

The value of ultrasound scanning in breast disease

WE Svensson

Ultrasound is the modality of choice for imaging breast masses. Most benign and malignant lesions can be accurately categorized as a result of improvements in grey scale imaging and the development of sensitive colour Doppler vascular mapping. Ultrasound contrast agents, harmonic imaging, elasticity imaging and other advances will further enhance the utility of breast ultrasound.

Ultrasound is a well-established imaging modality for the evaluation of breast problems. It is simple, safe, easily repeatable and cheap (Stavros et al, 1995). It has better sensitivity and specificity for solving symptomatic breast problems, particularly breast masses, than any other imaging modality (Duijm et al, 1997). It is less useful for screening or assessment of the remaining normal breast and contralateral breast. Mammography is a more sensitive modality for screening clinically normal breast tissue. Magnetic resonance imaging and nuclear medicine breast imaging are most suited for assessment of recurrence of breast cancer or extent and staging of breast cancers and for evaluation of specific problems such as those associated with breast prostheses (Svensson, 1997).

HISTORY

The earliest reports of breast ultrasound date from the early 1950s when Wild and Reid (1952) reported the use of an A mode system with a 15 MHz probe. Over the next 20 years first static and then real-time ultrasound systems were developed for breast, small parts and superficial imaging. Early real-time grey scale ultrasound systems used lower frequencies in the 5 MHz range with less image detail. Increasing depth of tissue causes degradation of the ultrasound beam, with the loss of information increasing with the higher ultrasound frequencies necessary for high resolution.

The improvement in image detail over the last 15 years is demonstrated in *Figures 1* and *2*. Both cancers are in images of similar magnification and size (5 cm across by 4 cm deep). *Figure 1* was taken with a 5 MHz linear array probe on an Acuson 128 in 1988 (Acuson Corporation, Mountain View, California), and *Figure 2* was taken with a 13 MHz multi-frequency linear

array on an Acuson Sequoia in 1999 (Acuson Corporation, Mountain View, California). Both images are good examples of the abilities of top-of-the-range breast ultrasound equipment for their time. The improvements include smaller pixel size with improved image contrast, and good resolution from the skin surface to 4 cm depth. In *Figure 2* the skin and subcutaneous layers are clearly differentiated. The distorting and invasive nature of the cancer is more obvious.

Recent developments of improved transducer design, increases in computing power and processing speeds, combined with parallel processing, now provide high quality grey scale images with probe peak frequencies of 15 MHz (Chersevani et al, 1995). Broad band frequency probes, which can produce and receive a wide frequency range, use the greater computing power to produce detailed images using high frequencies for superficial layers and lower frequencies to image deeper tissues.

EQUIPMENT AND PRACTICE

Breast ultrasound, like mammography, is a complex technique which is dependent on the expertise of the sonographer. The better the quality of the equipment the greater the amount of information that can be obtained. Breast ultrasound should be performed with a multi-hertz linear array probe with a top frequency of not less than 12 MHz. The ultrasound equipment, ideally, should be less than 5 years old, because of the rapidity of ultrasound development. Top-of-the-range equipment may remain diagnostic for a longer period.

Careful attention to machine settings is necessary to optimize image quality and diagnostic information. Altered settings may be needed not only with each patient, but within different areas of the same breast. Incorrect settings can result

Dr WE Svensson is Consultant Radiologist in the Department of Radiology, Ealing Hospital, Southall, Middlesex UB1 3HW and Honorary Senior Lecturer in Imperial College Medical School

in misdiagnosis. For example, with gain (amplification) set too high, reverberation echoes in a simple cyst can be misinterpreted as indicating a solid lesion (Figures 3a and b).

Ultrasound of most regions depends on anatomical variation to enable initial recognition of abnormality.

