of breast cancer who present for their routine annual mammogram can be included in audits of screening outcomes and were included in one of these series (47). Bilateral whole-breast US imaging can be performed in patients who present for diagnostic mammography, but such results should be considered separately (27,72). Across the four series to date (45–48), 42 cancers were detected across 16676 reported prevalent technologist-performed screening US examinations for an average incremental cancer detection rate (ICDR) of 2.5 cancers per 1000 examinations. This is lower than the average ICDR of 4.3 cancers per 1000 (51 cancers per 11803 examinations) achieved in the prevalent round in multicenter trials of physician-performed screening US (2,4) ($P <$ .007). This difference at least in part is caused by differences in disease prevalence, and while only 20% of participants in the ACRIN 6666 protocol met ACR high-risk criteria (11), all had at least one risk factor in addition to breast density (1,2). In the series by Kolb et al (25), 14 cancers were seen only at physician-performed US imaging in 2914 women who were at elevated risk because of personal history, first-degree relative with breast cancer, or previous biopsy showing high-risk histopathologic result. The ICDR of these women was 4.8 cancers per 1000 examinations versus 14 cancers per 7901 examinations (ICDR of 1.8 cancers per 1000 examinations) in women without additional risk factors ($P = .011$). Similarly, Crystal et al (23) reported four cancers per 318 examinations (ICDR 12.5 cancers per 1000 examinations)

