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Ultrasound Visualization of the Breast in Symptomatic Patients[1]

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More than 400 breast patients (primarily symptomatic) have been examined with ultrasound alone and in combination with low-dose mammography. Symptomatic pregnant women and young patients with palpable masses were examined with ultrasound alone. In young, dense breasts, ultrasound was found to surpass mammography in the differential diagnosis of both cystic and solid masses. In older patients, the tumor characteristics displayed on ultrasound augmented those of mammography, resulting in increased diagnostic accuracy.

INDEX TERMS: Breast neoplasms, ultrasound diagnosis • Ultrasound, instrumentation • (Breast, ultrasound, 0[0].1298) • (Breast, neoplasm, 0[0].300)

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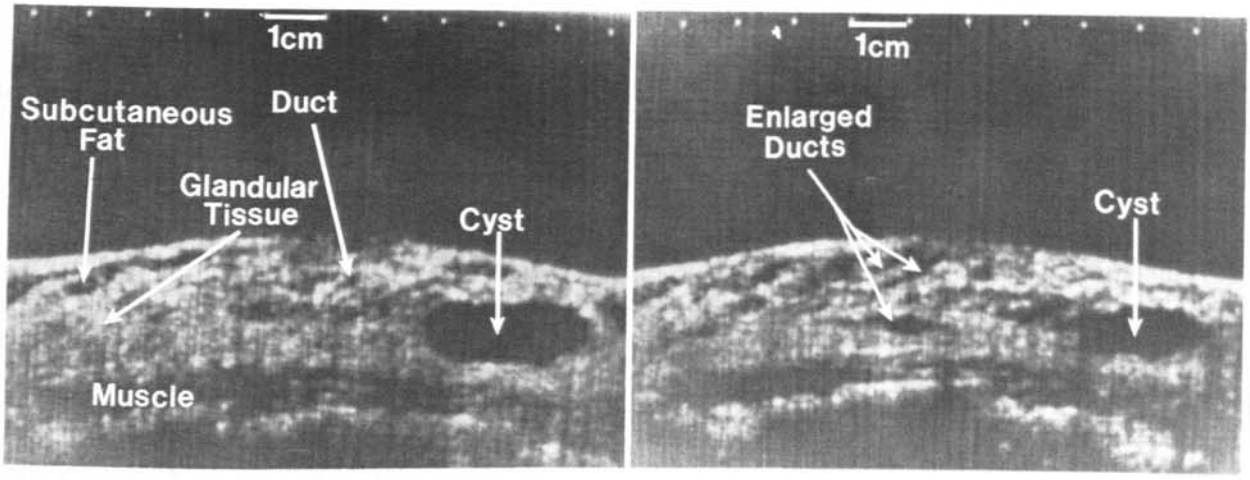
Since June, 1978 we have studied 409 patients (primarily symptomatic) using ultrasound alone and in combination with low-dose mammography (1–4). A wide range of breast pathology was distributed in this population. A number of symptomatic pregnant women and young patients with palpable masses were examined solely with ultrasound.

METHODS AND INSTRUMENTATION

Our unit is a composite of a commercial B-mode ultrasound scanner and a research instrument specifically designed for detection and diagnosis of breast tumors. The patient is supine, and a water bag used for coupling. Linear ultrasound scanning is automatic with the transducer traveling a horizontal path of 12 cm at step intervals of either 5 or 1 mm in approximately 30 sec. per nine-scan series. The water bag's transparent, compliant material allows good contouring to the skin surface as well as direct viewing of the scanning area. The outline of palpable masses is marked on the skin (this marked region is clearly visible through the bag) and the region of the palpable mass, or other region of suspicion, is scanned, as well as the immediately surrounding normal areas. The complete breast is always scanned when there is reason to suspect a widely distributed pathology. Scans can be performed in horizontal, longitudinal, or diagonal planes. Ultrasound breast images are recorded in a multiple image format on 8 × 10-in. (~20 × 25-cm) x-ray film. The single focus transducers used in this instrument (not commercially available) were designed specifically for breast examination. Excellent range and lateral resolution for the full depth of the breast, *i.e.*, from skin to pectoral muscles, were achieved by considering the primary design param-



1a,b

Fig. 1. **a** and **b**. A 35-year-old woman with a history of fibrocystic disease had transverse scans of the upper half of the right breast at 5mm intervals. A large cyst is apparent in each image. Note enlarged ducts (**b**).