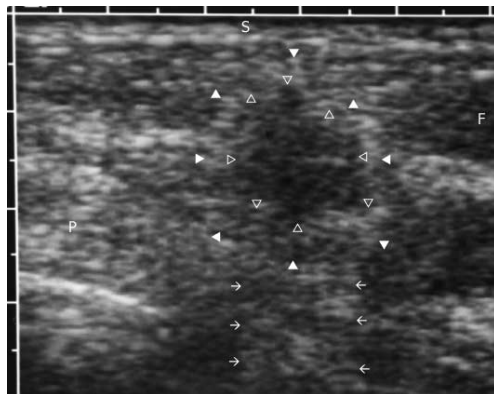


Figure 1. Invasive ductal carcinoma. Tumour nidus of reduced echogenicity (open arrowheads) surrounded by a halo of increased echogenicity (solid arrowheads). Note the irregular outline of both the central tumour nidus and halo. Deep to the tumour there is an area of bright up (arrows). This is a result of the relative decrease in absorption of sound by the tumour compared with the adjacent tissues. F = fat, P = parenchyma, S = skin. The image was obtained from an Acuson 128 ultrasound machine using a 5 MHz probe in 1988 (top of the range technology at that time). Note the lack of skin detail and large pixel (mottle) sizes compared with the cancer demonstrated in Figure 2. Both images have identical scale settings, covering an area of 5 cm (across) by 4 cm (deep).



Figure 2. Invasive ductal carcinoma. Low echo nidus of tumour (open arrowheads) with echogenic surrounding halo (solid arrowheads). This classical breast carcinoma appearance is caused by absorption of the sound within the cancer. This results in posterior shadowing (arrows) with no detail deep to the tumour. This image was obtained on an Acuson Sequoia with a 13 MHz linear array probe with multiband frequency in 1999. Note the fine detail associated with the smaller pixel (mottle) size from the skin layer to over 2 cm depth. The detail is not as fine in the deep layers because of the lower frequency being utilized for image production.

In the breast, the diversity of normal parenchymal appearance, with the paucity of standard anatomy, makes pattern recognition of greater importance. For example fibroadenomas in a ductal mottle pattern (most often seen in a young breast) are easily identifiable (Figure 4), whereas the mainly fatty or mixed fat parenchymal pattern (of the older woman) may be difficult or even impossible to differentiate from the isoechoic surrounding fat (Figure 5). The complexity of breast ultrasound requires that some specialized training is necessary in order to provide an effective breast ultrasound service (Madjar et al, 1999).

INDICATIONS

Breast ultrasound is ideally suited for the imaging of symptomatic breast problems caused by focal abnormalities (Table 1). It is the first-line investigation for the imaging of palpable masses in women under the age of 35 years and during pregnancy. In women over the age of 35 years mammography should precede ultrasound

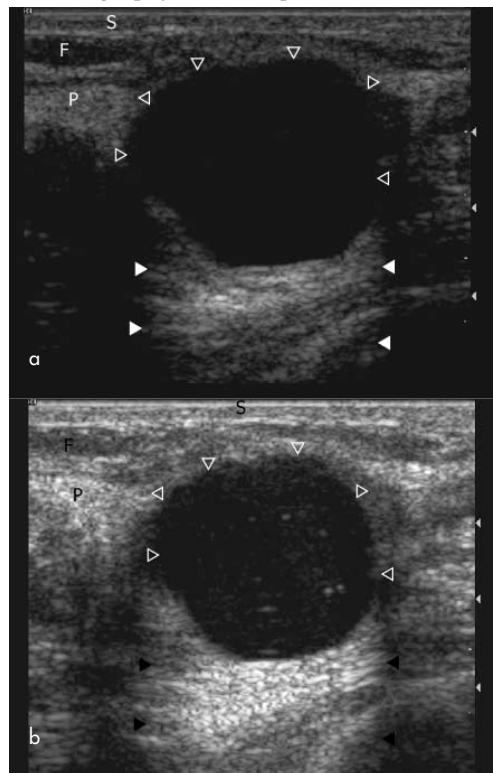


Figure 3. a. Cyst with correct gain. Anechoic area (open arrowheads) is the cyst. No internal reflections with louder echoes from the deep structures ('bright up', closed arrowheads) when compared with adjacent tissues. b. Same cyst with gain (ultrasound amplification) turned too high. Almost all the echoes seen within the cyst (open arrowheads) are reverberation artefact. They did not appear to move and could be misinterpreted as echoes from a solid lesion. Black arrowheads show deep layer bright up. F = fat, P = parenchyma, S = skin.

because it may demonstrate other abnormalities which may also require ultrasound evaluation. Although ultrasound has greater sensitivity and specificity than mammography in evaluating a palpable mass, mammography is needed to evaluate the remainder of the symptomatic breast and the contralateral normal breast. In addition the residuum of ultrasound gel left on the breast

