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ULTRASONIC VISUALIZATION OF THE BREAST

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Ultrasonic visualization of the breast allows a detailed cross-sectional representation of the tissue composition of the breast and the underlying structures. The technique has been found useful in determining the extent of involvement of breast disease and in particular for demonstrating the size, position and attachment of space-occupying masses.

ULTRASONIC VISUALIZATION of soft tissues has been used with considerable success in obstetrical and ophthalmological investigations (Robinson *et alii*, 1967; Hughes and Dadd, 1969). The technique provides an accurate anatomical cross-sectional picture of the examined organ showing very small changes in tissue structure. Because sound, which is a mechanical form of energy, is used in the examination, the technique has been shown to provide information not obtained by other methods.

Investigations of the breast began in the 1950's (Wild and Reid, 1954), when it was shown that tumours may be visualized ultrasonically. More recently several other investigators (Tanaka *et alii*, 1965; Wells and Evans, 1968; Deland, 1969; Kelly Fry *et alii*, 1969) have successfully displayed echograms of various types of breast disease. A joint project between the Commonwealth Acoustic Laboratories and the Professorial Sub-Unit in Surgery of the University of Sydney located at The Royal North Shore Hospital of Sydney (Buddee *et alii*, 1969) was organized to study the applications of ultrasonic visualization of the breast, and the clinical investigations were started in 1967.

The central component of the equipment (Figure 1) is a transducer which emits pulses of ultrasonic energy into the breast. Echoes are received by the same transducer from changes in tissue structure, displayed on an oscilloscope as intensity modulation of the trace (Robinson *et alii*, 1967). The oscilloscope is used in a normal mode with the camera shutter being open during the time when the transducer sweeps across the patient. This method of storage allows more shades of grey to be recorded on the "Polaroid" film than the method used previously, in which the echogram was stored by the oscilloscope itself operating in the storage mode. The intensity of the trace is adjusted to show a light grey in the absence of echoes, ensuring that small echoes will modulate the trace and therefore be recorded on the film.

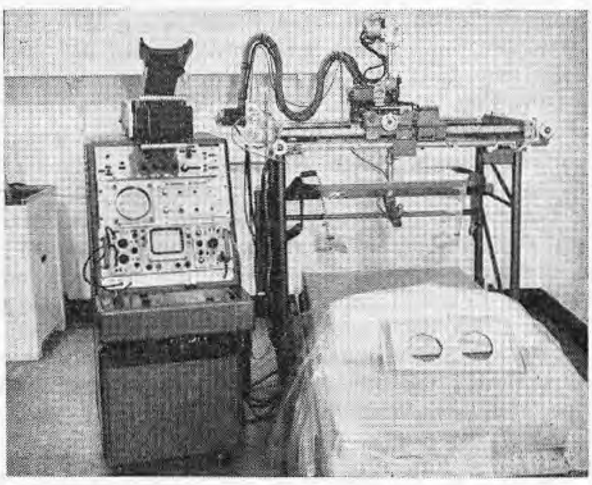

FIGURE 1: Ultrasonic echoscope.

Each patient is fitted with a surgical drape which has appropriate openings to allow exposure of the breast to the water into which the transducer is immersed. An aerosol adhesive is used to ensure that a watertight seal is obtained between the skin and the drape. A secondary "Perspex" tank supports the drape, and is filled with water kept at 30°C. This open-tank method of coupling is superior to the previously used closed polyethylene tank, which, when lowered onto the patient, compressed and distorted the breast. With the open tank, the breast is not constrained and thus assumes its natural shape, which facilitates the interpretation of the echograms.

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The transducer is focused at a distance of 10 cm to give a lateral resolution of 2 mm and a depth resolution of 1 mm. An electronic focus marker is inserted in the echograms and represents the region of best focus. For optimum resolution, the focus marker should intersect the structures of interest much in the same way as a microscope is focused, in order to obtain the sharpest image. The graticule on the echogram, represented by the parallel black vertical and horizontal lines, gives the scale factor which is normally either 1:1 or 1:0·75 reduction. Serial sections are usually taken 2·5 mm apart to obtain a complete representation of the breast.

