Automated Breast Sonography
Using a 7.5-MHz PVDF Transducer:
Preliminary Clinical Evaluation

Work in Progress

Breast ultrasound imaging performed with an automated machine was carried out in 89 patients, and images obtained with a conventional ceramic single-focus 4-MHz transducer and a 7.5-MHz polyvinylidene fluoride (PVDF) transducer were compared. The 7.5-MHz PVDF transducer improved overall image quality in 77% of patients and had equal penetration in 83%. It yielded greatly increased diagnostic information in 43% of 81 masses and improved visualization of calcification in 57% of 14 lesions in which calcium was visible on mammograms.

Several studies have shown that the combined use of ultrasound (US) and x-ray mammography in selected patients increases the rate of detection of benign and malignant breast masses (1-6). Present automated breast US machines in the Western world use relatively low-frequency transducers (3-4.5 MHz) to penetrate the naturally attenuating breast tissue (7). Drawbacks to current breast US examinations performed using various instruments include difficulty in imaging small solid masses, especially in fatty breasts (8-19), difficulty in reliably differentiating benign from malignant solid masses (11-13), rare visualization of microcalcifications (14), and occasional difficulty in differentiating fat lobules from tumors (6, 13). In a 1-year period, we examined 89 patients with a supine automated breast US unit and compared images obtained with a sharply focused (1/2) ceramic 4-MHz transducer and those obtained with a sharply focused (1/3) 7.5-MHz polyvinylidene fluoride (PVDF) transducer. The PVDF transducer has a number of advantages over ceramic transducers of the same frequency, including better axial resolution. Although the PVDF transducer has been used for breast sonography in Japan (15-18), to our knowledge it has not been used in commercially available breast US equipment in the United States.

There were two major questions to be answered in this study: (a) whether the higher frequency PVDF transducer produced images of adequate quality, showing complete penetration of the breast by the US beam, when used with our supine breast US unit, and (b) whether the resulting images contained more diagnostic information than images obtained using the sharply focused 4-MHz transducer.

Patients and Methods

Patients were selected for this study from the population referred to the breast imaging service of the Indiana University Medical Center. Of the 89 patients in the study, 68 were referred for evaluation of a symptomatic breast mass and 21 were referred for screening mammography. The patients ranged in age from 18 to 85 years. Preliminary x-ray mammograms were obtained in 74 patients, and each showed a mass or residual density in the breast thought to warrant US evaluation. The 15 patients who did not undergo x-ray mammography were all under the age of 30 and had a large amount of fibroglanular tissue; in these patients US findings were thought to be sufficient for diagnosis.

All sonograms were obtained using a dedicated supine breast US unit (Labsonics Inc., Mooresville, Ind.), designed for examination of the symptomatic patient. This B-mode linear scan unit produces static images of the breast in supine patients with compression provided by a water-filled, optically transparent, semicompliant plastic bag. A unique aspect of the design of the Labsonics breast scanner is that the water bag (with indwelling transducer) does not simply couple the sound and apply pressure to the breast. It also allows an advantageous angle of incidence of the US beam to both the skin surface and to internal masses. The manually manipulated, delicately controlled angular and vertical motions of the water bag, when used in conjunction with appropriate patient positioning, can yield an angle of sound beam entrance that minimizes refraction and the associated beam defocusing. If a mass is not adequately visualized during a specific scanning procedure, it is sometimes possible to improve visualization of the region of interest by altering the angle of incidence of the US beam and placing the center of focus of the transducer within this region. In this respect, the instrument combines, to a limited degree, the advantages of a hand-held probe and an automated scanner.

US scans were obtained at 3-5-mm intervals longitudinally and/or transversely and at 1-mm intervals through the area of interest. Whenever possible, identical scan planes were used for imaging the
The findings of this study were consistent with those of the previous study, which showed that 4-mm transducer was sufficient for the detection of breast lesions. The 4-mm transducer provided adequate spatial resolution and contrast, allowing for the clear visualization of small lesions. However, the 7.5-mm transducer was found to be more effective in detecting larger lesions, due to its superior sensitivity and penetration. Overall, the results of this study support the use of 4-mm transducers for breast imaging, as they provide high-quality images suitable for the detection of small lesions. Further studies are needed to evaluate the long-term effects of using 4-mm transducers in breast imaging.
attenuation backscatter values of fat, parenchyma, and skin. They found a significant difference in the backscatter coefficient value between fat and infiltrating ductal carcinoma in the two masses examined. Since these investigations were carried out at only a single frequency, it is not possible to evaluate frequency-dependent characteristics. Based on the preliminary results described in our study, however, it can be postulated that the frequency-dependent backscatter coefficient of breast fat may be considerably greater than that of some malignant and benign breast masses. Continued investigation of the frequency-dependent characteristics of US breast imaging, including our current studies on the use of transducers that have multiple frequency outputs (3.0–10.0 MHz) (36), may lead to further improvements in this modality.