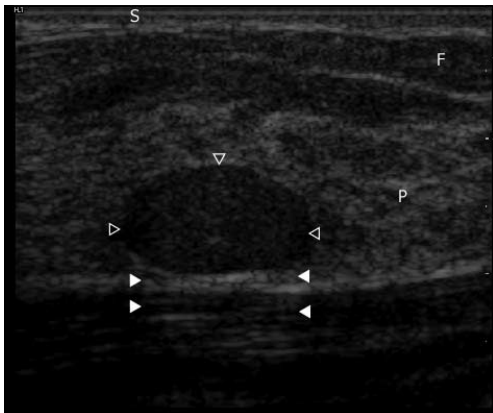


Figure 4. Fibroadenoma (open arrowheads) in a breast consisting mainly of parenchyma which has a ductal mottle pattern (P). There is some fat (F) just beneath the skin (S). The fibroadenoma is of fairly homogeneous reduced echogenicity and exhibits posterior 'bright up' (solid arrowheads) because there is less absorption of the sound within the fibroadenoma compared with the adjacent tissues, resulting in louder (brighter) echoes returning from deep to the fibroadenoma.

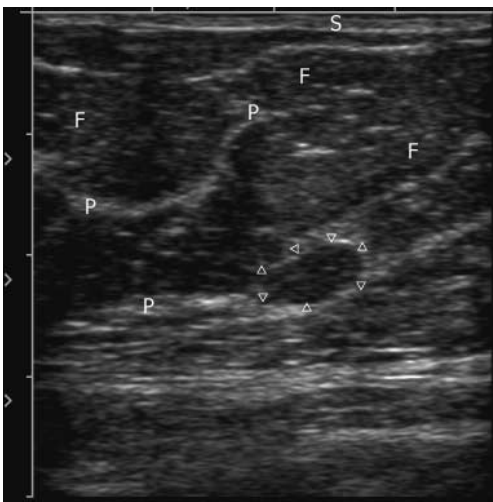


Figure 5. Small isoechoic fibroadenoma. A <1 cm diameter fibroadenoma which was clearly seen on mammography because the patient's breast consisted almost entirely of fat. On ultrasound the fibroadenoma (open arrowheads) was almost the same echogenicity as the fat lobules (F) which are outlined by parenchymal strands (P). S = skin. (This fibroadenoma was removed using wire localization placed under ultrasound control with check mammograms confirming that this area was indeed the mammographic abnormality. Subsequent histology confirmed it to be a fibroadenoma.)

makes mammography technically more difficult if the mammography is performed immediately after an ultrasound examination.

Ultrasound is an important imaging investigation in the 'triplet' evaluation of palpable breast masses (Green et al, 1995) used in specialist breast clinics. Following clinical examination, either ultrasound or mammography should precede fine needle aspiration cytology or percutaneous needle core biopsy. The haemorrhage associated with these two procedures can change the ultrasound appearance of a benign lesion from a classical benign appearance to an equivocal or occasionally to a frankly malignant appearance (Svensson et al, 1992). *Figure 6* shows a basic algorithm for the evaluation of a suspicious breast mass. This approach is ideally suited to a one-stop breast clinic (Gui et al, 1995).

In women under the age of 35 years and during pregnancy, breast ultrasound is the imaging

TABLE 1.
Indications for breast ultrasound

Characterization of	Palpable breast masses
	Impalpable breast masses of uncertain aetiology seen on mammography
Primary evaluation of palpable masses	In women under 35 years of age In the pregnant or lactating breast
Evaluation of	Asymmetry or distortion on mammography Lesions seen in only one mammographic projection
Imaging of	The augmented breast The male breast with a suspicious mass or unilateral gynecomastia The juvenile breast Inflammation The tender breast
	The postoperative breast
	To identify haematoma and seromas To evaluate new lumps in the scar of patients who have had previous surgery for cancer
Breast cancer staging	Measurement of tumour size
	Identification of
	Spread along ducts Satellite or second primary tumours
	Identification of abnormal nodes in the
	Axilla Supraclavicular region Parasternal region
Guidance for interventional techniques	Cyst aspiration Abscess aspiration Fine needle aspiration for cytology Needle core biopsy Localization for surgery either with skin marker or internal localization wire

modality of choice because of the high incidence of benign lesions, low incidence of cancers, and relative insensitivity of mammography. Under the age of 35 years the risks associated with mammography are greater than the risks of not performing mammography, except in exceptional circumstances. In this age group mammography should be restricted to women with very high risk factors in the presence of normal ultrasound and normal fine needle aspiration cytology or core biopsy in the assessment of a suspicious palpable mass. The commonest palpable mass in this age group is fibroadenoma.