The interpretation of echograms requires knowledge of the echo-producing structures. The size and the tissue content of the breast varies and is dependent on the age, the habitus and hormonal cycle of the patient at the time of the examination. To aid the interpretation, specimens of breast tissues were ultrasonically scanned, sectioned, and then photographed. A comparison was then made and the echo-producing tissue interfaces identified. A typical section (Figure 2) and its echogram (Figure 3) are illustrated. When the breast is examined, the transducer moves above it, in a lateral plane, known as linear scanning, whilst also undergoing oscillations about its own axis, which is known as sector scanning. The combination of linear and sector scanning is known as compound scanning. The nipple is easily recognized, and the thickness of the skin may be measured. Skin thickening may indicate the presence of malignant tissue, so that this measurement may be of clinical significance. The technique is also sufficiently sensitive to show the change in composition of the skin over the breast and the areola, especially when the transducer undergoes only sector scanning. The subcutaneous fat does not in itself produce strong echoes and appears as a light grey background. The fat is lobulated, and some of the boundaries between the lobules produce echoes, as can be seen on either side of the nipple. The fat beneath the glandular tissue also does not produce strong reflections. In this echogram, the glandular and ductal tissues which terminate at the nipple are displayed only when they are at right angles to the ultrasonic beam. Directly beneath the nipple, they are viewed mainly along the beam and produce much smaller echoes. They are not displayed in this echogram, but have been displayed with recent improvements in sensitivity (Figure 4). Away from the nipple the glandular tissues produce strong echoes. Strong echoes are produced by the pectoral fascia outlining the pectoralis major muscle and by the clavipectoral fascia outlining the pectoralis minor muscle.

In the normal method of coupling, the patient is supine and exposed to the water. In the axilla method, the patient is tilted, allowing coupling of only one breast and its axilla. The normal method allows detailed examination of the inner quadrants and the sternum, but is less suitable for scanning the outer quadrants which, being on the extremities of the transducer path, are not seen by the transducer as many times as the centrally located structures. The axilla method is used whenever the structure of interest is lateral to the nipple, and allows detailed examination of the outer quadrants and the axilla. Three echograms are generally required for a complete cross section of both breasts obtained by the normal method (Figure 5). The orientation is such that the echogram represents the section obtained when viewed from the head. The previously described tissues are clearly outlined, and the echogram illustrates the large amount of information which can be obtained about the tissue composition of the breast and the underlying structures.

The presence of the diseased tissues is displayed by the intrusion of tissue amongst the normal structures of the breast and by the displacement of the normal echo-producing interfaces. Unfortunately the large amount of the information from the normal tissues tends to mask the subtle changes associated with pathological conditions.

Liquid-filled cysts are easily recognized (Figure 6), being displayed as circular structures with no internal echoes. The top and bottom surfaces are clearly defined, while the side walls are not well delineated, owing to the inclination of the beam. Cysts up to 1·5 cm in diameter tend to be circular in cross section. Larger cysts are usually more irregular, owing to more severe constraint from surrounding tissues. The number of cysts in any particular cross section may be counted, and by taking serial sections, the total number of cysts and their relative positions may be accurately determined. The focus marker may be seen intersecting the two top cysts. The same cross section examined by the axilla method of coupling (Figure 7) illustrates the additional information obtained from the outer quadrants and the axilla and a small loss of detail from the inner quadrants.

The extent of skin involvement produced by von Recklinghausen's disease may be ascertained (Figure 8). The echogram shows the skin to be up to 0·8 cm thick over the diseased area. The echogram also shows a liquid-filled cyst, whose existence was undetected before the ultrasonic examination.

A lactating breast (Figure 9) has numerous echo-free areas radiating from the nipple, which most likely represent liquid-filled areas. So far we have been unable to distinguish individual ducts in the breasts, but it is hoped that these will be outlined by improvements in the resolution. In the three cases of examined lactating breasts the lobules of fat, which are evident in the normal breast, are reduced, as the breast consists mainly of glandular tissue. This tissue appears to be more attenuating, reducing the strength of deeper echoes.

Fibroadenosis of the breast appears as a diffuse pattern of groups of incomplete lobulations containing internal echoes dispersed amongst the normal echo-producing structures (Figure 10). The interpretation of these patterns has been uncertain, since it is not a condition for which the breast is removed, and therefore there has been no comparison with histological sections.

As yet we have seen few cases of fibroadenoma. The illustrated example (Figure 11) shows it to be a smoothly outlined mass with few internal echoes.

Scirrhous carcinoma (Figure 12) generally intrudes into the normal tissue contours, producing discontinuities in the normal outlines. The tumour usually has jagged edges, shows some degree of encapsulation and contains small internal echoes. Skin attachment, where it occurs, may be visualized (Figure 13).

Once a tumour is outlined, it is examined in more detail with sector scanning, where the transducer undergoes lateral oscillations, but does not move across the patient. Although the method gives less complete representation, it is possible to display weaker echoes. For example, scirrhous carcinoma with a characteristic but less-defined jagged outline, when examined with compound scanning (Figure 14), appeared as a single large mass. A sector scan of the same tumour (Figure 15) shows it to consist of three areas of involvement.

