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Ultrasound in the Evaluation of Solid Breast Masses[1]

Ultrasound image characteristics and radiographic features of 31 benign and 41 malignant breast masses were cross-tabulated and analyzed to determine the ultrasound image characteristics most useful for diagnosis and the frequency with which some imaging features occurred. The most common malignant mass (the ductal carcinoma) exhibited a jagged wall (88%), homogeneous internal echoes (12%), nonhomogeneous internal echoes (70%), internal echoes not discernible due to attenuation effects (18%), and attenuation shadowing (97%). In contrast, the fibroadenoma (the most common benign mass in this study), exhibited smooth walls (94%), homogeneous internal echoes (89%), and no demonstrable posterior shadowing (67%).

Index terms: Breast neoplasms, ultrasound diagnosis • (Breast, ultrasonography, 0[0].1298)

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APPLYING specific ultrasound instrumentation and experimental techniques in a study of approximately 1300 patients with breast lesions, we found it was possible to differentiate benign and malignant masses with a high degree of accuracy (1). The ultrasound diagnosis was confirmed by pathologic study in 95% of the 43 malignant masses found in that population. In reviewing these data, we thought it would be of value to make a careful analysis of the ultrasound image characteristics that are heavily weighted by physicians when making a diagnosis on the basis of the ultrasound images, and to compare the radiographic and ultrasound image data for those patients that were examined by both modalities. In order to accomplish this, we evaluated the principal imaging factors used for diagnosis in a retrospective analysis of 72 solid masses (41 malignant and 31 benign) that had been correctly diagnosed by ultrasound imaging and proved by biopsy.

MATERIALS AND METHODS

Instrumentation

The ultrasound instrument used was developed by the Indianapolis Center for Advanced Research, Inc. It was a B-mode linear scan unit and provided close-interval (1 mm) static images of the compressed breast with the patient in a supine position. Motor-driven f2, 3.7-MHz transducers with an axial resolution of 0.8 mm and a 6-dB beam width of 1.2 mm were used. The sound intensities of the two separate 3.7-MHz transducers applied in this study were: at the transducer face, 0.25 mW/cm^2 and 0.44 mW/cm^2; at the focus (20-dB beam width), 25 mW/cm^2 and 110 mW/cm^2. The transducer was immersed in a transparent polyester water bag that readily adapted to the contours of the breast surface, providing constant compression and allowing visual inspection of the skin surface during scanning. The transducer could scan transversely, longitudinally, or diagonally at either 1-mm or 5-mm intervals. The flattening of the breast by the water bag, in combination with orientation of body position, provided close to normal incidence of the sound beam to the region of interest.

Using low-dose techniques, x-ray mammograms were obtained of 62 of the patients. The highest possible radiographic contrast was obtained by the use of a dedicated mammographic x-ray machine using a microfocus x-ray tube system with a focal spot size of approximately 100 μm. Kodak Ortho M film and Kodak Min R screens were used.

Methods

The ultrasonic imaging characteristics evaluated were: the size of the mass, recorded as the largest diameter in centimeters; the wall structure, defined as being either well demarcated from the surrounding tissue or not, and as either smooth or jagged; the degree of attenuation shadowing (marked, moderate, or slight), judged by the "blackness" of the shadow and not dependent on its width, and the

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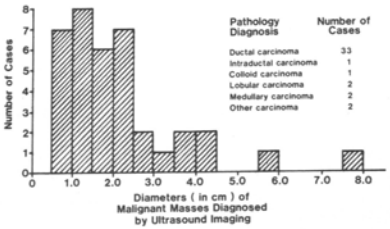
Figure 1



Maximum diameter of malignant masses retrospectively analyzed for their ultrasound imaging characteristics. Of the total of 41 masses analyzed, four could not be measured due to their diffuse nature. The histologic types of carcinomas encountered in this study are also shown.

volume location of the shadowing (entire volume of mass or small portion), determined by 1-mm scanning throughout the mass; the internal echo pattern of the mass, recorded as being homogeneous, nonhomogeneous, or not visible.

The radiographic characteristics evaluated were: borders of the mass, described as well demarcated from the surrounding tissue or not, and as either smooth or jagged; presence of microcalcifications within the mass.

