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ULTRASOUND BREAST IMAGING—THE METHOD OF CHOICE FOR EXAMINING THE YOUNG PATIENT*

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Abstract—It is shown in this paper that relatively simple ultrasound techniques, in combination with specific scanning protocols, can provide a more accurate diagnosis for pathologies in the breast of young subjects than does X-ray mammography. Static, *B*-mode ultrasound instrumentation with close-interval scanning and transducers designed for the specific examination regime, was used to examine 116 symptomatic breast patients under 30 yr of age. Approximately 50% of the patients were diagnosed by ultrasound as fibroadenoma cases; biopsy of 22% of these cases indicated 100% diagnostic accuracy for the ultrasound technique. Thirty-one percent of the cases diagnosed as fibroadenoma by ultrasound were also examined by X-ray mammography; in 80% of these cases, X-ray mammography did not adequately image the mass.

Key words: Breast neoplasms, Ultrasound breast diagnosis, Ultrasound mammography, Ultrasound breast imaging.

INTRODUCTION

Although significant advances have been made in radiographic imaging of the fatty, non-dense breasts of middle aged and older subjects, this progress has not significantly improved accuracy of diagnosis of masses present in the dense breast of the young subject (Gregl *et al.*, 1977). Breasts of a majority of patients under 30 yr have a predominance of glandular tissue and are usually characterized, for purposes of radiographic imaging, as "dense breasts". The term "dense breast", as used in X-ray mammography, refers to a breast which contains a predominance of dense tissue, such as glandular tissue, and at the kilovoltages used in mammography, shows poor contrast between the predominant tissue and other breast tissues, either normal or pathological (Egan, 1972).

As indicated in review publications on breast examination by ultrasound visualization, a large proportion of the investigators in this field have concentrated their efforts on use of this modality for diagnosis of malignancies, normally a disease of the older woman (Kobayashi, 1975; Kelly-Fry, 1980; Cole-Beuglet *et al.*, 1980). However, ultrasound techniques have unique advantages for diagnoses of masses in the breast of young women. In most cases these masses are not malignant.

In this study, we attempted to determine if masses in the breasts of "symptomatic" patients under 30 yr could be definitively imaged and diagnosed by means of ultrasound visualization. In carrying out this investigation, both X-ray and ultrasound mammography were used in the first phase of the study, but after a period of approximately 6 months, ultrasound scanning was the sole technique applied to patients in this age group.

METHODS AND INSTRUMENTATION

The first stage of this study concerned development within a research laboratory of a relatively inexpensive ultrasound instrument with the capability of accurately diagnosing masses in the breasts of "symptomatic" patients. This development was accomplished by using a commercial *B*-mode linear scan unit as the base of the new instrument and adding to this a number of features which have been found in a long-term research program to be significant to accurate diagnosis of masses within the breast. An important addition was the use of signal focus transducers designed and fabricated to yield a range and lateral resolution which is sufficient for diagnosis of breast masses less than 5 mm. This resolution capability was achieved by considering the primary transducer design parameters asso-

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ciated with resolution requirements (frequency and f number) in association with: the specific method of coupling the sound to the skin, including the choice of compression or non-compression of the breast; the position of the patient in terms of the tissue path traversed by the sound beam and with respect to the entering angle of the sound beam; and the physical construction of the transducer. Degradation of the range resolution associated with excessive ringing of the transducer was prevented by the use of special transducer backing materials. Loss of sensitivity caused by this damping was compensated for by use of a highly sensitive ceramic (lead metaniobate) for the piezoelectric element. Initial verification of the adequacy of the transducer characteristics was obtained by scanning: (1) physical targets; (2) phantom targets which simulated the imaging and attenuation characteristics of benign and malignant tumors; (3) human subjects. An $f2$, 3.7 MHz transducer with a 6 dB beam width of 1.2 mm and a fractional bandwidth of 27% was applied for most of the breast examinations discussed in this paper, but transducers of other frequencies were used to study attenuation characteristics of some masses (Kelly–Fry *et al.*, 1978). The spatial average-temporal average intensity (SATA) output of all transducers used in this study is less than 25 mW cm^{-2}.