In association with mammographic screening of the asymptomatic breast, ultrasound can be particularly useful in evaluation of persisting mammographic asymmetry or distortion on mammography and evaluation of lesions which are only seen on one mammographic projection. In these situations ultrasound can provide an imaging diagnosis or further imaging information and, more importantly, may allow ultrasound-guided intervention to obtain a definitive tissue diagnosis.

Ultrasound is particularly useful in evaluation of the augmented breast, both for demonstrating leakage (*Figure 7*) as well as for evaluation of a

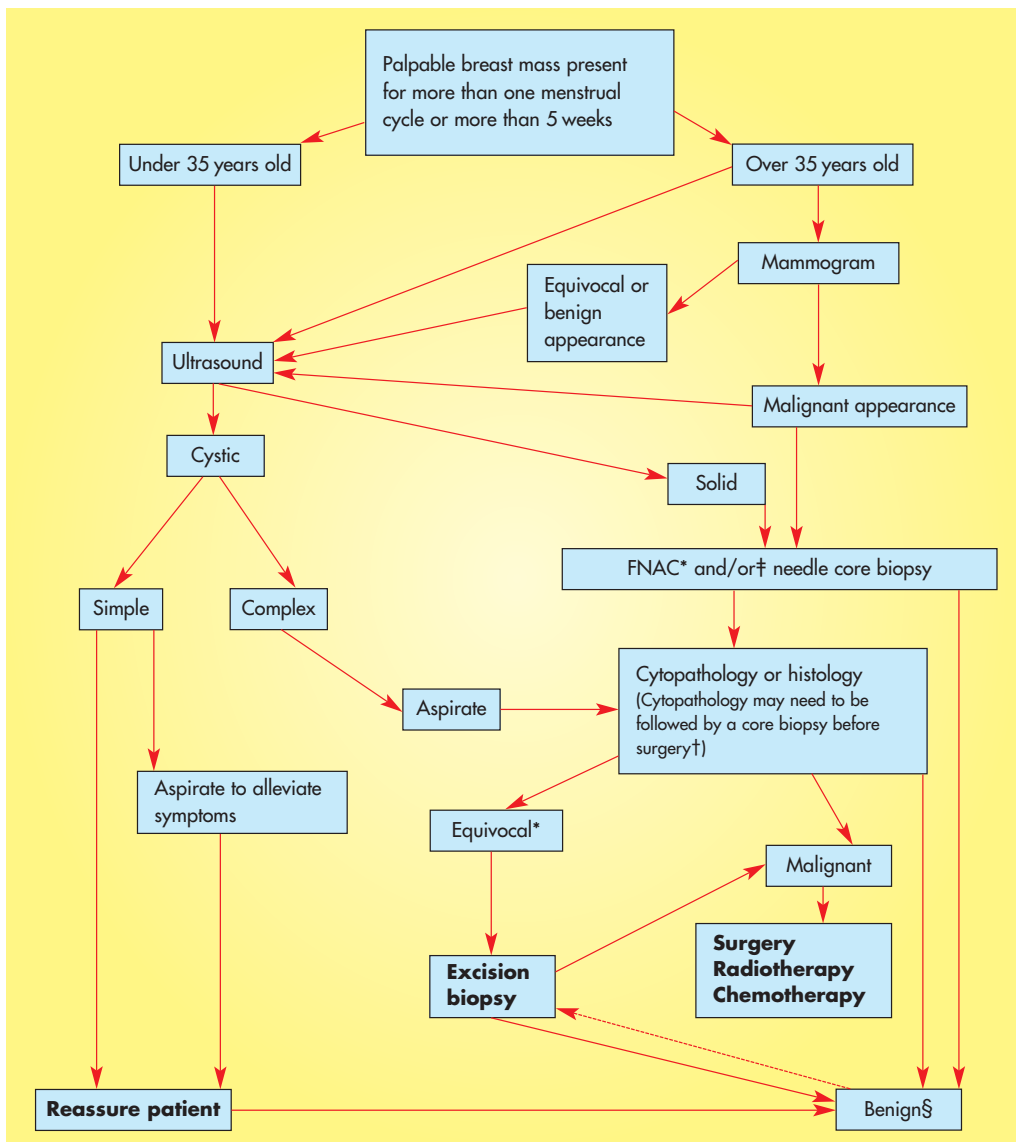


Figure 6. Algorithm for triple assessment of palpable breast masses causing clinical concern. FNAC = fine needle aspiration cytology. *Equivocal results must be followed up by a more definitive test (FNAC by needle core biopsy or surgical excision biopsy) or serial imaging. †FNAC may need to be followed by core biopsy to confirm a benign diagnosis or to aid further management of a malignant diagnosis. ‡There may be rare cases where cytopathology or histology is not needed but such a decision should only be made by experienced breast clinicians. §Benign lesions may sometimes need excision biopsy.

palpable mass (Caskey et al, 1994). The density of a silicon breast prosthesis obscures much of the breast in mammography, reducing the sensitivity of mammograms. Fine needle aspiration and needle core biopsy of suspicious areas in a breast with a prosthesis can be undertaken more safely under ultrasound guidance, sometimes obviating the need for open biopsy.

Ultrasound should be used as the first imaging modality in the evaluation of breast inflammation or the acutely tender breast. Cysts and abscesses can be identified and drained, which may well help to alleviate some of the pain and, in the case of abscesses, may help avoid the need for formal surgical drainage while antibiotics are taking effect. Mammography, if indicated, should be performed as soon as the patient's symptoms have abated enough to allow sufficient compression for good quality mammography.