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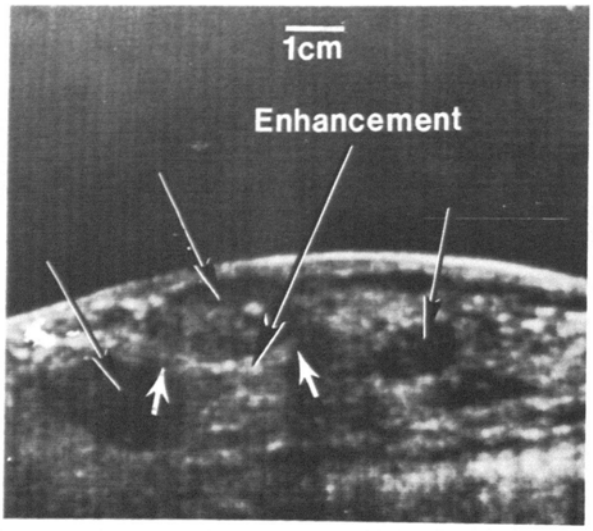

Fig. 2. A 23-year-old pregnant woman with palpable breast masses which appeared to be increasing in size. Three fibroadenomas are seen (black arrows). The middle tumor demonstrates smooth wall structure, relatively homogeneous internal echoes, the lateral shadow sign (two white arrows) and enhancement of the echoes deep to the mass.

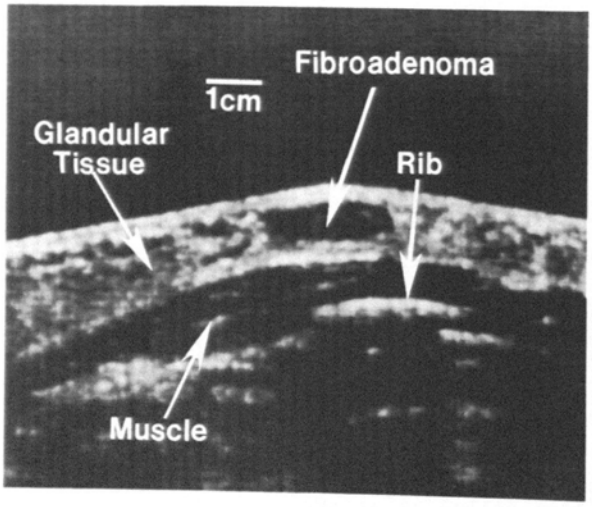

Fig. 3. A 17-year-old girl with a recently palpable mass. Ultrasound demonstrates a benign solid mass compatible with a fibroadenoma.

eters associated with resolution requirements (frequency and f-number) in association with the method of coupling the sound to the breast and physical construction of the transducers. The theoretically possible range resolution of less than 0.5 mm provided by piezoelectric elements vibrating at frequencies above 3 MHz was approached by applying a special backing to the vibrating element which prevented degradation of the resolution by excessive ringing. Loss of sensitivity (response of the transducer in generating and electrically responding to sound waves) caused by this damping was compensated for by using a highly sensitive ceramic (lead metaniobate) for the piezoelectric element. Verification of the adequacy of the transducer characteristics was obtained by scanning physical targets (which, to some degree, simulated a breast containing various sizes and types of tumors) followed by scanning of human subjects. The transducer used for the breast images shown in this paper is a single focus unit with a midband frequency of 3.7 MHz, a beam width (directly related to lateral resolution) of 0.8 mm at 3 dB down, and 1.2 mm at 6 dB down, and a range resolution of 1 mm in tissue (less than 1 mm for physical targets). The average intensity output of the transducer is 23 $mWcm^{-2}$. Other specially designed transducers with frequencies ranging from 2 to 5 MHz were used to provide imaging information on the frequency-dependent attenuation characteristics of breast tumors for the purpose of delineating their benign or malignant character (3).

