ADVANCES IN THE TECHNOLOGY OF SONOGRAPHY INTRODUCED BY THE ULTRASONICS INSTITUTE

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In 1955, on the advice of Norman Murray, the Director of the Commonwealth of the Acoustic Laboratories, the National Health and Medical Research Council of Australia set up, under his chairmanship, an Ultrasonics Committee, to keep brief on the developments which were occurring in applications of ultrasound in physiotherapy, surgery and diagnosis. In 1958, following publication by Ian Donald of his initial results in obstetrics, the Committee recommended that a permanent position of a physicist be created to undertake investigations in the field of medical ultrasound. The Committee also recommended that this position be staffed within the Commonwealth Acoustic Laboratories, which were part of the Commonwealth (Federal) Department of Health and were, at that time, the only organization in Australia to undertake investigations into acoustics. I was appointed to this position to head the Ultrasonic Research Section of the Laboratories in March 1959 on my graduation as Bachelor in Electrical Engineering, University of Sydney.

The next six months were spent reviewing the literature and .·-~arning about ultrasound. I found the text book by Heuter and Bolt a particularly helpful introduction into the physics of

ultrasound and a good lead into the fascinating literature into the bioeffects of ultrasound emanating from the Bio-Acoustic Laboratories of the university of Illinois, and which had given rise to the quote "Tissues Fry until they are Dunn", The publication by Jack Reid and John Wild were most instructive on the operational features of sonographic equipment while the superb images obtained by Doug Howry and Joe Holmes convinced me that we should attempt to develop a waterpath, compound scan echoscope for obstetrical examination.

Bill Garrett and I met in September 1959 and a formal liaison was established with the Royal Hospital for Women, Paddington, to set up a joint project to construct and evaluate an obstetrical scanner. David Robinson joined the Section in October 1960 and working in a true interdisciplinary manner, the three of us proceeded to obtain the first obstetrical sonograms in May 1962, just in time for presentation at the conference held at Allerton Park, Illinois later that month.[1]

The main technical achievement, at that time, was the development of criteria for the design of sonographic equipment,2 The spot size of the display unit was used as the unifying performance criterion and all aspects of the equipment, such as the transducer axial and lateral response, signal processing characteristics, position monitoring requirements and the mechanical stability of the scanner were designed to meet this criterion. The equipment and the quality of imaging that was achier 'd in June 1962 is illustrated in Figure 1.

Over the next seven years, Jack Je1lins, Mike Dadd and David

carpenter joined the Section and we undertook research into techniques to optimize the visualization of interfaces examined in the compound scan mode and displayed on bi-stable storage tube oscilloscopes. The scope of clinical applications was increased to include opthalmology which was investigated with Bill Hughes at the Royal Prince Alfred Hospital commencing in 1962, cardiology with David Wilcken at the Prince Henry Hospital and the examination of the breast with Tom Reeve at the Royal North Shore Hospital from 1964.

As the performance of the equipment was refined, particularly with regards to transducer dynamic range and side lobe level, we began to obtain low level echoes from within soft tissue. These did not have the same reflecting properties as the large interfaces between boundaries of organs and this led to the realization that we were obtaining echoes from a different class of interface, namely the small interfaces representing the structural and glandular organization of tissue, The magnitude of echoes from large specular reflectors is highly affected by their geometry and cannot be used as a reliable clinical indicator of impedance mismatches which are present. Small interfaces reflect the incident beam diffusely and as such do not have significant inclination dependence. The magnitude of the echo received from soft tissue is determined by the number of interfaces within the ultrasonic beam and the internal impedance mismatches and as such is influenced by the morphological condition of the tissues. The techr',ue of grey scale echography was introduced in September 1969 by modifying the equipment to allow the display of magnitude

of echoes by time exposing a photographic film during the scan and by changing the non linear characteristic of the signal processing to emphasize the display of echoes received from internal interfaces while compressing those received from specular reflectors.[3],4 The change in appearance of sonograms and the wealth of increased clinical information obtained in going from bi-stable to grey scale echography is illustrated in Figure 2.

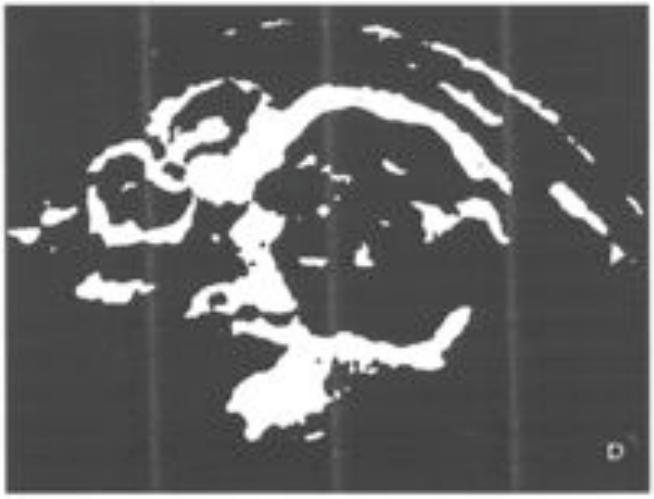
In 1972/73 Dave carpenter spent sabbatical leave with Kit Hill at the Royal Marsden Hospital, London. There he transferred the grey scale technology to the contact scanner in use at that hospital and participated with Ken Taylor in the introduction of grey scale scanning to the examination of the upper abdomen.[S] Example of scans obtained with this equipment are shown in Figure 3,