In breast cancer staging ultrasound can provide useful information. Tumour size assessment is at least as accurate as mammography while identification of abnormal lymph nodes in the axilla is more sensitive than mammography. Ultrasound is particularly helpful in monitoring response to chemotherapy which is used to shrink the primary tumour before a definitive surgical procedure is performed (Gawme-Cain et al, 1995). This approach often allows less mutilating surgery in women with large tumours for whom total mastectomy confers no additional benefit compared to primary chemotherapy followed by breast-conserving surgery. In the postoperative breast ultrasound is the imaging modality of choice for identification of haematomas and seromas as well as the evaluation of new lumps in scars of patients who have had previous surgery.

In the male breast ultrasound is particularly useful in the assessment of suspicious breast masses or gynaecomastia if imaging is clinically indicated. For the patient it is preferable to mammography and, as in the female, has greater sensitivity and specificity than mammography for the assessment of a palpable mass. In infants and juveniles, ultrasound can be used to confirm that swellings within the breast are normal breast tissue if there is concern about unilateral or precocious breast development. The ultrasonographer should be aware that the developing breast disc can be an oval well-defined mass of reduced echogenicity with posterior bright up and may not be symmetrically placed beneath the nipple, and should not be confused with a fibroadenoma. Removal of the developing breast disc at this stage is disastrous. This stresses the importance of breast ultrasound being performed by an ultrasonographer who has sufficient breast ultrasound experience and work-

load to maintain their expertise. Like mammography there are many pitfalls in breast ultrasound, and breast ultrasound should not be performed by the occasional breast ultrasound practitioner.

Interventional breast procedures are best performed under ultrasound guidance (Fornage et al, 1992). Needles or wires can be positioned, with real-time ultrasound guidance, in abnormalities which can be identified. Cysts and abscesses can be aspirated while fine needle aspiration, cytology or core biopsies can be performed on solid lesions. If surgical excision biopsy is required, lesions can be localized either by marking the overlying skin, or by insertion of a localization wire through the abnormal area. The procedure is performed with the patient supine on a comfortable couch. Local anaesthesia is used if indicated and ultrasound is used for real-time guidance allowing accurate placement of wire or needle tip in the lesion every time. Syncope is rarely a problem and the procedure is more patient friendly and less uncomfortable than mammographic guided techniques.