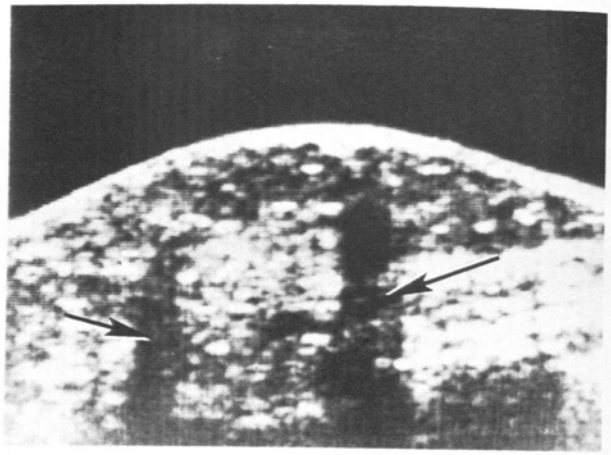

Fig. 4. A 55-year-old woman with a palpable right breast mass. Ultrasound reveals two abnormal areas of shadowing suspicious for malignancy (arrows).

TABLE I: PATIENT SUMMARY

Diagnosis	No. Examined by Ultrasound	No. Examined by Film Mammography	No. Confirmed by Pathology
Ductal carcinoma	20	20	19
Cystosarcoma phylloides	4	4	4
Fibroadenoma	47	7	13
Fibrocystic disease (including dominant cysts)	76	12	12

BREAST PATHOLOGIES

Fibrocystic Disease

These patients complained of bilateral nodular breasts with masses of varying sizes emerging at different stages of the menstrual cycle. Some women had had multiple