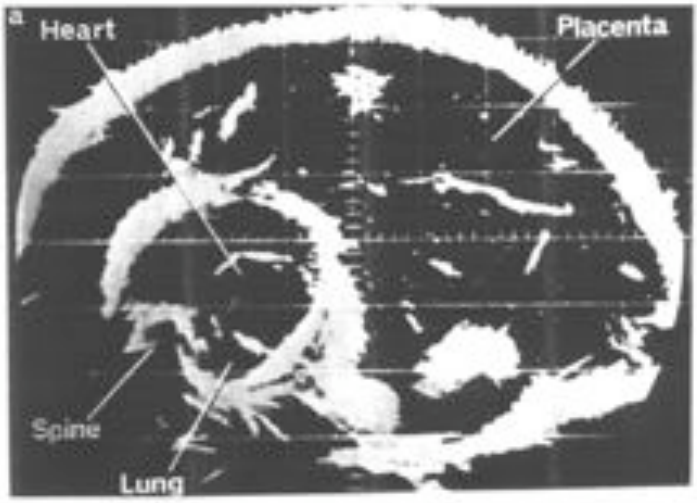
Research into the technology of ultrasonic transducers has always been a major activity of the Ultrasonic Research Section. The contributions include design techniques to optimize the beam patterns of focused transducers[6] and the use of quarter-wave matching techniques to improve the axial response.[7] In 1973, the Section introduced to clinical imaging, the use of large aperture, mechanically prefocused, annular array transducers.[8] The original transducer operated at 2MHz, was 13 cm in diameter and consisted of a central disc with seven outer rings and generated a dynamically focused beam over a depth of 17.S to 40 cm. The array and its beam pattern are shown in Figure 4.

T May 1975, the Ultrasonic Research Section was established as an independent Ultrasonics Institute of the Commonwealth

Department of Health. Shortly after the Institute initiated research into Doppler techniques, when Bob Gill joined the Institute in August 1975. Methods to measure the velocity of blood flow were being studied by many investigators at that time and the thrust of the research of the Institute was to develop a quantified technique to allow volumetric measurement of flow in vessels. This was achieved in 1977 by combining the information on the diameter of vessel and its spatial orientation obtained by sonography with that on the average velocity of the blood flow obtained by pulsed Doppler which uniformly insonified the vessel. The technique was introduced in obstetrics in August 1977 to measure the blood flow to the fetus supplied by the fetal umbilical vein. The principle and first results obtained by the technique[9] are illustrated in Figure 5.

In summary, the advances attained by the Ultrasonic Institute have been the result of the combined effort by the professional and technical staff of the Institute, We have been fortunate to have had the opportunity to undertake our joint investigations with outstanding c1inicians/u1trasono1ogists in particular Bill Garrett, Tom Reeve, Peter Warren and Richard Picker. They pioneered not only new clinical applications but also made many contributions which impacted technical achievements as befits true interdisciplinary research and share with us the achievements of the Institute. The beaming faces of the staff of the Institute and of the clinical consultants are shown in Figure 6,

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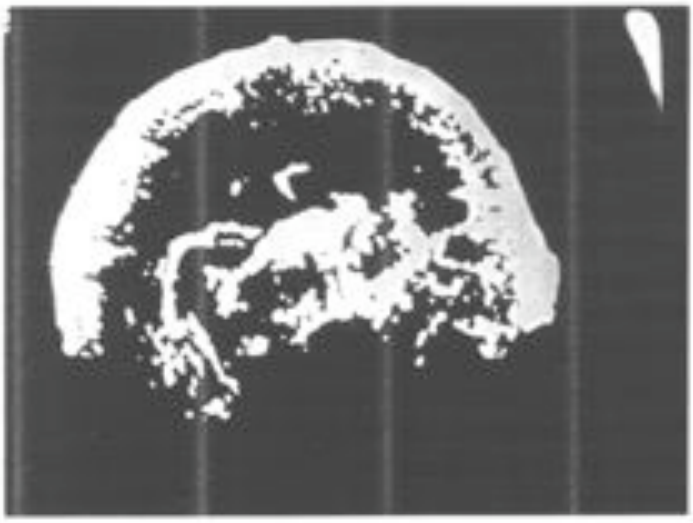