Figure 5

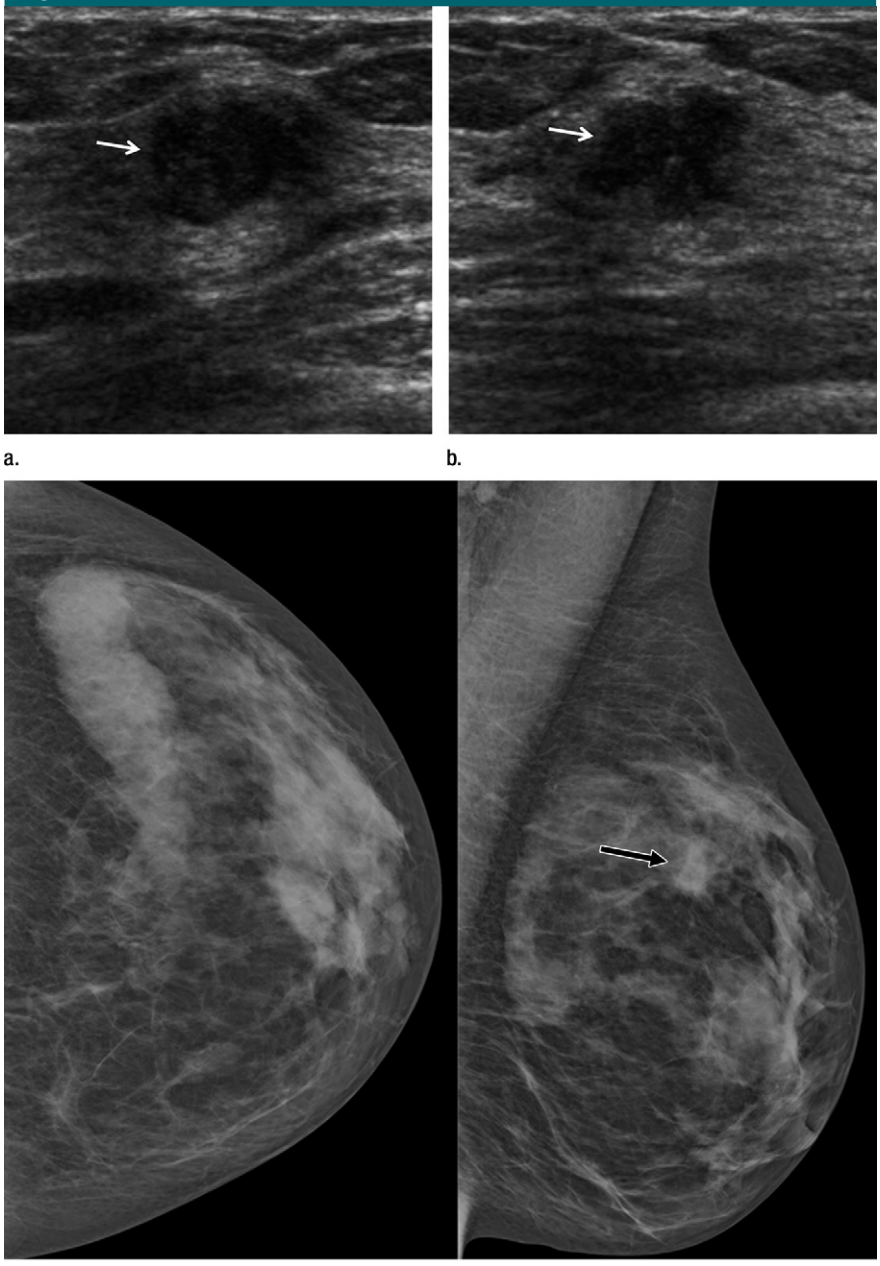

Figure 5: Images in a 55-year-old woman with a greater than 2.5% 5-year risk of breast cancer was found to have an oval, hypoechoic mass with posterior enhancement on screening US. On **(a)** radial image, the mass (arrow) appears at least partially circumscribed and might have been erroneously dismissed as a complicated cyst. **(b)** Antiradial image shows microlobulated and indistinct margins (arrow), BI-RADS category 4c. **(c)** Craniocaudal and mediolateral oblique mammograms show moderate scattered fibroglandular tissue. In retrospect, the mass is evident only on the mediolateral oblique view (arrow). US-guided core biopsy and excision showed 1.5-cm grade-3 invasive ductal carcinoma with ductal carcinoma in situ, node negative.

for physician-performed US in women with a first-degree relative with breast cancer and three cancers per 1199 examinations (ICDR 2.5 cancers per 1000 examinations) in those without ($P <$ .04). In Japan, where there is lower prevalence of disease than in the United States, Tohno et al (73) reported 57 cancers were detected by technologist-performed handheld US imaging among 28629 women aged 40 or older (ICDR 2.0 per 1000).

The types of cancers found by technologist-performed screening US parallel those in physician-performed series, with 36 of 42 cancers (86%) invasive and 29 of 33 cancers (88%) with available staging node negative (45–48). Mean invasive tumor size on US images ranged from 0.7 to 1.0 cm, with mean size at histopathologic analysis ranging to 1.9 cm (48). In multicenter physician-performed screening US studies (2,4), 66 of 69 cancers (96%) seen only sonographically were invasive and 57 of 65 cancers (88%) were node negative, with mean invasive tumor size of 10 mm at histopathologic analysis. ICDR for screening US has been the same (55) or higher (4) in women aged 40–49 years as in older women in physician-performed studies. Distinctions by age have not been addressed with technologist-performed studies to date. Results from incidence-screening US by technologists have not yet been published, but the ICDR for screening US in the second and third screening rounds in ACRIN 6666 was not different from the first screen (2).

Technologist-performed Screening US: Other Performance Benchmarks

The vast majority of recalls from screening US are recommendations for short-interval follow-up (BI-RADS category 3, which represents 8.5% of women across the series [45–48], Table 2) or biopsy (BI-RADS category 4 or 5, which represents 4.5% of women across the series) rather than additional imaging (BI-RADS category 0), if the examination is interpreted together with the most recent mammogram. The collective incremental increase in recall

Table 2

Summary of Results from the Prevalence Round of Technologist-performed Screening US

Author, Year	No. of Examinations	Women with Cancer Detected	Incremental Cancer Detection Rate per 1000*	Recall Rate†	Women Assessed as BI-RADS Category 3 on Screening US	Women Recommended for Biopsy; BI-RADS Category 4 or 5‡	Lesion-Level PPV of Biopsies Performed
Kaplan, 2001 (46)	1862	5	2.7	176 (9.5)†	72 (3.9)	97 (5.2)	6/96 (6.3)§
Hooley et al, 2012 (45)	648‖	3	4.6	154 (23.8)†	108 (16.7)	46 (7.1)	3/58 (5.2)§
Weigert and Steenbergen, 2012 (48)	8647	24#	2.8	1196 (13.8)†	767 (8.9)	429 (5.0)	25/418 (6.7)#
Parris et al, 2012 (47)	5519	10	1.8	680 (12.3)**	452 (8.2)	185 (3.3)	10/181 (5.5)§
Overall	16676	42	2.5	2206 (13.2)	1399 (8.4)	757 (4.5)	44/753 (5.8)

Note.—Data in parentheses are percentages.