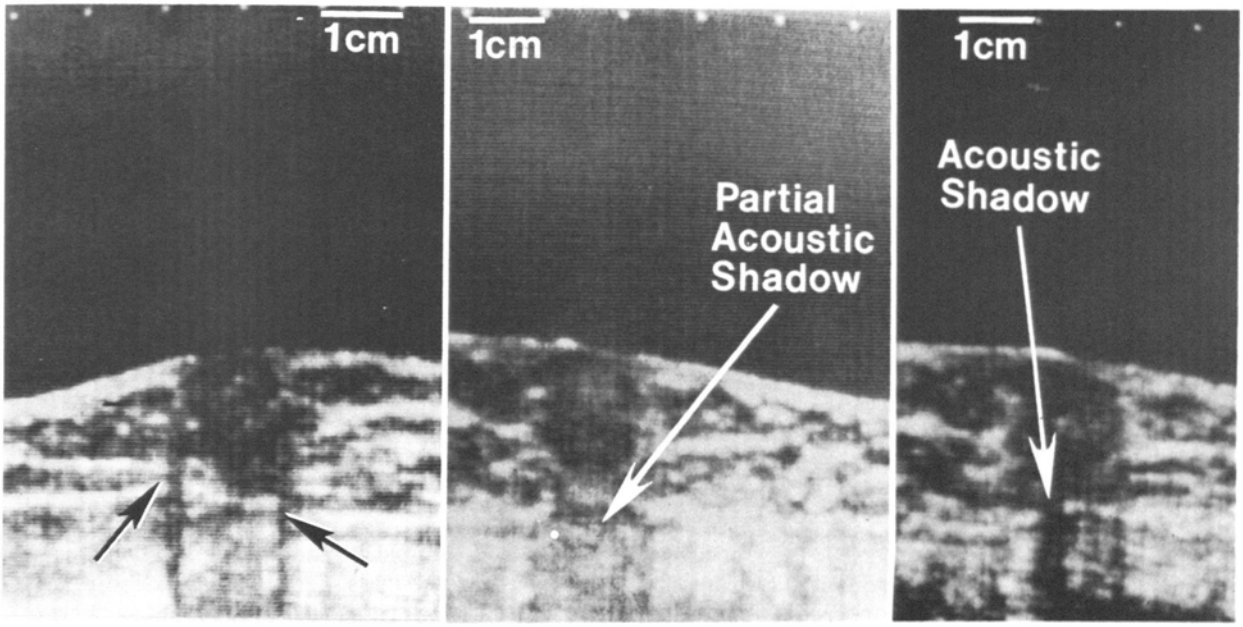

Fig. 5. A 60-year-old patient with a palpable mass. Initial scans at 5mm intervals indicated tumor imaging characteristics consistent with fibroadenoma (**a**). Scans through the mass at 1mm intervals revealed that this smooth-walled mass had slightly attenuating regions, therefore suspicious for malignancy (**b**). Further 1mm scans exhibited more specific signs characteristic of malignancy, namely, jagged wall structure and increased attenuation of the sound by the tumor (**c**).

surgical biopsies because low-dose mammograms could not adequately delineate these lesions. In the present study, ultrasound breast examination with transducers specifically designed to resolve small tissue masses has detected cystic lesions as small as 2 mm. This automatic scanner eliminates the necessity of biopsy. Since scans are readily reproduced, cystic masses can be followed at smaller time intervals than is normally done with film mammography (Fig. 1).

The Pregnant and Postpartum State

The pregnant patient with a newly palpable breast mass presents a dilemma to the obstetrician because malignancies in these women grow rapidly and the increased glandular tissue causes difficulties on mammography. On ultrasound, though, these masses are well delineated and a differential diagnosis is easily obtained (Fig. 2).

Benign Solid Masses: Most benign solid masses in our

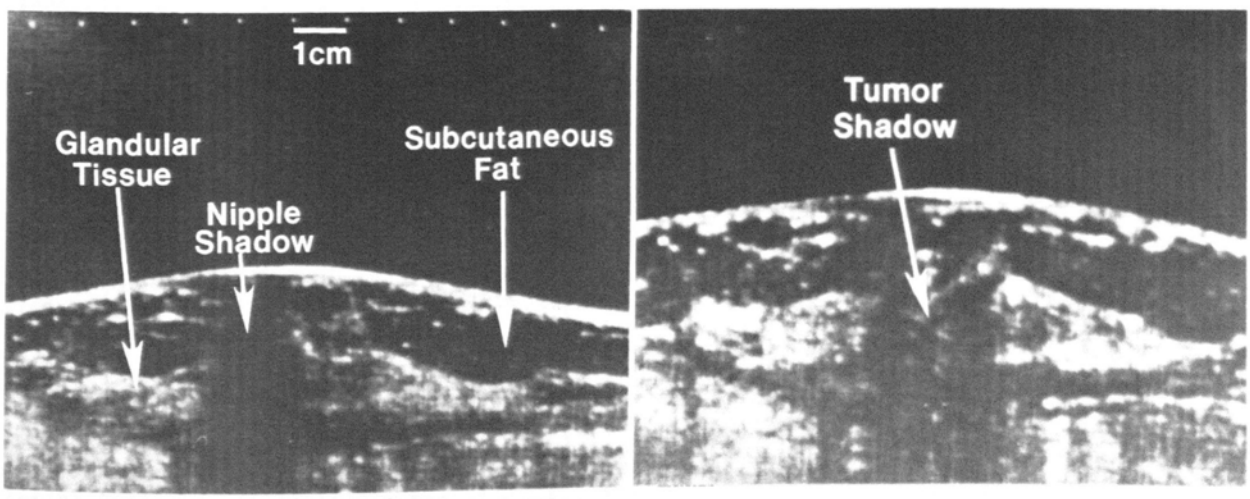

Fig. 6. Abnormal, irregular mass adjacent to the nipple was identified on x-ray mammograms of this 55-year-old woman. The nipple and its normal acoustic shadow were identified on the ultrasound image (**a**), and shadowing in regions lateral to this area was then identifiable as due to tumor attenuation. Image obtained 1.0 cm lateral to the nipple is shown in **b**.

