ASUM Ultrasound Bulletin 2004 August 7:3: 22–26

An historical look at ultrasound as an Australian innovation on the occasion of the ultrasound stamp issued by Australia Post – 18 May 2004

Kaye A Griffiths

Figure 1a CAL MKI Abdominal echoscope, under construction. Left David Robinson, right George Kossoff

Figure 1b Obstetrics ultrasound examination. Foreground, George Radovanovich DMU, Background, Patricia Horton, midwife

18 May 2004 – Australia Post issued stamps recognising five Australian Innovations, and featured these innovations to illustrate and celebrate the spirit and culture of Australian innovation[1]. This stamp issue suggests that, while 'they may not be Australia's best known innovations, they are now part of everyday life, not just in Australia, but around the world'. One of the five, 'Ultrasound Imaging 1976', recognised that 'George Kossoff and colleagues at the Ultrasonics Institute (then part of the Commonwealth Health Department, later transferred to the CSIRO) pioneered the use of ultrasound in medical diagnosis. They made a technical breakthrough called 'grey scale ultrasound', which enabled them to produce images of much greater clarity and detail. It was an important step leading to the widespread adoption of ultrasound throughout the world'. The aim of this article is to provide a brief outline of that period, including presentation of some historical images.

The Ultrasonics Institute and its precursor, the Ultrasonics Research Section of the National Acoustics Laboratory, played an internationally recognised role in the development of medical uses of ultrasound. The Institute commenced in 1959, with George Kossoff as director and Dr William Garrett, obstetrician – Royal Hospital for Women, Paddington, Sydney, providing clinical advice. Its objectives were to conduct research in medical ultrasound to create a centre of technical expertise in the field and also to set up joint research programs with suitable organisations for the clinical evaluation of newly developed techniques. Within 10 years of its formation, the Institute had established dialogue with other medical fields in Sydney (1960 – Dr Herbert L Hughes, ophthalmologist, Royal Prince Alfred Hospital, Camperdown; 1964 – Prof Thomas S Reeve, surgeon, Royal North Shore Hospital, St Leonards; Prof Dennis E Wilken, cardiologist, Prince Henry Hospital, Little Bay). It was unique in its field in several respects:

Projects were initiated by a nucleus of engineers and physicists rather than clinicians. Despite the emphasis on clinical evaluation, technical advances were the heart of the Institute's work.

It enjoyed a stability of scientific and technical staff throughout its history.

This group of technical experts had close working collaborations with a variety of medical specialists with a complementary research interest who had clinical appointments at teaching hospitals in Sydney.

By 1969, the basic considerations of grey scale scanning were formulated, and all the echoscopes were modified to operate in this mode.

Grey scale imaging was introduced into the abdominal

Correspondence to
Kaye A Griffiths AMS, DMU
ANZAC Research Institute
Sydney University
CRGH
Concord NSW 2139 Australia
email kgriffiths@med.usyd.edu.au

(obstetrics), eye and breast ultrasound machines by 1970 following innovations in signal processing, image recording and transducer resolution. Imaging was initially obtained by a time-exposed film, the 'open shutter' technique, which was suitable for mechanically driven scanners, giving even and repeatable scan patterns. Following later technological development of the analog and digital scan converter, the technique could be installed in manually driven contact scanners, which became commercially available by 1974.

Obstetrics

In 1961, the first machine was constructed by Kossoff and David Robinson (CAL MK I Abdominal Echoscope). It consisted of a trolley running on a circular track, and performed compound scan motions, arc sector in the horizontal plane and linear sector in the vertical plane, through a water bath. The transducer was a 2.5MHz, 25 mm weakly focused disc. The original electronics were built entirely of vacuum tubes, and used a Hughes Tonotron storage tube for image display. The patient stood on an angled stretcher and her abdomen was brought into contact with the flexible window on the wall of the coupling tank (Figure 1). On 11 May 1962, the first Australian obstetrics examination was performed at the Royal Hospital for Women, Paddington, Sydney – David E Robinson, engineer and William J Garrett, obstetrician. Only one week later on 18 May, the examination showed that the fetus could clearly be displayed and that some echoes were seen within the fetal boundary (Figure 2). Examples of this work were presented by George Kossoff at a symposium, held at the University of Illinois, USA in June 1962, and were acknowledged as state-of-the-art for their time. It was the first step in establishing the international reputation of the Ultrasonics Institute.