* Not seen on mammography; incremental cancer detection rate.

† Recalls include women recommended for additional imaging, short-interval follow-up, or biopsy, not including those recalled on the basis of mammographic findings; total given BI-RADS category 0 was 50 women across series (0.3%). Recalls constitute positive US tests for purposes of auditing.

‡ Biopsies prompted by screening US, after correlation with mammography; includes cyst aspirations for diagnostic uncertainty.

§ Includes cyst aspirations (Kaplan, $n = 41$; Hooley et al, 13 procedures were in women assessed as BI-RADS category 3 and overall there were seven aspirations, all benign; Parris et al, $n = 4$).

‖ Results are summarized for the 648 women who had negative screening mammography.

In the series by Weigert and Steenbergen, 28 cancers are reported, but two were in the same patient; one case of lobular carcinoma in situ and two of atypical ductal hyperplasia are excluded from this analysis,
for a total of 24 women diagnosed with cancer.

** BI-RADS category 0 ($n = 43$); BI-RADS category 3 ($n = 452$); BI-RADS category 4 ($n = 170$); BI-RADS category 5 ($n = 15$).

rate because of technologist-performed US of 2206 recalls per 16676 examinations (13.2%) (Table 2) was lower than the rate in the 1st year of ACRIN 6666 (2) of 401 recalls per 2659 examinations (15.0%) ($P = .010$), and it is expected to decrease substantially with incidence screening (similar to ACRIN 6666, where incremental recall rate increase because of US was 7.4% in years 2 and 3).

When the screening mammogram is viewed together with the screening US examination, there will be some findings that can be dismissed as benign. Examples include a mass seen on mammography that corresponds to a cyst on the screening US, or a solid mass seen on US which is found to correspond to a stable benign-appearing mass on mammography. In the 1st year of the ACRIN 6666 trial, with physician-performed US, of 2659 women, 306 women were recommended for recall based on (usually incidence) screening mammography, and 555 women were recommended for recall on the basis of (mostly prevalence) screening US alone, yet only 707 of these 861 women (82.1%) required recall after integrated interpretation of the two modalities together (2). In multicenter experience from Japan, when screening US was added to mammography, overall recall rate decreased from 4.9% to 2.6% (31). Multiple bilateral circumscribed oval solid masses can be reevaluated by using sonography in 1 year (63).

Across series, the positive predictive value (PPV) 1 (PPV1; ie, the number of women with cancer divided by number recommended for further testing) of technologist-performed handheld US was 42 per 2206 women (1.9%), compared with 14 women per 401 examinations (3.5%) for recalls because of physician-performed screening US in the 1st year of ACRIN 6666 (2) ($P < .059$) and a median of 4.5% for screening mammography in the Breast Cancer Surveillance Consortium (74). The PPV2 (ie, number of women with cancer divided by number recommended for biopsy) was 42 per 757 women (5.5%), far lower than the median of 25% for screening mammography (74). Of 753 lesions actually biopsied (Table 2), including diagnostic cyst aspirations, only 44 (5.8%) showed malignancy (ductal carcinoma in situ or invasive cancer). Note that lobular carcinoma in situ and other high-risk lesions, such as atypical ductal hyperplasia, should not be included among malignancies. The PPV of biopsies performed after technologist-performed US, at 44 cancers per 753 biopsies (5.8%), is similar to the rate for lesions suspicious only on US in the first round of ACRIN 6666 (114 cancers per 264 biopsies [5.3%]; $P = .878$). Across the series of technologist-performed US, there were no malignancies among diagnostic cyst aspirations, which suggests that such lesions should be downgraded from BI-RADS category 4 (suspicious) to BI-RADS category 3 (probably benign), or even BI-RADS category 2 (benign with diagnostic follow-up in 1 year), which is consistent with the malignancy rate observed

across ACRIN 6666 (60) and six other series (four malignancies per 1244 complicated cysts aspirated or biopsied [0.3%]) (29,75–79).

PPVs will be lower for screening US than for mammography, in part because cancers detected at both mammography and US imaging are attributed only to mammography when considering US as a supplemental test, and in part because results are nearly always incidence screening for mammography (with fewer false-positive findings). Even if US were to get full credit for all cancers seen at US, there are far more false-positive findings than for mammography. Incidence results for technologist-performed screening US should show improved PPVs compared with the prevalence screening, as seen in years 2 and 3 of the ACRIN 6666 protocol (2).