In its final form, this instrument is a simple *B*-mode linear scan unit which includes an analogue scan converter and which provides, by means of a motor driven transducer, close interval static images of the compressed breast of a subject in a supine position.* The automatically controlled transducer is immersed in a 20×8 cm water bag which is constructed of 0.5 mil transparent polyester sheeting and contains approximately 1.8 l. of distilled water. The polyester material meets the requirements of readily contouring to the breast surface, providing constant compression to the breast and allowing visual inspection of the skin surface during scanning. This water bag system is counterweighted and can be manually lowered onto the surface of the breast, angulated to conform to the breast contour, rotated so that the transducer can scan transversely, longitudinally, or diagonally and, when positioning is complete, can be automatically held in that position. For each single ultrasound scan the transducer travels a linear path of 12 cm. If the lateral aspect of the breast is being scanned, the subject is lying slightly on her side with a pillow support under her shoulder so that the area of the scan is directly facing the transducer. This arrangement, in combination with flattening of the breast surface by the water bag, provides normal incidence of the sound beam to the region of interest.

The automatically controlled transducer motion provides multiple ultrasound scans either at 1 or 5 mm tissue path intervals. If 5 mm spacing is chosen, nine scans are automatically performed in a period of approximately 30 sec. If 1 mm spacing is chosen, 41 scans are automatically performed. These scans may be interrupted at any time in the series for study or photographing. The breast images are recorded in a multiple image format on 8×10 X-ray film.

For all patients in whom ultrasound is the only imaging procedure, each breast is completely scanned at 5 mm increments by alternately positioning the scanner head so all breast quadrants are examined. If any abnormality is demonstrated, this area is then re-examined at 1 mm step intervals. The sole exception is that in the pregnant patient only the breast quadrant containing the mass is scanned. For all patients with a palpable mass, the location of the mass and the surrounding area into which the mass may move, as a result of normal arm and body motions, is marked on the skin while the patient is in the scanning position. This marked area is scanned at 1 mm space intervals.

For the patients examined early in this program, X-ray mammograms were performed using low dose film techniques. The highest possible radiographic contrast was obtained with the use of a dedicated mammographic X-ray machine which utilizes a microfocus X-ray tube system with a tungsten target at a 45° angle. The focal spot size is approximately 100 μm with low voltage grid cut-off. For an average breast the radiographic techniques are 25 kV, 8 mA at 1 sec. Images with a magnification of two can be obtained with this unit and this technique is used in patients with very small breasts and for better definition of mass lesions and microcalcifications. Craniocaudal and mediolateral projections are routinely performed with strong compression of the breast tissue.

*This instrument was developed by the Indianapolis Center for Advanced Research, Inc.

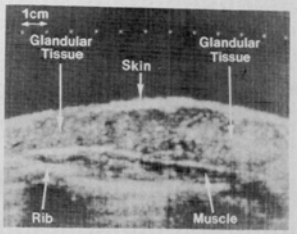

Fig. 1. Ultrasound (3.7 MHz) visualization image of the dense breast of a young subject (26 yr). The large component of glandular tissue in this breast and its consequent dense character make it unsuitable for X-ray mammography imaging. This subject had a 2 cm cyst in her opposite breast. The area of the breast imaged here is normal except for a few small (2–3 mm) scattered cysts.

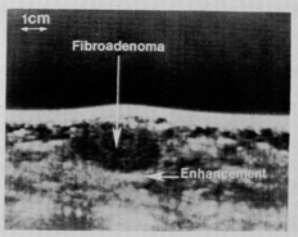

Fig. 2. Ultrasound (3.7 MHz) visualization image of breast of 17 yr-old subject. The ultrasound diagnosis of fibroadenoma was confirmed by pathologic examination.

