EFSUMB History of Ultrasound

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Introduction, Origins of BMUS

During the 1960s, members of the various British research groups working on the different ways in which ultrasound can interact with living tissues began to meet informally to exchange news of their work, in what became known as the Bioacoustics Discussion Group. At the same time, Douglas Gordon, a loner radiologist, was running a series of privately organised meetings on diagnostic topics. That time also saw the beginnings of serious interest in the investigative potential of ultrasound and the holding, in Vienna in 1969, of the 'First World Congress on Ultrasonic Diagnostics in Medicine'. It was at that conference that plans were launched to form an international, continent-based organisation of medical ultrasound societies – what became WFUMB – raising the question of how things might need to be arranged within Europe in particular. Sitting together in the back row during that session were two young physicists, Peter Wells and Kit Hill, who had already been making plans for a scientific meeting later in the year on what medical ultrasonics might learn from related fields, such as radar, sonar and NDT. The two promptly decided to use that meeting to also discuss setting up a British Medical Ultrasonics Group. This indeed happened, the name subsequently being changed, by others who thought that 'Society' would seem more dignified. The date was fixed for early December, as being the one clear space in the conference calendar. This became an annual cause for members' grumbles ("Too close to Christmas", etc), but it has never been bettered. Professor Ian Donald was elected first president, bringing in a refreshing view of the balance between science and administration: scientific sessions would finish at 17.25, allowing five minutes for the annual business meeting before drinks were served at 17.30. BMUG/BMUS was initially established with the help of the then Hospital Physicists Association and the British Institute of Radiology, on which its constitution was modelled: an equal partnership between clinicians and physical scientists, with an appropriately alternating presidency; Peter Wells became the second president.

Pioneers

Lord Rayleigh became the British father figure of acoustics with the publication, in 1877, of The Theory of Sound, which he had started writing (on the back of student exam scripts) during an 1871 honeymoon sailing trip up the Nile . Curiously, in 1911, shortly after the "unsinkable"

Titanic had hit an unseen iceberg, and sunk, it was on a similar trip, this time with his new wife rowing the boat, that the young Lewis Richardson, equipped with starting pistol and stopwatch, recorded the timing of acoustic echoes from cliffs off the south coast of England [(1)]. He took out a patent on his echo-ranging idea [(2)] but then, as a Quaker pacifist, decided not to follow it up for fear that it would be put to military use. But in vain: by October 1915 the nuclear physicist Rutherford was reporting "I am hoping to get quite a big scheme of scientific work started under the Admiralty..... My chief business deals with the acoustic detection of submarines[1]". Among the team sent down to Harwich to make trials was Frank Hopwood [(3)]. Some time later, when he had become professor of physics at St Bartholomew's (Barts) Hospital, Hopwood followed up his interest in ultrasound, particularly noting that, in parallel French wartime work carried out by Langevin in Toulon harbour, "fish entering a beam of high-frequency sound waves were frequently killed by it" [(4)].

Medical pulse-echo imaging only became feasible with the advent of the fast electronics that was being developed, by Firestone in USA and also in Britain by Watson-Watt and others, for use in radar. This particularly enabled methods of non-destructive testing in metals (NDT), with a device for the purpose – "Supersonic Flaw Detector" - being developed and manufactured in Glasgow by Henry Hughes & Son (later Kelvin-Hughes). It was an engineer working in this field, Donald Sproule who, in 1944, befriended John Wild, a trainee surgeon working in London at the North Middlesex Hospital, and seems to have given him an idea. Two years later Wild was practicing in Minneapolis and happily discovered a nearby US naval base that was using an ultrasonic pulse-echo device in a trainer for aircraft pilots. Wild gained entry, and was soon starting to publish the first of a remarkable series of papers that effectively set the agenda for much of the future work in the field of ultrasonic imaging [(5, 6)].

Accounts differ, but it was one of Wild's early papers that was picked up by either David Smithers or his colleague Val Mayneord, both professors at the Royal Marsden (then Royal Cancer) Hospital, in London, whilst two of their research students, Walton and Durdon-Smith, had seen, at an industrial exhibition, a Hughes flaw detector, and spotted its medical potential. The outcome was that work was started on possibilities for investigating anomalies in the

[1] This seems to refer to hydrophones. Echo methods seem not to have been used during WW1. Langevin's transmitter was continuous-wave, and thus lacked range resolution.