A second and upgraded echoscope (MKII) was installed at Paddington in 1967 and became the focus of obstetrics research. The grey scale technique display for signal processing was incorporated into the scanner in 1970. This led to the first display of the soft tissue internal contents of the fetus and placenta, allowing the accurate distinction between liquid and solid tissues and their localisation (Figure 3).

A large aperture, eight element dynamically-focused annular array transducer was incorporated in 1973. Operating at 2MHz, it was 130 mm in diameter with a mechanical focus of 260 mm, used weak focus on transmission and full dynamic focus on reception. The beamwidth of 4 mm was significantly less than the fixed focus transducer. It improved image quality dramatically, as seen in comparative images of the fetal chest (Figure 4). Experience gained with this scanner formed the basis for the design and development of the UI Octoson in 1974.

The UI Octoson prototype was devised to overcome the issues of scanning a transducer over a long mechanical path, and began clinical trails at the Royal Hospital for Women in 1974, under the direction of David Carpenter and George Radovanovich. It used eight transducers on a circular arm, supported on a gantry operating inside a water tank and operated in longitudinal, transverse and oblique planes with automatic position incrementing. The eight transducers, which were mechanically linked, scanned simultaneously, but operated as independent ultrasonic transmitters and receivers. A full scan (8 transducers) took approximately 4 seconds, during which time about 500 ultrasonic lines of sight were obtained from each transducer.

The machine was set up similar to a water bed, with most examinations performed with the patient lying prone on a polythene membrane (Figure 5). It was excellent for its primary purpose, examination of the pregnant uterus. It was also exceptional for examining neonates who needed no

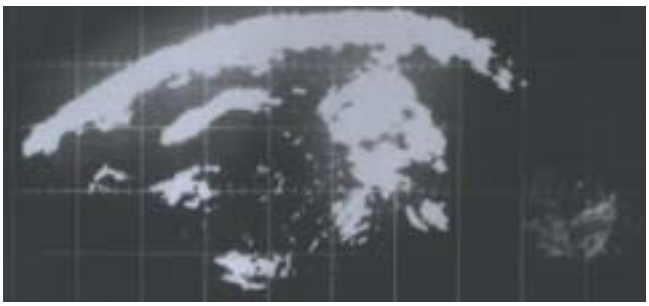

Figure 2 1962 obstetrics scan through fetal trunk, with the spine – defined by the 'pyramid' echoes to the left of the circular structure

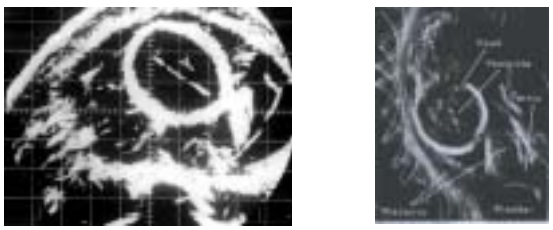

Figure 3c and Figure 3d Comparison of bistable and grey scale images of the fetal head (3c – CAL MK1; and 3d – CAL Contact Scanners). In Figure 3c, only 'specular' echoes within the head are seen, however in Figure 3d 'diffuse' reflectors display some brain anatomy and the placental location