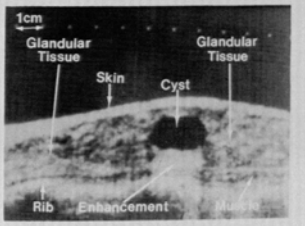

Fig. 3. Ultrasound (3.7 MHz) visualization image of breast of 26 yr-old subject with an overt cyst.

Initially Kodak NMB film with MIN-R screens was used but currently the newer Kodak Ortho M film is utilized.

RESULTS

Table 1 summarizes the results obtained from the examination of 116 patients under 30 yr of age with the previously described ultrasound techniques. Figure 1 demonstrates a typical ultrasound image of the type of young breast that is not suitable for examination by X-ray mammography. This breast is extremely dense with the primary components consisting of glandular tissue and muscle. For example, in this case, the small layer of subcutaneous fat normally seen in the young breast is not present and no fat deposits are evident in any of the deeper portions of the breast.

It should be noted from the data presented in Table 1 that 66 patients out of a total of 116 were diagnosed by ultrasound visualization as having a specific benign pathology and, of these, almost 50% (32) were designated as fibroadenoma.

An ultrasound image of the breast of a 17 yr-old subject is presented in Fig. 2. The mass shown in this figure was diagnosed as a fibroadenoma, based on the ultrasound image pattern, and this diagnosis was confirmed by a subsequent biopsy and pathologic examination.

Approximately 22% (7) of the fibroadenomas diagnosed by ultrasound were biopsied and all proved to be a correct diagnosis. Three of these biopsied fibroadenoma cases were also examined by X-ray mammography. For two of these cases, aged 16 and 18 yr, no mass could be recognized on the X-ray mammogram. For the third subject, 28 yr, X-ray mammography imaged a 4 cm mass with sufficient clarity to indicate its benign character, but no specific tumor designation could be made.

Thirty-one percent (10) of the cases diagnosed as fibroadenoma by ultrasound were also examined by X-ray mammography. In 80% of these cases (8), X-ray mammography could not detect any mass within the breast of the subject, while a distinct diagnostic image did result from the ultrasound scanning of all these subjects.

As indicated in Table 1, eleven of the young patients had overt cysts which ranged in size from 2.0 mm to 4.0 cm in greatest diameter. Figure 3 demonstrates the clarity with which these fluid filled masses in dense breasts can be imaged by ultrasound visualization. The smooth walls of this mass, the total lack of echoes from its internal structure, and the enhancement of the echoes at the posterior border of the mass, should be noticed in this high gain ultrasound image. Since the images of the overt cysts in the 11 patients scanned were unambiguously diagnostic, further examination by X-ray mammogrpahy or biopsy was not recommended but, in some of these cases, aspiration of the cyst did take place. A breast abscess was diagnosed in one patient and, following a course of antibiotic therapy, it was shown on the basis of ultrasound reexamination and clinical evaluation that the abscess was no longer present.

None of the tumors found in the breasts of subjects under 30 yr were diagnosed as malignant.*

*Malignant tumors were diagnosed by ultrasound in the breasts of two patients, 36 and 39 yr. The younger subject was examined by ultrasound only; the 39 yr-old had received an X-ray mammogram at another hospital but, because of the dense character of the breast, this technique was non-diagnostic. Both of these cases were confirmed by pathology.

Table 1. Ultrasound diagnosis of patients under 30 yr of age

Ultrasound diagnosis	Number	Size range	No. biopsies	Ultrasound diagnosis confirmed by pathology
Fibroadenoma	32	0.5–5.0 cm	7	7
Dominant cyst	11	0.2–4.1 cm	None	N/A
Fibrocystic disease	5	—	None	N/A
Duct enlargement, fibrosis, abcess, papilloma or other benign pathologies	18	—	3	3
Negative	50	—	None	N/A
Total	116	0.2–5.0 cm	10	10

N/A = not applicable.