The information obtained was coded into a machine-readable format, fed into a computer, and evaluated in terms of imaging features that were associated with specific diagnoses.

Figures 1 and 2 illustrate the maximum diameter of the malignant and benign masses as recorded on the ultrasound images, and provide a numerical breakdown of the diagnostic categories. Ductal carcinomas (the most common type of breast malignancy) represented 80% of the malignant masses in this study. The results given for the general class of malignant masses are, therefore, heavily weighted for ductal carcinomas. The results specific to ductal carcinomas are also indicated. In view of the absence of a statistically adequate representation of sizes for the pathologic categories, it was decided that conclusions based on cross-tabulation data relating size of these masses and the image characteristics were not warranted.

RESULTS

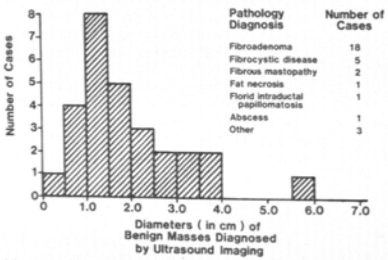
Wall Structure

The walls or a section of the wall structure of all of the malignant masses could be sufficiently visualized by ultrasound to determine their character (including those in which the maximum diameter could not be exactly determined due to interference from surrounding architecture), and 88% of them exhibited a jagged wall structure. A typical example is illustrated in Figure 3. For the 12% of malignant masses (5 cases) that exhibited smooth walls, it was found that other imaging features were present that provided the basis of the correct diagnosis. Four of the five masses were various types of ductal carcinoma, and the remaining case was a clear-cell papillary carcinoma. Ninety-four percent of the fibroadenomas exhibited a smooth wall structure on ultrasound imaging. Approximately 70% of the patients with fibroadenoma masses were less than 35 years of age, and the average age was 29. The smooth-walled structure of the typical fibroadenoma is illustrated in Figure 4.

For other types of benign lesions examined with ultrasound, such as the varying forms of fibrocystic disease, it was found that in 10% of the cases the wall structure could not be adequately evaluated because of its diffuse nature. Pathologically, these masses were diffuse florid intraductal papillomatosis, reactive hyperplasia, and fibrosis. For the remaining cases, 29% exhibited irregular walls similar to the wall contour of carcinomas, and 71% had a smooth wall appearance. However, there was only one fibroadenoma that showed an irregular wall; since this mass was difficult to separate from adjacent dilated ducts, this factor may account for the unusual wall appearance.

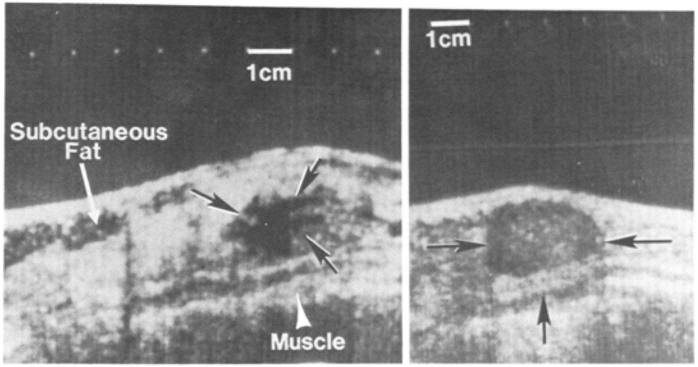
For 63% of masses, the wall structure was sufficiently visualized with both x-ray and ultrasound techniques that a comparison could be made between the two modalities in regard to the jagged or smooth appearance of the wall, and excellent correlation (84%) was found. In some cases, however, a mass that was well visualized with ultrasound imaging could not be adequately appreciated with x-ray techniques, although other changes of malignancy, such as asymmetry, abnormal increased density, and retraction of the skin were identified on the x-ray mammogram (2). This can be accounted for by the fact that the x-ray mammogram is an image of all of the breast tissue compressed into a single

Figure 2



Maximum diameter of benign masses retrospectively analyzed for their ultrasound imaging characteristics. Of the total of 31 masses analyzed, three could not be measured due to their diffuse nature. The histologic types of benign lesions encountered in this study are also shown.

Figures 3 and 4



3. 4.