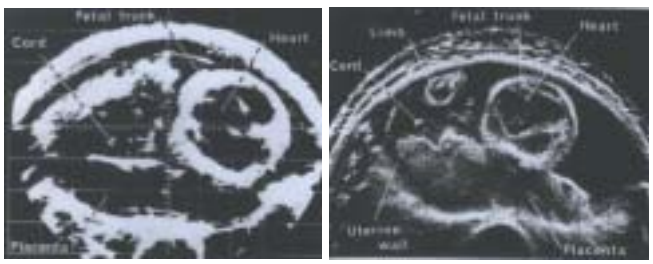

Figure 3a and Figure 3b (circa 1962–72) Comparison of bistable and grey scale images at the level of the fetal chest. Note the introduction of 'diffuse' reflectors allows delineation of the fetal lungs and also gives texture to the placenta

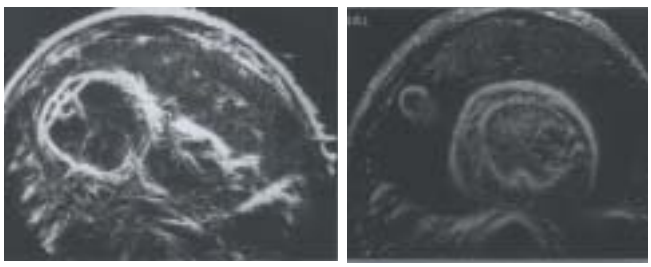

Figure 4a and Figure 4b Figure 4a comparison of grey scale ultrasound of the fixed focus transducer and, Figure 4b annular array transducer at the level of the fetal chest with improved image resolution

Figure 5 UI Octoson. Eight transducers encased within a water bath, allowing the patient to easily lie on a plastic membrane.

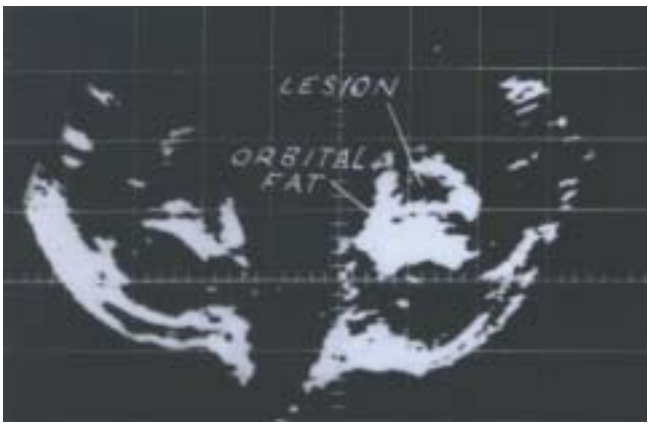

Figure 7a Bistable image of the eye identifying the anterior and posterior chambers and a retrobulbar tumour.

Figure 6 CAL Eye echoscope with patient coupling on the right and recording equipment on the left.

Figure 7b Grey scale shows an anterior chamber lesion with improved ability to demonstrate the anatomy and lesion dimensions.

sedation, and also for scanning the breast, which, for the first time could be scanned in the longitudinal and oblique planes. The UI Octoson was manufactured by Ausonics Pty Ltd, in Australia, and over 200 were sold world-wide between 1976 and 1985.

Ophthalmology

1964 saw the installation of the first ophthalmic echoscope at the Royal Prince Alfred Hospital Camperdown, Sydney – CN Liu (later Michael J Dadd), engineers; Herbert (Bill) L Hughes, ophthalmologist. The machine used a weakly-focused 8MHz transducer with a 20dB beamwidth of approximately 2.5 mm, and both eyes were examined in one pass, using compound scanning (Figure 6). The clinical emphasis was on the retrobulbar space. This machine was the first to have grey scale signal processing in 1969, and the technology was first described in 1971.

In 1972 a high resolution, grey scale machine with an 8MHz, 36 mm diameter highly focused transducer with a 20dB beamwidth of 1 mm was installed. It was motor driven and able to scan in both compound and simple modes. Each eye was separately examined, with the focal region optimised to the area of interest, leading to the examination and interpretation of pathologies in both the anterior and posterior chambers of the eye (Figure 7).