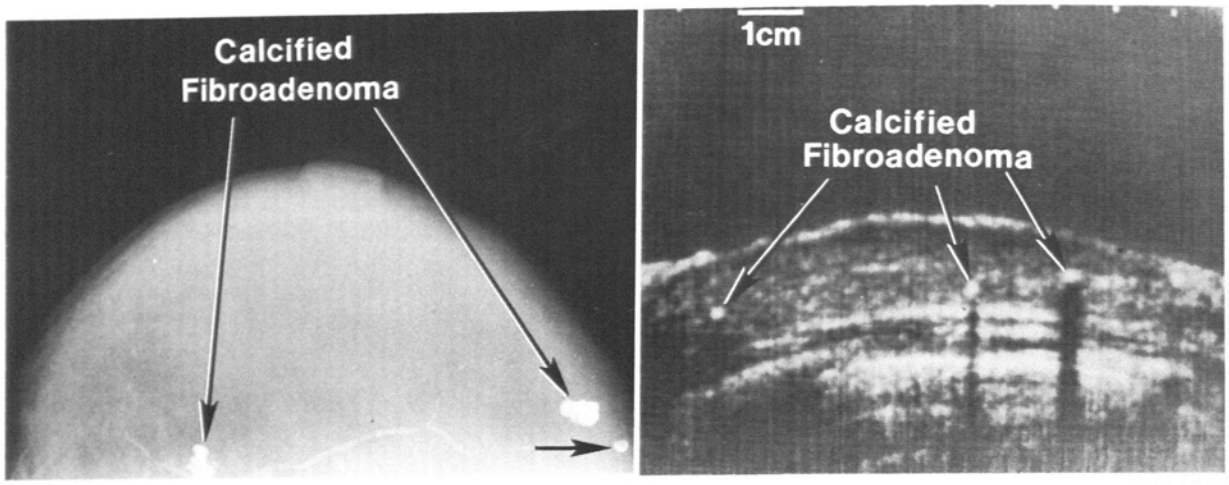

Fig. 7. A 70-year-old woman with calcified fibroadenomas demonstrated by mammography and ultrasound.

series were fibroadenomas (Figs. 2 and 3). These occurred mainly in the 15- to 35-year age range with a few found in women over 40. On ultrasound, the walls of most fibroadenomas are smooth, the internal echoes are relatively homogeneous, and either no attenuation of the beam can be visually observed or it is extremely minor. Japanese investigators have demonstrated the importance of the so-called "lateral shadow" sign (two narrow shadows at the posterior edges of a mass), and the "tadpole-tail" sign (an enhancement of reflections at the posterior border of the tumor) for the diagnosis of benign masses (5). If these two signs are present (Fig. 2), they are a significant indicator that the mass is probably benign, but their absence is not significant (Fig. 3).

Initially, both mammography and ultrasound were performed but since mammography was nondiagnostic in the majority of patients under 30 with a palpable mass, we now use ultrasound as the initial examination and mammography is done only if the ultrasound scan indicates possible malignancy.

Malignant Masses: There were 19 pathologically proved malignant masses, all correctly diagnosed as ductal carcinoma. The patients ranged in age between 40 and 70 years. The masses ranged from 0.7 to 2.2 cm, with an average diameter of 1.5 cm. The most common ultrasound characteristics of ductal carcinoma were irregular walls, non-homogeneous internal echoes, and attenuation of the ultrasound beam as indicated by acoustic shadowing (Fig. 4). The extent of these characteristics varied in different regions of the tumor, *i.e.*, there may be areas of a ductal carcinoma with smooth walls which are non-attenuating (Fig. 5) (see Discussion). No medullary or mucoid malignant tumors were encountered; they may have different characteristics than those outlined above (6).

TABLE I shows the results in patients with either benign or malignant pathology. All those with a diagnosis of malignancy underwent surgical biopsy.

A single false-positive diagnosis of malignancy was made in a 71-year-old woman whose mammograms exhibited a very dense mass with an irregular wall. This mass was attenuating on ultrasound. The pathology study revealed florid intraductal papillomatosis, fibrocystic disease, and a proliferation of ducts and lobules, each duct surrounded by fibrous connective tissue and supportive stroma. In some areas, the ducts were impacted with fibrous tissue. It must be assumed, in this case, that the attenuation noted on ultrasound was associated with the dense fibrous connective tissue in the region of the mass (3).