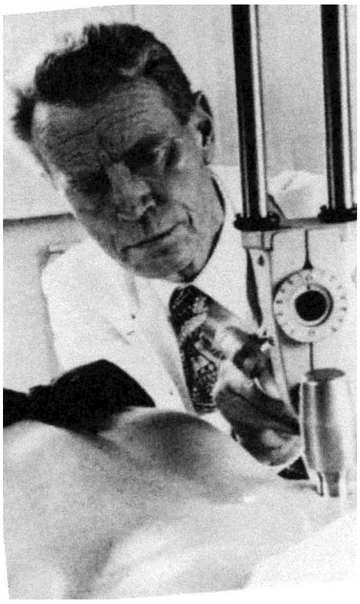
brain – then radiologically a frustratingly silent organ [(7)]. This seems to have been the start of European pulse-echo investigation. An historical account of the background to some of this work has been given by Francis Duck [(8)].

Figure 1 W Val Mayneord. European pioneer of medical echo.

Mayneord had earlier (1924-26) worked at Barts Hospital under Hopwood, and so was familiar with his ultrasound interest. But, as has since become evident, he was unfortunate in starting on the brain, acoustically awkward as it is. Even so it is interesting, in retrospect, that the later 1950s saw considerable activity internationally in so-called echoencephalography, with many of the main figures in medical ultrasonics at that time working in that field: people like Lars Leksell, Denis White, Hans-Ruedi Mueller and Carlo Alvisi. The Marsden work was initially with A-scans [(9)] and later progressed to development of a B-scanner [(10)], but its main impact was in arousing the interest and enthusiasm of a newly appointed Regius Professor of Midwifery in the University of Glasgow, one Ian Donald [(11)]. He (as did Wild) paid several visits to Mayneord, eventually taking home the Hughes flaw detector. Donald persuaded Kelvin Hughes to second to him one of their engineers, Tom Brown, forming a partnership that led to the development of the Diasonograph, a B-scanner specifically designed for obstetric work, which became the world's first commercial machine of its kind – marketed initially by Smith's Instruments and later by Nuclear Enterprises. Donald's powerful personality and strong principles led him to become very concerned with the ethical implications of his work

– particularly around issues to do with abortion, on which clinical responsibility could conflict with his religious background.

Figure 2 Ian Donald, with his Diasonograph. Pioneer of obstetric ultrasound.



With the honourable exception of Wild, who early on had grasped the need to record soft tissue echoes [(5)], much of the emphasis internationally in the 1960s had been on echoes from organ boundaries, which would be picked up preferentially by so called compound scanning, partly at the expense of recording tissue echoes. The answer to this came from technical improvements in display screen technology, coupled with a method of non-linear signal processing that had been developed by colleagues in Australia, under George Kossoff. With the help of a sabbatical visitor from that group, Dave Carpenter, a new team at the Royal Marsden were able to develop a scanner that could do a credible job of visualising abdominal pathologies [(12)], thus playing a part in what might be termed the “grey scale explosion” of the 1970s [(13)]. This was largely a European phenomenon. Back in 1955 an influential report from the US Atomic Energy Commission had concluded that echo techniques would never be able to penetrate beyond superficial tissues. Whether or not it was for that reason, in 1974, 24 Years after Wild started publishing his work, the US National Cancer Institute found it necessary to invite three of the Marsden team to come and tell them whether ultrasound might have a role in cancer management. There was a downside, however – for industry. After three years of apparently heavy investment in R&D, their Central Research Labs, working alongside the Marsden group, had made the EMI company ready to manufacture and sell what would be a top-of-the–range ultrasound scanner, to go alongside their already successful CT machines. But high finance intervened: the company was sold, to Thorn, who thought they could make more money out of entertainment than from 'difficult' medical equipment. Some Japanese companies thought otherwise.

Technology

Tissue Characterisation/Image Parameterisation

From the early days there was an awareness that tissue echoes could provide specific, diagnostically useful information, beyond just a relative amplitude. One of the first attempts at systematic measurement, by Mountford and Wells [(14)], was to quantify echo levels relative to that from a perfect reflector. A rather different approach was an exercise in the physics of scattering, in broad analogy to x-ray diffraction. First to tackle this was Chivers [(15)], whose work led to investigations, by Bamber and Dickinson, of the nature of the coherent scattering that had been a feature of all ultrasonic images [(16)]. This in turn led to ideas for eliminating speckle noise from images, and also, whether by speckle tracking or otherwise, extracting rheological properties of tissues ("remote palpation") – the process that has subsequently developed widespread use as Elastography [(17, 18)].

