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OBITUARY

In memoriam: John R. Mallard (1927–2021)

David John Lurie[1] · **Peter Frederick Sharp**[1]

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John Mallard (Fig. 1) passed away on 25th February 2021. He made many important contributions to medical physics, particularly in imaging, and put together the team at the University of Aberdeen which built a whole-body MRI scanner in the late 1970s and used it for the world's first clinical diagnostic body scan in August 1980 [1].

John Mallard was born and brought up in the English town of Northampton. He attended the local grammar school, then won a scholarship to study for a degree in physics at the University of Nottingham (at the time a college of the University of London). His doctorate, also at Nottingham, was on "The magnetic properties of uranium and uranium-iron alloys". Following his PhD, he moved into medical physics in 1951, with his first job as Assistant Physicist at the Liverpool Radium Institute. His involvement with imaging started there, using hand-held detectors to map the distribution of ^{131}I in the thyroid gland. In 1953 he moved to London, to set up a National Health Service (NHS) radioisotope laboratory at the Hammersmith Hospital and Royal Postgraduate Medical School, where he became Head of Department in 1957. In the early 1960s he moved briefly to Guy's Hospital, before taking up the newly created Chair of Medical Physics at the University of Aberdeen in 1965, a position he held until his retirement in 1992.

Mallard's interest in magnetism, which began during his doctoral studies, continued throughout his career. While he was in London, he had started to investigate small samples of animal tissues using electron spin resonance (ESR) [2]. He found—much to his excitement—that tumours gave different ESR signals to those from surrounding normal tissues [3], providing an indication (probably for the first time), that magnetic resonance might provide the means to diagnose cancer non-invasively. Although he had published this work in Nature [2, 3], it went largely un-noticed by the research community at the time.

When he moved to Aberdeen in 1965, Mallard brought equipment with him from London, including the ESR spectrometer. Already convinced that magnetic resonance would become a useful tool in medicine, he started to hire staff to take this work forward; one of his first appointments was James (Jim) Hutchison, who had completed his PhD in ESR at St Andrew's University. At Mallard's behest, Hutchison built a 100-MHz ESR spectrometer intended to study mice in vivo [4], but limitations of the technology available at the time meant that animal studies on the device were not successful.

Meanwhile, Damadian had shown in 1971 that the NMR spin–lattice relaxation time could be used to differentiate between ex vivo normal and cancerous tissues from the rat [5], so the decision was taken that the Aberdeen team should investigate NMR, as well as ESR. Roy Gordon had already joined the department as a PhD student; having read Damadian's paper he switched his research topic to NMR and, working with Hutchison, put together an electromagnet-based pulsed NMR spectrometer that allowed the measurement of relaxation times in biological samples [6]. When Lauterbur demonstrated that imaging by NMR using magnetic field gradients was possible [7], the Aberdeen team quickly added a planar gradient-coil assembly to

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✉ David John Lurie
d.lurie@abdn.ac.uk

[1] Biomedical Physics, School of Medicine, Medical Sciences and Nutrition, University of Aberdeen, Foresterhill, Aberdeen AB25 2ZD, UK

Fig. 1 John Mallard in 2012. Image courtesy of the University of Aberdeen

their home-built device and repeated Lauterbur's experiment using a capillary-tube phantom; the hardware and results were described in Roy Gordon's PhD thesis [6]. Following these successes, Mallard and Hutchison went on to build a new device, based on a commercial 0.06 T Watson type permanent magnet, capable of imaging mice using NMR [8]. The scanner employed stepwise-rotated gradients and spin-echo detection to produce two-dimensional images using projection reconstruction, with an inversion pulse included to provide T_1 information. Since the imaging procedure took *ca.* 1 hour, the animal was euthanised by cervical dislocation prior to the experiment. The resulting T_1-weighted image clearly showed the different organs as well as the oedema around the animal's broken neck, representing the first demonstration of pathological changes by MRI.

Mallard was determined that the Aberdeen team should go directly from mouse to man, without any intermediate jumps in scale. After a struggle, he persuaded the UK's Medical Research Council to provide a grant of £30,000 to build what would become the Aberdeen Mark-I scanner. The 0.04 T resistive magnet was built by Oxford Instruments to Hutchison's design and was delivered in 1977. By this time the NMR team had been bolstered by the addition of several PhD students and by American postdoctoral researcher Bill Edelstein; together they designed and built the scanner, which incorporated RF coils made from copper pipe from a hardware store and gradient coils wound on a discarded plastic tube from a local park's playground. Mechanical parts (including water cooling for the magnet) were built by Mallard's departmental workshop. Initial results from the scanner, based on line-scanning techniques, suffered from severe motion artefacts [9]. However, in 1980 the team demonstrated the spin-warp method [10], resulting immediately in images which were artefact-free and of genuine diagnostic quality. A steady stream of patients was imaged using the scanner, thanks to the enthusiasm of radiologist Francis (Frank) Smith [1].