This machine was later further converted to allow imaging of the anterior neck, with clinical consultation provided by Dr Ernie Crocker, physician.

Breast

The first breast echoscope was installed at the Royal North Shore Hospital, St Leonards, Sydney in 1966 – Jack Jellins, engineer; Thomas S Reeve, surgeon. This machine, with a medium focused 4MHz transducer with 2 mm lateral resolution, could image in compound, linear and sector modes.

The breast presented coupling problems which were dealt with in different ways in successive machines (Figure 8). Initially, the patient laid supine with the transducer in a large water bag lowered onto her chest. However, the weight of the water resulted in tissue distortion and patient discomfort. The final modification to the machine saw the patient positioned prone with the breasts dependent in the water tank, while the transducer scanned from below.

Importantly, one of the first grey scale findings was the low internal echo amplitude of cancers, contrary to previous publications in which the high echoes from surrounding tissues had been reported as cancer.

This group documented a comprehensive range of primary diagnostic criteria including – disruption of architecture, internal echo content, boundary detail, central shadowing/enhancement, refractive edge shadowing and shape – for differentiating breast lesions.

Because the breast maintained its natural shape, secondary characteristics – distortion of skin outline, skin involvement, thickened Cooper's ligaments and attachments to surrounding tissues were added. Again the natural breast shape allowed the documentation of the breast appearance with parity and changes with aging.

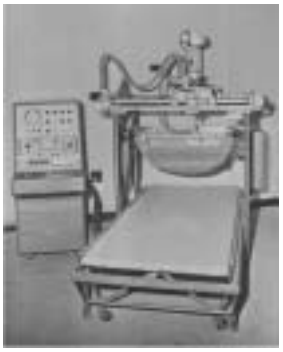

Figure 8a MKI breast echoscope (closed bag)

Figure 8c MKII breast (grey scale) echoscope with breast drape, which was adhered to the patient's chest wall

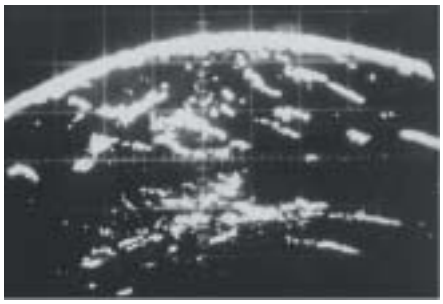

Figure 8b Note distortion of the breast by the weight of the water and only bistable tissue differentiation

Figure 8d MKII breast (grey scale) echoscope 5mm brest cancer with thickened Coopers ligaments and skin flattening

This machine was also modified, in 1974, to study the thyroid and the scrotum, again in consultation with Thomas Reeve.

Paediatric brain

With the recognition of the intracranial structures of the fetus, in 1972 attempts were made to study the intracranial structures in the newborn and older children, at the Royal Hospital for Women, again with William Garrett's consultation. A manually operated contact scanner, originally built in 1967, to investigate the differences between water delay and contact imaging was employed (Figure 9). The success of the method was critically dependent on the technique, as the grey scale images were captured on time-exposed film and perfectly even scans were necessary.

To scan with this machine (which was also used in obstetrics and abdominal examinations) each cross section, be it in early or late pregnancy, a panoramic image of an abdomen or the smaller target of a child's head, had to be scanned in 17 seconds. The sonographers' training in contact scanning techniques was undertaken by scanning in rhythm with a metronome and timed by a stopwatch until the technique was mastered! The development of the analog scan converter, thankfully relaxed the method. An ultrasound atlas of the brain structures was derived and development of this technique resulted in the cessation of pneumoenchephalography in 1974 (Figure 10).

In 1977, in a paper he presented by invitation, during the AIUM meeting in Dallas, USA, marking the 25th anniversary of cross-sectional echography, George Kossoff said of grey scale echography " . . . it is probably the transformation of the schematic sections that used to be obtained with bistable equipment to images that resemble anatomical sections that has played the greatest role in its acceptance . . .".