3. Ductal carcinoma in a 39-year-old patient. The ultrasound image demonstrates a markedly jagged wall (black arrows).

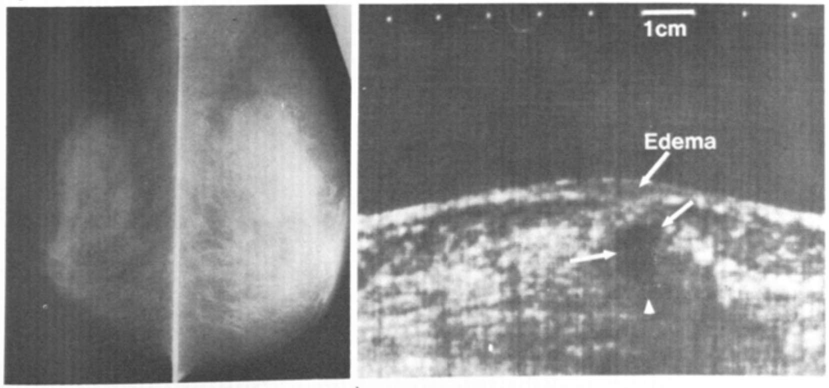
4. Ultrasound image of a fibroadenoma (arrows) in an 18-year-old patient. The image exhibits smooth walls and a homogeneous internal echo pattern. Slight posterior echo enhancement is seen. Enhancement of echo amplitude posterior to a mass is not unusual for low-density lesions.

plane, whereas with ultrasound, the lesions are being examined in tomographic planes (3) (Fig. 5).

Internal Echo Pattern

A homogeneous internal echo pattern was found in only 12% of the malignant masses; 71% of these masses exhibited nonhomogeneous internal echoes. In 17% of the malignant masses the internal echo pattern was not discernible, generally because of the marked attenuation effects of the tumor. If the 17% of cases with nonimaged internal echoes are excluded, then the internal echo pattern was nonhomogeneous in 85% of the cases. For ductal carcinomas, the internal echo pattern could not be definitively imaged in 18% of the cases, was nonhomogeneous in 70%, and was homogeneous in 12% of the cases. Additionally, many of the ductal carcinomas

Figure 5



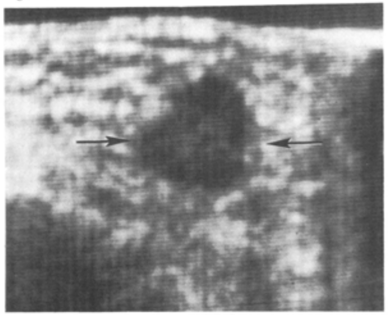
a. b.

Infiltrating ductal carcinoma in a 56-year-old patient.

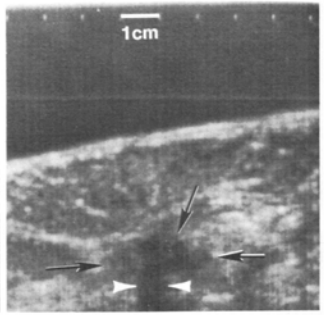
a. X-ray mammograms show asymmetric increased density and skin edema of the left breast, without a discrete mass.

b. The ultrasound image obtained in the region of increased density shows a well-defined mass (arrows) with skin edema and posterior shadowing (arrowhead). Highly reflective, probably fibrotic, tissue adjacent to the mass also shows posterior shadowing.

Figures 6 and 7



6.



7.

6. Ultrasound image of a ductal carcinoma (arrows), magnified 1.5X, in a 59-year-old patient. A nonhomogeneous internal echo pattern is present in the image of this mass.

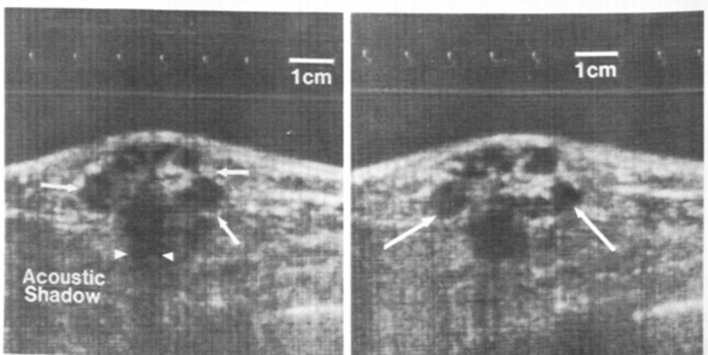
7. Ultrasound image of a ductal carcinoma (arrows) in a 69-year-old patient. Marked attenuation shadowing (arrowheads) was present throughout a large portion of the volume of this mass.

exhibited low-intensity echoes. A nonhomogeneous echo pattern is illustrated in Figure 6.