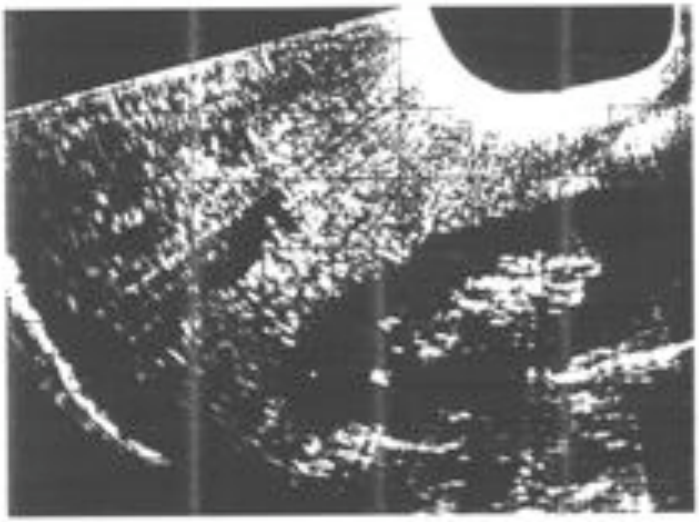

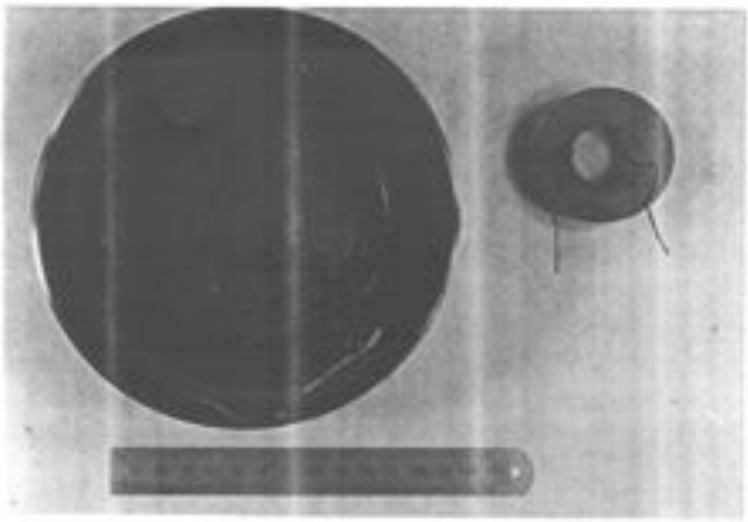

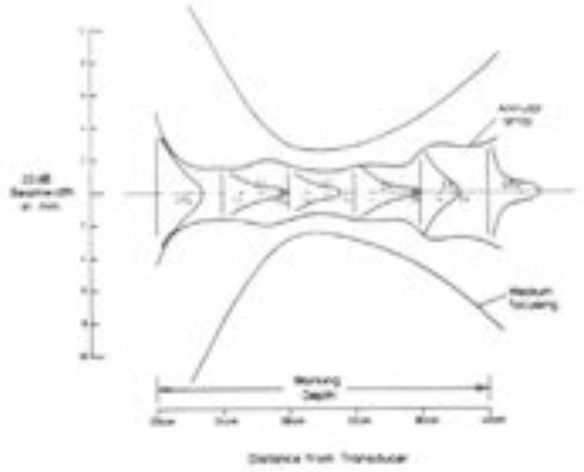
Working
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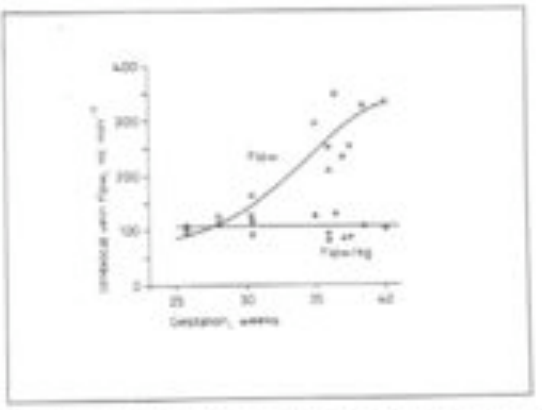

Fig. 2. Fetal umbilical vein flow in 12 patients, showing that flow per kilogram of fetal weight remains essentially constant.

FIGURES

Figure 1
- a) The CAL Mark I obstetrical scanner
- b) Echogram of the fetal trucnk obtained in 1962. The fetal spine and limb are visualized.

Figure 2
- a) Bi-stable and b) Grey scale echogram illustrating the increased clinical information obtained with this technique.

Figure 3
- a) ai-stable and b) Grey scale echogram of the upper abdomen.

Figure 4
- a) Dynamically focused annular array used clinically in 1973 and b) Beampattern of the array.

Figure 5
- a) Principle of volumetric flow measurement technique and b) First measurements of flow in the fetal umbilical vein,

Figure 6
- a) Staff of ultrasonic Institute at the time of its establishment in May 1975.
- b) More recent photograph of the clinical consultants to the ultrasonic Institute.