"Grey scale ultrasound imaging, an Australian innovation that is part of everyday life, not just in Australia, but around the world" has been recognised, 42 years-to-the-day from the capture of those inspiring images which were presented internationally the following month, by issue of this stamp! How precious is that?

Figure 9 CAL contact echoscope and paediatric brain examination, 1973. Left: Kaye Griffiths, centre: George Kossoff, right: Margaret Tabbrett.

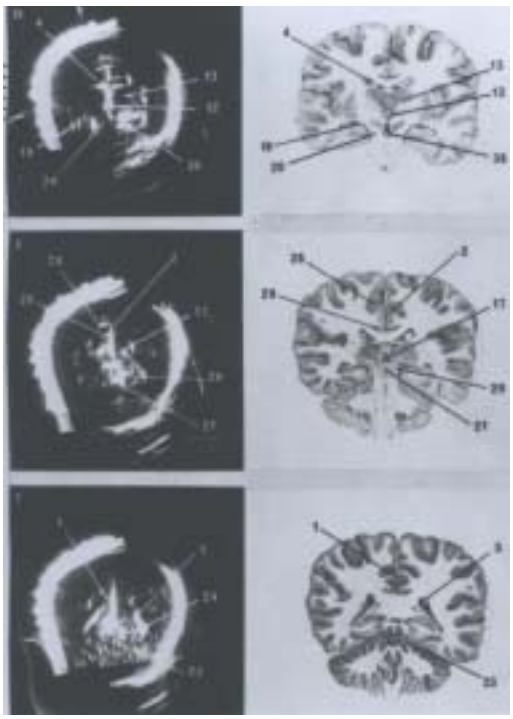

Figure 10a Left, grey scale images comparison of ultrasound anatomy with Echelscheimer's Brain Atlas (1972)

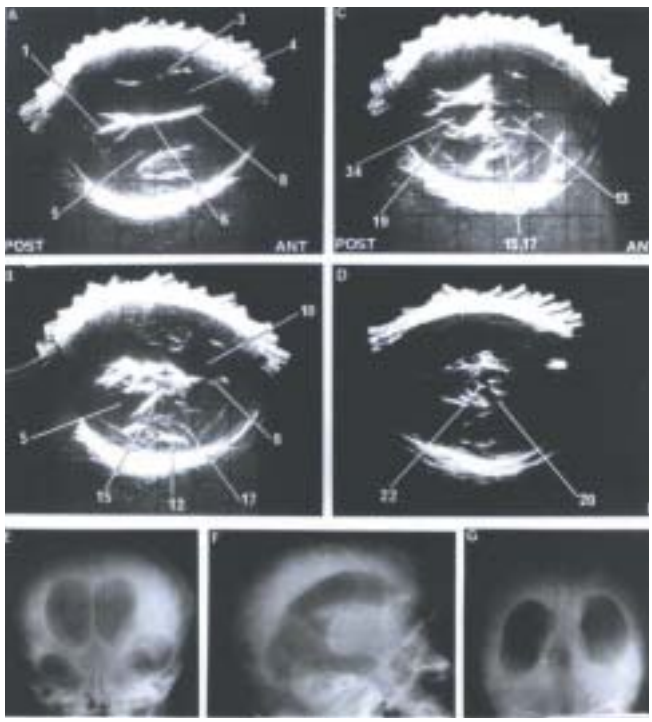

Figure 10b comparison of grey scale ultrasound enchephalography with pneumoencephalography (1974)

References

1 Australia Post's other Innovations Black Box Flight Recorder 1962; Raecam TV Sport Coverage 1979; Baby Safety Capsule 1984: Polymer Banknotes 1988. Australian Innovations Stamps designed by Mike Heine.
2 Diagnostic Ultrasound – the view from down under. JCU 1978; 6 (3): 144–149.