More cases of fibroadenoma and fibrocystic disease were scanned than biopsied because of the youth of the patients and the excellent ultrasound imaging of these pathologies.

Specific Limitations of Current Ultrasound Mammography

Two important limitations associated with ultrasound breast diagnosis are nipple attenuation and imaging of microcalcifications. In routine clinical ultrasound, masses located deep to the nipple may not be detected because the nipple attenuates the sound beam resulting in an acoustic shadow (7). In this study, the degree of acoustic shadowing varied from patient to patient. It is postulated that the extent of nipple attenuation, and, therefore, the degree of image shadowing, is associated with (*a*) frequency and focal field design characteristics of the transducer; (*b*) area of placement within the tissue of the focal field of the transducer; and (*c*) the variable biological makeup of these tissues. In patients with normal breasts, attenuation is usually equal for each breast. It is often possible, therefore, to detect an abnormality in the nipple-areola region by comparing both breast images. Another approach is to angle the scan head of the instrument in order to prevent the sound from passing through the attenuating nipple-areola structures. One should also mark

the nipple position on the echograms so that attenuating tumors close to this region will not be missed because the shadow cast by the malignant tumor is mistaken for the nipple shadow.

Clustered microcalcifications are an important diagnostic sign of malignancy (8, 9). In its present stage of development, ultrasound is not as capable as x-ray mammography of clearly imaging microcalcifications of 0.2–0.5 mm. However, ultrasound can detect calcifications larger than 0.5 mm. In some cases, calcifications associated with breast cancer can be relatively large (10). Although the present scanning device was not designed to detect microcalcifications, overt calcium masses greater than 0.5–1.0 mm in diameter associated with both benign and malignant tumors have been imaged (Fig. 7).

DISCUSSION

With the exception of work at specific clinical and research centers in various parts of the world (5, 6), ultrasound has not been extensively used for breast examination. This study, combining x-ray mammography and ultrasound visualization, was specifically designed for patients with overt breast pathology, such as palpable masses. In these patients, ultrasound has clear advantages: In older women, ultrasound tumor characteristics can be used in conjunction with mammography to yield increased diagnostic accuracy. For the younger patient with a fibrocystic breast or other benign breast pathology, ultrasound provides accurate diagnosis without the use of ionizing radiation and, in most cases, eliminates the need for biopsy. Further, unlike x-ray imaging, ultrasound can image the dense breast of the young subject with as much clarity and resolution as is normally obtained with the less dense, older breast. Finally, this modality can be repeatedly used in the same subject to follow the time course of a benign pathology without any known damaging or cumulative effects.

Teixidor and Kazam (11) carried out an earlier study of combined mammography and ultrasound in symptomatic breast patients. The B-mode unit designed for examining structures other than the breast was a limiting factor in these investigations, but use of the combined techniques resulted in an increased diagnostic accuracy for both benign and malignant pathologies in comparison to the accuracy of mammography alone.

Since the tissues of malignant tumors are usually not homogeneous, it is absolutely essential to scan overt masses at small step space intervals. In our program, each mass is scanned at 1mm intervals. In some clinical programs, scans are carried out primarily over the central regions of a mass or, if the complete mass is scanned, at step intervals as large as 5mm. Examining only a small volume of a mass probably accounts for some failures in ultrasound diagnosis of malignancies. This is obvious in Figure 5, in which the large interval (5mm) step scanning yielded images characteristic of a benign mass while close interval (1mm) scanning clearly revealed the malignant nature of the tumor.

CONCLUSION

On the basis of results obtained in this study, we recommend that 1) ultrasound visualization, without accompanying x-ray mammography, be the initial method of examination for young patients with a palpable mass, and for all patients with fibrocystic disease, and 2) for the older patient with a palpable mass or with a strong suspicion of malignancy, the combined approach of x-ray mammography and ultrasound visualization should be used.

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