The scanning of high-risk patients has shown masses up to 1 cm in diameter whose origin is still unconfirmed (Figure 16). With greater correlation between ultrasonic scanning and histological sections, these presently unidentified masses will be interpreted and will allow diagnosis at earlier stages.

Most investigators have assumed a constant velocity of sound through the breast. Measurements *in vivo* (Kelly Fry *et alii*, 1996) have shown that the velocity in the breast varies from 1,445 to 1,575 m/sec, depending on the amount of fat, glandular and fibrous tissue present. Electronic compensation is being developed to allow for this variation relative to the velocity of the water-coupling medium.

CONCLUSION

Ultrasonic echoscopy allows a detailed representation of the tissue composition of the breast. Much of this information is not available by any other diagnostic method. The wealth of available information makes the diagnosis of small masses difficult. More histological sections of normal and diseased breast tissue will facilitate the recognition of variations expected in the breast. The eventual identification of all echo-producing structures will allow the earlier diagnosis of breast disease.

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APPENDIX

The echoscope employs a 2 MHz. PZT5 transducer, 4 cm in diameter, with an epoxy lens with a radius of curvature of 5 cm. The focal region extends from 8·5 to 13 cm, while the focus marker is inserted at 10 cm. The transducer is energized at a repetition rate of 1·5 KHz. The echoes are amplified with time-variable gain, activated by the first echo, which gives a gain variation from 20 to 40 dB, then by a logarithmic amplifier with a dynamic range of 50 dB. An attenuator is used between the pre-amplifier and the logarithmic amplifier. The echoes are displayed on a Hewlett Packard 141A oscilloscope used in the normal mode and photographed on "Polaroid" film type 107. The transducer is swept linearly over a distance of 25 cm in 10 sec while undergoing oscillation of $\pm 25°$ every one second.

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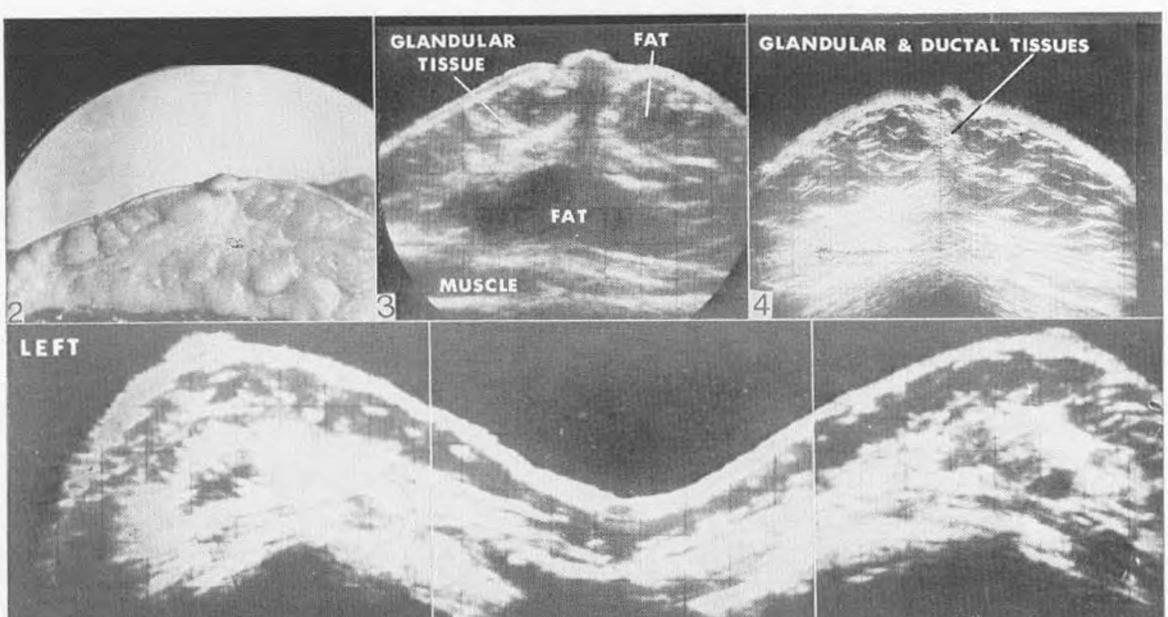

FIGURE 2: Section of a breast. FIGURE 3: Echogram of a section shown in Figure 2. FIGURE 4: Glandular and ductal tissues. FIGURE 5: Composite echogram of both breasts.