A homogeneous internal echo pattern is more characteristic of the benign breast mass (4) and, in this study, was found in 71% of the benign cases. Thirteen percent of the benign masses exhibited nonhomogeneous echoes. In 16% of the benign masses, the images of internal echoes could not be adequately evaluated, either because so few echoes were imaged or they were not imaged with sufficient clarity. However, only one fibroadenoma exhibited this characteristic. Since the other benign cases consisted of fibrocystic disease, fat necrosis, and florid intraductal papillomatosis, it is probable that the failure to image internal echoes adequately in these cases was associated with attenuation effects of fibrous or necrotic tissue. If such cases are eliminated and only masses for which adequate imaging was obtained are evaluated, then 85% of benign masses exhibited homogeneous echoes.

Eighty-nine percent of fibroadenomas exhibited a homogeneous internal echo pattern. A typical textural pattern is shown in Figure 4. In one fibroadenoma mass, the echo pattern was not well visualized, and in another a nonhomogeneous internal echo pattern was present. This latter mass occurred in a 53-year-old patient, and showed a transonic area that may have represented a small area of degeneration within the mass. Fibroadenomas that do not spontaneously recede eventually tend to undergo atrophy, hyalinization, and calcification (5). Nonhomogeneous internal echo patterns were found in only three other benign masses: a breast abscess, a foreign body response, and fibrosis.

Figure 8



a. b.

Ultrasound images of a medullary carcinoma (arrows) in a 63-year-old patient, demonstrating attenuation shadowing (arrowheads, **a**) posterior to only a small region of the mass. Image **b** was obtained only 3 mm distant from image **a**. Note lack of attenuation shadow posterior to this section of the mass.

Attenuation Characteristics

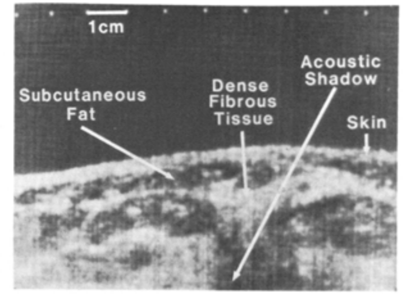
For the primary ultrasound frequency used in this study (3.7 MHz), attenuation shadowing was found to be a significant feature for diagnosis. Ninety-three percent of the malignant masses exhibited shadowing either through a portion or throughout the entire volume of the lesion, and this shadowing was marked to moderate in 73% of these cases. For well over half of the cases, the attenuation effect was not evident over the full volume of the mass; rather, it was associated with only a small volume of the mass (6). This means that scanning at large increments (3–5 mm or greater) could have resulted in missing this characteristic in 25 masses (61%) that proved to be malignant. A typical example of attenuation shadowing posterior to a malignant mass is demonstrated in Figure 7. Figure 8 is an example of a mass that exhibits shadowing in only a narrow region. Ninety-seven percent of ductal carcinomas exhibited attenuation shadowing, with 79% of these being marked to moderate; the attenuation effect was present in only a portion of the tumor in 64% of the cases. The malignant masses that demonstrated no acoustic shadowing were a necrotic ductal carcinoma, a medullary carcinoma, and an intraductal carcinoma.

In approximately 55% of the benign masses there was no demonstrable acoustic shadowing, in 16% very slight shadowing, and in 29% there was marked to moderate shadowing. Three of these latter masses, which consisted of either fibrocystic disease, fat necrosis, or foreign body response, demonstrated a dense shadow throughout the entire volume of the tumor. Kelly-Fry *et al.* (7–9) have previously reported the phenomenon of attenuation shadowing posterior to benign masses. In some cases of fibrocystic disease the highly echogenic fibrous tissue superior to the shadow, along with an ill-defined mass, alerts one to the diagnosis; this is demonstrated in Figure 9.

