EDITORIAL

Nobel Prize in Physiology or Medicine 2003 awarded to Paul Lauterbur and Peter Mansfield for discoveries concerning magnetic resonance imaging

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Nobel Prize in Physiology or Medicine 2003 awarded to Paul Lauterbur and Peter Mansfield for discoveries concerning magnetic resonance imaging

The award of the Nobel Prize in Physiology or Medicine recognizes discoveries concerning the use of magnetic resonance to visualize different structures. The Assembly’s decision to recognize the discoveries underpinning efficient spatial mapping of biological properties reflects the singular importance of imaging to the medical application of this technique. Without this, abnormalities in morphology cannot be recognized. Equally, the wealth of physiological information that can be obtained by manipulation of the magnetic resonance signal is of little value unless localized to identified organs, pathology or areas of tissue. Based on these early discoveries, a wide range of imaging and measurement techniques, together with enabling instrumentation, have been developed over the last 30 years. Commercial equipment became available in the early 1980s, and some 60 million MRI examinations are now performed each year. The power of the technique, and the range of applications, continues to develop rapidly.

Paul Lauterbur has been recognized for his discovery that the addition of magnetic field gradients to the normally homogeneous main magnetic field, used to create the nuclear magnetic resonance (NMR) signal, allowed spatial encoding of signals. In a seminal paper in 1973 (Lauterbur P C 1973 Nature 242 190–1) he showed that by adding additional linear magnetic field gradients to a homogeneous magnetic field, and by then obtaining a set of projections of the signal distribution from two test tubes of normal water within a larger container of deuterated water, he could reconstruct an image by filtered back-projection. Lauterbur termed this approach zeumatography. This technique was employed by a number of investigators, and used in the first reported MR image of the human head (Clow H and Young I R 1978 New Scientist 588). Although superseded for most MR investigations, it continues to be used for some applications requiring rapid measurements and short echo times. Intrinsic to the recording of the projections is the use of a gradient that ‘frequency encodes’, an approach that remains part of most current MR imaging. It is interesting to note that Lauterbur’s initial manuscript was rejected by Nature (see Hollis D P 1987 Abusing Cancer Science (Strawberry Hills Press, Chehalis, Washington) pp 145–8) but in this case the author’s persistence prevailed.

Paul Lauterbur was born in 1933, and is at the University of Illinois, Urbana, USA.

Peter Mansfield has been recognized for discovering that the use of additional magnetic field gradients produced signals that could be analysed directly to provide spatial information, and for the subsequent development of echo-planar imaging, providing for extremely rapid imaging. The experiment cited by the Nobel Academy described the use of a magnetic field gradient to separate signals from interleaved layers of camphor and cardboard (Mansfield P and Grannell P K 1973 J. Phys. C: Solid State Physics 6 L422). The presence of a gradient resulted in three peaks, rather than the one seen in the absence of a gradient, at discrete resonant frequencies and hence spatial positions. The paper included a mathematical description of the transformation from a time signal to a spatial representation. A further paper (Garroway A N, Grannell P K and Mansfield P 1974 J. Phys. C: Solid State Physics 7 L457) described the concept of selective irradiation, providing for slice selection. This remains a component of most current imaging approaches. Echo-planar imaging, allowing a complete image to be obtained in a single excitation, was first proposed by Mansfield as
multi-planar image formation using NMR spin echoes (Mansfield P 1977 J. Phys. C: Solid State Physics 10 55). This work was based on the principles identified in the earlier paper on camphor described above. The rapid acquisition and fast gradient switching requirements made heavy demands on instrumentation, meaning that effective implementation required many instrumental developments. These requirements led to a range of pioneering hardware developments by Mansfield and colleagues at Nottingham, which contribute greatly to the quality of current clinical systems. Peter Mansfield was born in 1933 and is at the University of Nottingham, Nottingham, UK.

Both Mansfield and Lauterbur subsequently contributed to the further development of slice selection, based on the concept of frequency selective pulses, to limit measurements to a single slice (Mansfield P, Maudsley A A, Baines T 1976 J. Phys. C: Solid State Physics 9 271; Lauterbur P C, Kramer D M, House W V Jr, Chen C-N 1975 J. Am. Chem. Soc. 97 6866). Both Mansfield and Lauterbur have continued to actively contribute to research and development in the field of MR, with a number of papers being published in Physics in Medicine and Biology. Grannell and Mansfield published a report building on the initial measurements in camphor to demonstrate the acquisition of projections from Grannell’s finger (Grannell P K and Mansfield P 1975 Phys. Med. Biol. 20 477–82). This is the first report of spatially localized signal from a human subject. In a further paper Mansfield and Maudsley (1976 Phys. Med. Biol. 21 847–52) showed how the concept of spatial frequency dependence could be used to define a narrow strip in a disc shaped object, using the projection technique to obtain a spatially dependent signal along the strip. This line-scan technique could then be applied to neighbouring strips to progressively build up an image of the disc. The technique was applied to a number of biological specimens. Shortly afterwards the authors published the first cross sectional MR image of part of a human subject, again a finger (Mansfield P and Maudsley A A 1977 Br. J. Radiol. 50 188). Examples of the realization of some of these developments in a method of echo-planar imaging to rapidly measure T1 relaxation time maps were reported by Mansfield, Guilfoyle, Ordidge and Coupland (1986 Phys. Med. Biol. 31 113–24). Lauterbur continued an interest in the methodology of reconstruction, publishing on the use of one dimensional projections in the presence of suitable one-dimensional gradients to reconstruct a 3D image (Lai C-M and Lauterbur P C 1981 Phys. Med. Biol. 26 851–6).

The development of NMR has resulted from a number of key developments. Isador Rabi demonstrated resonant behaviour using molecular beams, recognized in a Nobel Prize for Physics in 1944. Resonance absorption in solids was independently demonstrated by Felix Bloch and Edward Purcell, for which they received the Nobel Prize in Physics in 1952. Following on from the use of NMR in understanding physical properties, the technique has become a major tool in chemistry. Richard Ernst received a Nobel Prize in Chemistry in 1991 for his contribution to high-resolution spectroscopy, and more recently Kurt Wuthrich was awarded the Nobel Prize in Chemistry in 2002 for developing NMR spectroscopy for the determination of the 3D structure of biological macromolecules.

As with many other discoveries, the development of this new technique has depended on the vision of pioneers in the field, in recognizing the potential and then in persuading others of the same. Both Paul Lauterbur and Peter Mansfield have met with and overcome the difficulties of reporting, funding and realizing their discoveries. The clinical and laboratory use of MRI today has built on the contribution of very many scientists, engineers and clinicians, who have helped in the evolution of a remarkably versatile tool. MRI now plays a vital role in diagnosis, the management of disease and the planning of therapy. These achievements rest on the fundamental requirement for signal imaging now recognized by the Nobel Committee.

Martin O Leach (former Editor of PMB)