COMMON BREAST PROBLEMS AND THEIR APPEARANCE ON ULTRASOUND

Breast pain is one of the commonest symptomatic breast problems. On its own imaging, as a general rule, is not indicated. A careful history is necessary to determine whether it is common cyclical breast pain for which reassurance and sympto-

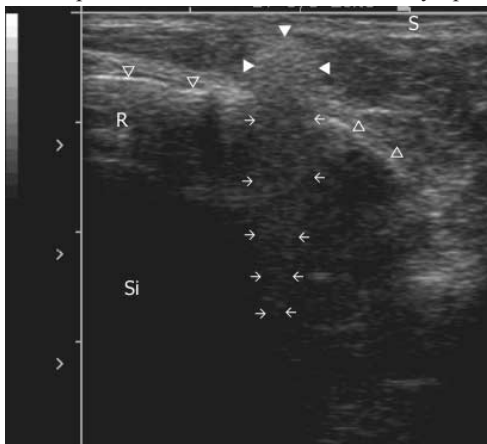


Figure 7. Silicone granuloma as a result of leakage from a prosthesis. The echogenic granuloma (solid arrowheads) lies within the breast parenchyma outside the capsule of the prosthesis (open arrowheads). There is a 'comet's tail' of reverberating echoes deep to the granuloma (arrows). The liquid silicone within the prosthesis (Si) contains no true echoes but reverberation echoes (R) just beneath the capsule are a result of sound bouncing backwards and forwards within the tissues superficial to the capsule. Because the position of the echoes is determined by the time taken for echoes to return, the more the reverberation, the deeper the echoes extend, as in the comet's tail (S = skin).

matic treatment is indicated, or whether it indicates a more sinister process when it is usually associated with other symptomatology such as a breast mass, swelling or other physical signs such as skin dimpling or tethering. If associated with a palpable mass which is not normal breast tissue or some other clinical sign, then imaging is indicated based on the other aspects of presentation.

Solid lumps or masses found by the patient which have been present for more than a complete menstrual cycle always require further evaluation unless they disappear completely. Ultrasound is particularly helpful in evaluation of such masses. The commonest mass to present in this way is a cyst or cysts. Cysts are easily identified because of their anechoic appearance with well-defined margins (*Figure 3a*). Occasionally cysts contain echogenic contents which, if mobile, are easily identified as being in a cyst, but if immobile may be difficult to differentiate from a solid lesion. Irregularity of a cyst wall or an internal solid component is indicative of an intracystic carcinoma or central necrosis of a carcinoma. One helpful characteristic, which modern ultrasound equipment can demonstrate, is the absence of any blood flow within such a lesion. Failure of aspiration of a cyst by a clinician may be the result of a distorting tough cyst wall, more than one cyst causing the palpable mass such that the aspiration needle passes between the cysts, or occasionally very viscid cyst contents. It is only in the last case that ultrasound-guided cyst aspiration may fail.

The commonest benign solid lesion is a fibroadenoma. Fibroadenomas are usually well-defined rounded or oval masses with a lobular appearance and internal septations. They are well-defined, usually with a fairly homogeneous low echo pattern with posterior bright up (increased echogenicity posteriorly) (*Figures 3 and 4*). Inhomogeneity occurs during involution with more complex patterns particularly if there is the coarse calcification often associated with involuted or involuting fibroadenomas. Colour flow imaging can be helpful in diagnosing fibroadenomas as they often have a classical blood vessel distribution around them and are generally less vascular than malignant lesions. Fibroadenomata are multiple in as many as 30% of women with fibroadenoma.

Ductal carcinomas (80% of breast cancers) are usually irregular masses with irregular spiculated margins, a bright irregular echogenic halo and a heterogenous centre of reduced echogenicity with posterior absorption of sound (shadowing) (*Figure 7*). Less commonly they can be better defined low echo masses with posterior bright up (*Figure 1*). In both situations there is usually increased vascularity with a disordered vascular distribution which is

often tortuous and with irregular branching. The better defined low echo appearance is also seen in the less common breast cancers such as mucinous, medullary and papillary cancers.

Nipple discharge is a common problem. If from more than one duct orifice it may be associated with duct ectasia. The dilated ducts of duct ectasia are easily identified on ultrasound, although if only one or two ducts are involved it can sometimes be difficult to differentiate from papillomatous lesions within ducts. Discharge from a solitary duct, particularly if blood stained, is often indicative of a ductal lesion. This can be associated with Paget's disease, a ductal carcinoma, a papillary carcinoma within the duct and a duct papilloma. All these lesions, if associated with visible ultrasound abnormality, present as heterogenous areas of reduced echogenicity within the duct. Blood flow can often be identified within them, particularly with modern high resolution probes with good colour flow sensitivity when using top of the range ultrasound equipment (*Figure 8*). Normal ultrasound does not exclude duct pathology in this situation, particularly with a persisting bloody discharge.