DISCUSSION

The majority of solid masses seen in patients under 30 yr in this study were fibroadenomas, the most common breast mass occurring during the childbearing years (Egan, 1972; Kern and Clark, 1973). At palpation, a smooth, firm, freely movable mass is normally detected. These masses are influenced by changes in the hormonal cycle and patients may experience pre-menstrual pain in the mass. With ultrasound visualization, two features are dominant and form a strong basis for differential diagnosis, namely, smooth walls and internal echoes (Fig. 2). For "classical" fibroadenomas, the internal echoes are homogeneous and this characteristic is significantly different from the disorganized internal echo pattern exhibited by most malignant masses. In this study, however, it has been found that homogeneity of the echo pattern is not a constant feature of fibroadenomas and it should not, therefore, be used as an absolute diagnostic criteria. In some cases, an enhancement of tissue echoes at the posterior border of the mass accompanied by two narrow lateral shadows (tadpole or waterfall effect (Kobayashi *et al.*, 1972)) are evident (Fig. 2). When this sign is present, in conjunction with internal echoes within the mass, it is a significant diagnostic feature. However, it has been found in both our clinical studies and our laboratory investigations of phantom breast masses that the presence of this sign is not a necessary component to diagnosis since this specific phenomena is partially dependent on acoustic parameters which may be variable in each examination.

The patients with cystic disease complained either of sensitive or nodular breasts and, in some cases, exhibited palpable masses which varied in size at different stages of the menstrual cycle. Clinical palpation examination indicated, in some cases, that the masses were probably cystic, but others could not be differentiated from solid masses by such examination. Ultrasound visualization not only definitively diagnosed the average sized overt cystic masses (Fig. 3), but detected smaller cystic lesions, some only 2 mm in size which often accompanied the larger cysts. If a patient is found to have a large overt cyst, such as that shown in Fig. 3, it is the normal procedure in this study to search her breast for other cystic structures, both large and small. Essentially all cysts demonstrated smooth walls and an echofree structure; in some cases there was enhancement of echoes posterior to the cyst (Fig. 3). As in the case of fibroadenomas, this phenomenon is associated with variable sound field factors and should not be a requirement for differential diagnosis.

Six of the patients in the series were either pregnant or immediately post-partum and all exhibited palpable masses within their breasts. Since malignancies in this type of patient are usually of the fast growing type and mammography is contraindicated both from the viewpoint of ionizing radiation and because it is not a good diagnostic modality for subjects with a large amount of glandular tissue, such patients present a serious diagnostic dilemma. If ultrasound visualization is not available, a biopsy would be indicated for a large percentage of these patients.

As previously indicated, to date we have not detected any malignant masses in this young age group of patients. However, since for older patients we have demonstrated that in some cases there are areas of the malignant masses that simulate the imaging characteristic of fibroadenomas and that correct differential diagnoses can be made in such cases if most of the volume of the mass is examined by close interval scanning, it is highly recommended that all overt masses be scanned in 1 or 2 mm intervals (Kelly-Fry *et al.*, 1978; Kelly-Fry, 1980; Harper and Kelly-Fry, 1980).

CONCLUSION

We have found that in patients with dense breasts associated with a preponderance of glandular tissue, typical in women under 30 yr, breast masses are well demonstrated with ultrasound visualization techniques. This method, used as the primary examination, is sufficient for diagnosis. Using appropriately designed but relatively simple instrumentation and certain ultrasound criteria, precise differential diagnosis can be made on all massses commonly found in the young breast. Ultrasound breast scanning in the patient population described above not only alleviates the need for mammograms and therefore, decreases the patient's exposure to ionizing radiation, but also provides better imaging of the breast than current mammography methods. Palpable masses can be re-examined over various time periods with ultrasound techniques to determine any change in size or characteristics. It is hoped that with increasing use of this technology the number of surgical biopsies performed on the young patient would decrease considerably.

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