Figure 3 Bob Chivers, Pioneer of tissue scattering physics – basis for most modern tissue characterisation

Doppler/ Blood Flow

Several individuals in the early years of Doppler in the UK contributed to a meeting held in January 1972. Ray Gosling at Guy's, working with Dave King and John Woodcock are associated with two particular advances. First, they used arterial pulse transit time to quantify arterial stiffness in arterial disease. Secondly they used audio spectral analysis of the Doppler waveform, which was done initially with an off-line speech analyzer (Kay Sonograph) before on-line Fourier analysis became available. Another pioneer was Henry Light at Northwick Park Hospital, who developed 'transcutaeous aortovelography' to evaluate cardiac function from blood flow patterns in the aortic arch and also used spectral analysis to show the waveforms, possibly before the Guy's group [(19)]. Finally Peter Fish at King's College Hospital was a clear pioneer in pulsed Doppler, although his MAVIS artery mapping system was superseded by Doppler imaging. Fish was an engineer who designed and built his own equipment, whilst Light and Gosling used the recently-available Parks Doppler equipment imported from America. Eventually the Guy's group developed a strong relationship with the Doptek company under Mike Teague.

Interventional/Surgical ultrasound

During the 1960s several members of the Bioacoustics Discussion Group were pursuing an interest in interventional possibilities. In Bristol, Angell James and Peter Wells were developing an ultrasonic technique for treatment of Mèniére's disease – using a calorimetric method of dosimetry – whilst Wells was simultaneously studying the effects of ultrasonic treatment on freshwater *Daphnia*. At Guy's Hospital, in London, Mary Dyson was starting to elucidate the mechanisms - beyond merely heating - by which ultrasound might be acting in its use in physiotherapy. At the same time Roger Warwick, Ken Taylor and other Guy's colleagues were following up the work by Bill Fry's group, at the University of Illinois, on the ablative/surgical potential of highly focussed ultrasound (HIFU). Also interested in HIFU, and aiming initially to understand the underlying biophysical mechanisms, was Kit Hill, at the Royal

Marsden/Institute of Cancer Research [(20)]. Subsequently Gail ter Haar took over the project [(21)], taking it on to its present day, full clinical trials.

Safety and 'Dosimetry'

With the prospect of increasing clinical use of ultrasound, the British Institute of Radiology, in1967, commissioned a review of its possible safety implications. When this was published [(22)] it became the first systematic appraisal of the existing evidence (and was subsequently paid the dubious complement of being heavily plagiarised in a US Government report). A while later, Gail ter Haar worked on a similar report for WHO, and went on to chair, for its initial years, the EFSUMB so called "Watchdogs" (Committee on ultrasonic radiation safety). This itself, partly on a British suggestion [(23)], was modelled on the well-respected ICRP (International Commission on Radiological Protection).

Also in the late 1960s the UK Medical Research Council set up, initially in pilot form, a prospective epidemiological study of the likely costs and benefits of mass obstetric screening. In support of this MRC also established, at the University of Surrey, a project for development of a method of quantifying exposure of patients to diagnostic ultrasound beams. This would be based on the use of a hydrophone, calibrated against an acoustic force balance, that could plot the instantaneous acoustic pressure field of interest [(24)]. The project liased closely with the National Physical Laboratory (NPL), initially with Keith Shotton and later Roy Preston. Then in 1970, meeting in London, the International Electrotechnical Commission (IEC) set up a new working group, on Medical Ultrasonic Equipment, with Kit Hill as its secretary/coordinator. The group subsequently carried out work on a variety of topics, particularly on recommended methods for measuring the acoustic output of medical devices and their diagnostic capability. This brought the British work into particular collaboration with the ultrasonic work of the German counterpart of NPL: the *Physicalisches Technisches Bundesanstalt (PTB*), under Klaus Brendel [(25)]. From the outset, the Surrey group had forseen a potential widespread need, calling for commercial involvement, for exposure measurement devices. This came about, with some involvement of ex-Surrey and Marsden staff, through the formation of Precision Acoustics Ltd., a small company set up in the West of England that has become active internationally.

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