Axillary swelling can be caused by axillary breast tissue (often seen during pregnancy) and lymphadenopathy. Ultrasound can reliably diagnose normal axillary breast tissue and differentiate it from lymphadenopathy. Reactive lymphadenopathy is commonly seen in patients with rheumatoid arthritis as well as chronic infective or inflammatory conditions of the upper limb. Lymphadenopathy associated with lymphoma, metastatic cancer (from breast and other sites), tuberculosis and sarcoid is usually associated with enlarged lymph nodes of low echogenicity. Ultrasound does not reliably differentiate between these possible causes of such an appearance.

FUTURE DEVELOPMENTS

Improvements in grey scale resolution will continue to improve detection of microcalcification.

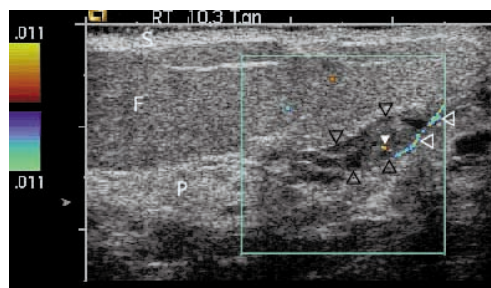


Figure 8. Ductal papilloma with feeding vessel. Colour Doppler image showing an intraductal papilloma (black open arrowheads) with its feeding vessel (white open arrowheads). Blood flow within the papilloma (closed arrowhead). F = fat, P = parenchyma.

Improved equipment colour Doppler sensitivity and use of intravenous ultrasound contrast agents are already providing increased information on vascular morphology, flow characteristics and perfusion dynamics. The development of three-dimensional vascular reconstruction (Carson et al, 1992) and automated analysis of vascular dynamics throughout lesions (Kedar et al, 1995) will provide information which will allow further differentiation of benign and malignant lesions.

Transmission and reflected ultrasound, which provide both velocity and attenuation information, combined with ultrasound computed tomography (Jago and Whittingham, 1991) will increase B-mode (grey scale) information. Other modalities, such as tissue harmonic imaging (Ward and Whittingham, 1999), and elastography which utilizes the deformability of tissues to differentiate between them, will provide entirely new ultrasound information (Doyle et al, 1996). Programs being developed to compare image data sets from recordings of whole breast imaging to detect changes in breast tissue over time will make breast ultrasound a screening tool as well as a symptomatic diagnostic modality. Incorporated in automated systems these techniques, as well as others, will further improve ultrasound diagnosis.

CONCLUSIONS

Breast ultrasound is best performed with a high frequency multi-hertz linear array probe on a mid to top end ultrasound machine by an ultrasonographer with breast ultrasound training. It is the imaging modality of choice in the evaluation of a suspicious palpable breast mass. In the under 35-year-old, during pregnancy, and in the presence of breast prostheses, ultrasound is the imaging modality of choice. As well as differentiating solid from cystic lesions, it provides information regarding the probable nature of solid lesions. As part of triplet assessment it reduces the risk of initial misdiagnosis of cancers. The vascular information provided by colour Doppler improves the accuracy of breast ultrasound. Future developments will make breast ultrasound screening a reality. **HM**

Conflict of interest: Dr Svensson has received financial assistance from both ATL and Acuson to transfer and store images from their ultrasound machines electronically.

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KEY POINTS

- Breast ultrasound should be performed by trained/experienced ultrasonographers.
- Equipment should have a dedicated breast probe running with a frequency of 7.5 MHz minimum (ideally with a peak frequency in the range 12–15 MHz).
- Colour Doppler should be sufficiently sensitive to demonstrate tissue and tumour vascularity accurately.
- Ultrasound is the ideal medium to image suspicious focal breast masses.
- Masses with a benign grey scale appearance, which are very common in young women, may occasionally be malignant. Colour Doppler can help identify some of these cases.
- Benign conditions may on occasions present with a malignant appearance.
- Triplet assessment is usually indicated for solitary suspicious breast masses. It consists of clinical examination, imaging and fine needle aspiration cytology or needle core biopsy. This should be performed by experienced breast clinicians/radiologists working in dedicated breast teams.