The Mark-I scanner's location in the University Medical School and its technical limitations meant that there was soon a desire to build a new version, planned to be sited in the hospital itself and to have a stronger field and wider patient bore. Funding for this device could not be found in the UK, but Mallard's persuasive nature again came to the fore, and the 0.08 T Mark-II scanner was constructed by the team [11], funded by a Japanese company (Asahi Medical) in exchange for know-how. The scanner was used as the prototype for a company, M&D Technology, that was set up by Mallard in Aberdeen to market the devices, but a lack of finance (and the fact that low field was already going out of fashion in the mid-1980s) resulted in only three scanners being sold. (Ironically, a 0.1-T scanner produced to a similar design by Asahi went on to sell almost 150 devices in Asia.)

To mention only John Mallard's success with MRI would be to miss out a large part of his career and his innate talent for spotting winning medical technologies, often before anyone else did. During his time at the Hammersmith Hospital in the 1950s he built a rectilinear scanner to automatically build up a picture of the distribution of a radiopharmaceutical in the body. This used a moving bed and a tapper mechanism to print out a colour coded image on a sheet of paper. This was the first whole-body scanner in the world and with it he pioneered clinical in vivo radioisotope scanning of the brain, liver, spleen, kidneys and joints. Around the same time, he used a pair of scintillation counters to demonstrate that positron-emitting radioisotopes of arsenic could be used to image brain tumours, providing an early demonstration of Positron Emission Tomography (PET) scanning.

As well as bringing his ESR spectrometer with him to Aberdeen, Mallard transported his rectilinear isotope scanner to the north. He went on to design and build two single-photon emission tomography (SPECT) scanners, the first of which was the world's first digital tomographic imaging device [12], as well as a rotating tomographic gamma camera. It is worth noting that this work was done several years prior to Hounsfield's invention of X-ray CT, which used similar technology.

When he took up his Chair of Medical Physics in Aberdeen, Mallard stated in his inaugural lecture that PET scanning would become a valuable diagnostic tool. In the early 1980s he set up a PET imaging centre in Aberdeen (the second one in the UK, the first being in London), in farm buildings purchased for a song adjacent to a hospital; a second-hand cyclotron (from Edinburgh) generated the radioisotopes, while a pre-owned PET scanner (from Hammersmith) did the scanning. This later provided leverage for

a new PET Centre in the region's main teaching hospital, now named the John Mallard Scottish PET Centre.

John Mallard was very deaf, from an early age. He wore hearing aids and also relied on lip-reading for one-to-one communication. The authors can both testify that he was an "old-school" head of department who would communicate with his staff primarily via hand-written memos from his triplicate machine (he kept one, another went to his secretary and the third to the recipient). These would sometimes ask for slides for a presentation or on other occasions they might say "I suggest you look at this paper" or give suggestions for avenues of research. One such suggestion by Mallard to one of the authors (DJL) in 1985 suggested that double magnetic resonance methods be investigated; this resulted in the invention of a dynamic nuclear polarisation (DNP) method for imaging free radicals [13], bringing the circle neatly back to Mallard's ESR research.

John Mallard was always cognisant of the importance of professional activity and education in medical physics. He set up an MSc course in Medical Physics at the University of Aberdeen in 1968 which, over 50 years later, is still running. He was a past President of the Institute of Physical Sciences in Medicine (IPSM), the Biological Engineering Society (BES), the International Organisation for Medical Physics (IOMP), the Founder Vice-President of the European Nuclear Medicine Society, the Founder President of the European Society of Magnetic Resonance in Medicine and Biology (ESMRMB), and the Founder President of the International Union of Physical and Engineering Sciences in Medicine (IUPESM) and succeeded in obtaining its Associate Membership of the International Council of Scientific Unions (ICSU).

He received many honours and prizes during his career, including the Landauer Memorial Plaque of the American Association of Physicists in Medicine, the Academic Enterprise Competition Prize of the British Technology Group, the Royal Society Wellcome Prize and Gold Medal, the George Van Hevesey Memorial Lecture Medal, The Royal Society Mullard award and the Gold Medal of the Royal Society of Edinburgh. He received the Fellowship of the International Society of Magnetic Resonance in Medicine (ISMRM) in 1996.

He was awarded the OBE in the Queen's Birthday Honours List in 1992, the Freedom of the City of Aberdeen in 2004 and the Freedom of his birthplace, Northampton, in 2018.

John Mallard was a visionary, who inspired, enthused and guided colleagues and students from all over the world.

Declarations

Conflict of interest The authors have no relevant financial or non-financial interests to disclose. The authors have no conflicts of interest to declare that are relevant to the content of this article. All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript. The authors have no financial or proprietary interests in any material discussed in this article.

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