The interval cancer rate is a measure of the success of a screening program. In extremely dense breasts, nearly 70% of cancers were interval cancers, compared with 20% in fatty breasts in one series (6). Importantly, screening US has been shown to decrease interval cancer rates in women with dense breasts to levels similar to those in women with fatty breasts (1.1 cancers per 1000 woman-screenings for women with dense breasts screened with both mammography and US vs 1.0 cancers per 1000 woman-screenings for women with fatty breasts screened with mammography alone) (80). In the ACRIN 6666 trial, the interval cancer rate was nine cancers per 7473 participant screens (1.2 cancers per 1000 woman-screens), with 8% of all cancers manifesting as clinical abnormalities across the three rounds of annual screening (including a 4th-year of follow-up) (2). Interval cancer rates are not yet available for technologist-performed US, but will be an important parameter to follow.

Automated US

Several approaches to automated whole-breast US exist that remove the need for the technologist to recognize abnormalities while obtaining images. Kelly et al (81) reported very favorable results in a prospective multicenter experience of semiautomated US where a standard linear array high resolution transducer that is used for breast imaging is mounted on a motorized arm that traverses the breast tissue superiorly to inferiorly acquiring uniplanar overlapping images, the technologist assuring good contact. Across 6425 examinations performed in this way, 23 cancers (3.6 cancers per 1000 examinations) were seen only with US. Incremental increase in recall rate because of US was 557 of 6425 (8.7%). Importantly, only 75 women (1.2%) underwent biopsy only because of US, and 23 (31%) of those biopsies were malignant (81).

A prospective international trial of automated whole-breast US screening by using large-footprint (15-cm) linear transducers in women with dense breasts was conducted. The acquired transverse images are reconstructed in coronal and sagittal planes, the coronal image depicting from anterior to posterior the entire breast from the skin to the chest wall, and the images are reviewed on workstations. ICDR has been reported to be 30 cancers per 16000 examinations, in other words, 1.9 cancers per 1000 examinations (82), which is not significantly lower than the average rate of 2.5 cancers per 1000 examinations (42 cancers per 16676 examinations) for technologist-performed handheld screening US ($P = .24$). Recall rates and other performance characteristics with automated whole breast US were also comparable to those with handheld US (83). For lesions that are initially identified with handheld US, lesion detection rates of 78% (243 of 310) for lesions 4–9 mm, 88% (66 of 75) for lesions 9–12 mm, and 92% (171 of 185) for lesions larger than 1.2 cm have been reported for automated US, with high reliability for lesion location and substantial agreement with handheld US for feature analysis (84). In one small series of 14 cancers initially seen at handheld US, only 57%–79% were seen on automated breast US (85), which suggests that sensitivity may be lower than with handheld US, though further studies that compare performance are needed.

Summary

In summary, standard technique for technologist-performed handheld screening breast US has been validated across four series in the United States, encompassing the prevalent screening for nearly 17000 women. ICDR, which averages 2.5 cancers per 1000 examinations, appears to be slightly lower than that seen with physician-performed screening US, which in part reflects differences in disease prevalence. An average of 4.5% of women was recommended for biopsy (including a few with a BI-RADS category 3 assessment), similar to the 5.6% (656 of 11816) rate in prospective multicenter trials of physician-performed screening US (2,4), and the PPV of biopsies performed remains low (5.8%) as has been seen with physician-performed screening US. The recall rate, averaging 13.2%, should decrease with incidence screening, but those results have not yet been reported. If a facility chooses to offer handheld screening breast US performed by technologists, it is incumbent on the facility to establish standard experience and documentation requirements and to audit its outcomes. To date, technologist documentation has routinely included orthogonal views of lesions, with and without calipers, and an optional Doppler image. A negative examination is documented by a minimum of one image per quadrant and one behind the nipple. Real-time physician rescanning of vague abnormalities will be necessary to reduce unnecessary biopsy or follow-up of normal variants and to help identify subtle malignancies. No matter which approach to screening US is utilized (physician or technologist-performed handheld US or automated US), one of the most important benchmarks of a successful program at the facility level is the demonstration of a low interval cancer rate of approximately one cancer per 1000 examinations, which represents about 10% of all breast cancers.

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