For fibroadenoma masses, slight attenuation shadowing could be discerned in 17% of the cases, but for the majority of cases (67%) no attenuation shadowing was evident. Sixteen percent demonstrated marked to moderate shadowing in a small portion of the mass, but no fibroadenoma showed shadowing over the entire volume.

The lateral shadow has been described by many previous authors as one of the characteristics of a benign mass (10–12). In our study, the lateral shadow sign was present in only 35% of benign masses, and was also found in 15% of malignant masses. The presence of this feature was not significant in this study for differentiation of benign from malignant masses.

Figure 9



Ultrasound image of confirmed fibrocystic disease and fat necrosis in a 43-year-old patient. An ill-defined area with attenuation shadowing, presumably associated with the overlying fibrous tissue, is present.

DISCUSSION

The large percentage of malignancies in our study that demonstrated shadowing (93%) is in contrast to some previously published data of Fields (13) and of Ueno *et al.* (14). Fields (13) found attenuation shadowing in only 43% of breast malignancies. Ueno *et al.* (14) found that only 50% of the scirrhous masses showed shadowing; for other classes of malignant masses the percentage figure for attenuation shadowing was much less. The discrepancy may be due to the fact that, in our study, acoustic shadowing was determined by searching millimeter by millimeter for the presence of this phenomenon in all regions of the mass. Kobayashi found that 83% of malignant masses, and 100% of scirrhous tumors, exhibited attenuation shadowing (15).

The fact that 29% of benign masses were found to exhibit moderate to marked shadowing clearly indicates that attenuation shadowing is not restricted to malignant masses. Kelly-Fry *et al.* (7) have pointed out that, in the "double pass" of the sound beam in pulse-echo methods, an attenuation shadow can result for some benign masses when they are imaged at commonly applied sound frequencies.

In order to evaluate the benign *vs.* malignant character of a solid breast mass by ultrasonic imaging, attention must be paid to several imaging characteristics rather than any single characteristic. The evaluation of wall characteristics, attenuation shadowing, and internal echo pattern, together with the patient's clinical history, is usually sufficient for accurate diagnosis. The entire volume of the mass must be scanned at close intervals (1 mm) if adequate evaluation is to be accomplished.

Analysis of the data in this study for the most common malignant breast mass, the ductal carcinoma, showed that the images of these masses exhibited a jagged wall in 88% of the cases, nonhomogeneous echoes in 70% of the cases, and homogeneous echoes in only 12%; 18% could not be visualized due to attenuation effects, and posterior shadowing was present in 97% of the cases. In 88% of the cases, the internal echoes were either nonhomogeneous or so attenuated they could not be imaged. By contrast, images of the most common solid benign tumor found in the young breast, the fibroadenoma, exhibited smooth walls in 94% of the cases, homogeneous internal echoes in 89% of the cases, and no demonstrable attenuation shadowing in 67% of the cases. In view of similarities between medullary carcinomas and fibroadenomas (16, 17), as well as the rare possibility of a fibroadenoma-like mass harboring a malignancy, extreme care must be taken in documenting all of these three characteristics for the full volume of the mass. The two medullary carcinomas encountered in this study demonstrated a slight jagged appearance of the wall structure and a markedly nonhomogeneous internal echo pattern, and one of the masses showed enhancement of echoes posterior to the mass.

SUMMARY

A retrospective analysis of the ultrasound imaging characteristics of pathologically proved solid benign and malignant masses showed that specific ultrasound imaging characteristics predominate in certain breast pathologies. The wall contour of breast masses, as visualized by ultrasonic imaging, is a significant feature for diagnosis and correlates well with the radiographic characteristics; malignant masses predominantly exhibit the jagged wall structure, and the most common solid benign mass in the young breast, the fibroadenoma, is typically a smooth-walled structure. The textural features of the mass, as characterized by the internal echo pattern, are predominantly nonhomogeneous in the malignant mass, and homogeneous in the benign mass. Attenuation shadowing may be present in the images of both the benign and malignant mass, but it is a much more common feature of the malignant mass (by a factor of two), and a greater degree of shadowing is generally present in the images of malignant masses. Adequate appreciation of these features will result if an instrument is used that provides good imaging of the fine structure of the breast tissue and if the entire volume of the mass is examined at close intervals.

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