The border characteristics of solid masses were most improved in cases in which the 4.0-MHz scan did not show the tumor well. For the remaining masses, while the wall structure was better seen, no additional diagnostic information for determining the etiology of the mass was gained using the higher frequency transducer. Similarly, while the internal echo texture was often better seen with the higher frequency transducer, this feature was of little help in determining the etiology of the masses. This is opposed to the findings of Koyabashi et al. (17), who thought that improved visualization of wall structure and internal echo texture was helpful in differentiating benign from malignant solid tumors. Early in our study, carcinomas appeared to be less echogenic than fibroadenomas, but as the study progressed it became apparent that there was overlap between the internal appearances of benign and malignant tumors. Only expansion of this series will determine whether the internal echo texture and its brightness relative to fat are useful in diagnosing malignancy.

Lateral shadow signs were seen in 37 masses. These shadows were more apparent on the 7.5-MHz images in 20 cases (54%). Lateral shadow signs were seen in a variety of benign and malignant processes and were of no help in the US determination of the etiology of a mass. In this series, 25 masses displayed posterior acoustic enhancement, and in 64% of these the degree of enhancement was judged to be the same at both US transducer frequencies. In only 12% was the enhancement more apparent on the 7.5-MHz scans. The presence of lateral shadow signs and enhancement is not dependent on various factors of the sound field that their absence is not thought to be diagnostically significant.

Although the 7.5-MHz transducer produced better-defined images of cysts in 75% of cases (Fig. 3), it yielded increased diagnostic information in only 10%. In only one instance were the 4.0-MHz scans of a cyst significantly better than the 7.5-MHz scans, and this was primarily because of a patient’s positioning problem. Thus, the 7.5-MHz PVDF transducer can be used to identify and diagnose cysts, but this task can be adequately carried out with the 4.0-MHz transducer.

A comparison of the performance of x-ray mammography and US at both frequencies (Table 1) indicates that although high-frequency US improves lesion detection, not all tumors are visualized. In our study, US at either frequency was better than x-ray mammography for the detection of cysts. As expected, all patients with positive sonograms but negative mammograms had residual fibro-glandular tissue obscuring the cyst in the x-ray study. The majority of solid tumors were detected on both mammography and US, with the 7.5-MHz transducer improving US performance considerably. Three masses were found only on x-ray mammography, but an equal number were seen only on US again because of residual density on the mammogram. It must be noted, however, that Table 1 represents a skewed population, because young patients did not undergo x-ray mammography if thought the US examination was sufficient for diagnosis. This group of patients would be more expected to have nondiagnostic mammograms. A larger series of patients studied with both modalities will be necessary if both modalities are to be compared.

The clinical utility of US visualization of calcifications is presently limited except in young patients, in whom US may be the sole imaging modality used, or in patients with prostheses, in whom large portions of the breast may be obscured on x-ray mammography. For the rest of the patient population, the role of US is purely adjunctive to x-ray mammography, a modality that clearly demonstrates microcalcifications. However, unless unforeseen US findings of minimal breast cancer are discovered, visualization of microcalcifications is essential if US is to be used in the future as a screening modality. It is obvious that the use of higher frequency transducers is a step in the right direction.

The disadvantages of the use of the 7.5-MHz PVDF transducer were minor. The decreased beam penetration found in 16% of the patients was regarded as mild. Small focal shadows occurred behind fibrous tissue in some patients on the 7.5-MHz scans, but these shadows did little to diminish the overall quality of the images. In a few very large masses, lateral shadow signs were much more prominent on the 7.5-MHz scans, making visualization of the wall structure and internal detail of the lateral portions of the mass difficult. Initially, we also had difficulty with an overly bright skin–water interface; this problem was eliminated by design changes initiated by Labsonis Inc., in the preamplifier and amplifier systems.

CONCLUSION

Based on our preliminary study, the detection of solid masses and microcalcifications is greatly improved with the 7.5-MHz PVDF transducer compared with the standard ceramic 4.0-MHz transducer, primarily because...
of improved contrast between fat and solid tumors. Because of the excellent image quality of most examinations, we believe that the 1/3, 7.5-MHz P2YD transducer can be used with our US instrument for routine scanning. However, there is no ideal frequency for breast US, and therefore lower-frequency transducers should be available for special cases. Only additional investigation will show whether use of the higher frequency transducer will improve the differentiation of benign from malignant solid masses. Unfortunately, because of the considerable overlap in the gross pathologic characteristics of these two groups, such differentiation may be too much to expect from anyatomic imaging modality.

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References