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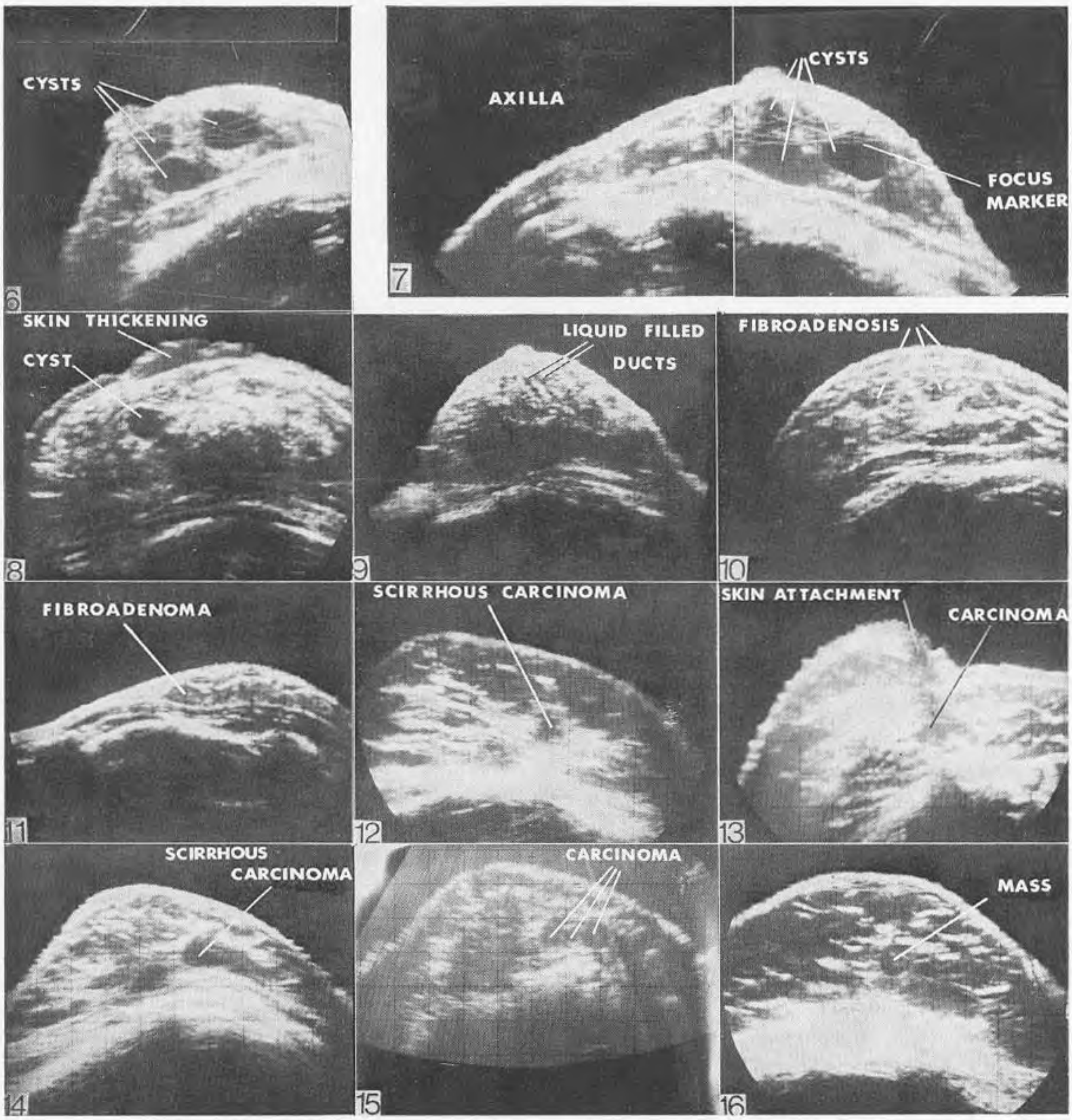

FIGURE 6: Liquid-filled cysts. FIGURE 7: Same section as in Figure 6, obtained by the axilla method of coupling. FIGURE 8: Skin involvement in von Recklinghausen's disease and cyst. FIGURE 9: Lactating breast, showing liquid-filled ducts. FIGURE 10: Fibroadenosis. FIGURE 11: Fibroadenoma. FIGURE 12: Scirrhous carcinoma; FIGURE 13: Skin attachment of carcinoma. FIGURE 14: An echogram of a tumour obtained with compound scanning. FIGURE 15: Same section as in Figure 13, obtained with sector scanning. FIGURE 16: An unidentified mass.