Magnetic Resonance Imaging: The Nuclear Option

Jonathan D. Kaunitz¹

Published online: 1 March 2018

© This is a U.S. Government work and not under copyright protection in the US; foreign copyright protection may apply 2018

In this ninth installment of the series Paradigm Shifts in Perspective, Drs. Roth, Haleboua-De Marzio, and Guglielmo describe the application of magnetic resonance imaging (MRI) to the diagnosis of gastrointestinal and liver diseases in an enlightening, comprehensive, and detailed review. MRI represents the culmination of over a century of scientific investigation, the bulk of which was in particle physics, with scarce recognition of its clinical applicability until the late 1970s. MRI is perhaps one of the greatest triumphs of translational medicine: the transformation of important discoveries made in the most fundamental of scientific disciplines, particle physics, into a powerful and essentially safe diagnostic medical technique.

The history of MRI extends back almost a century to the work of Niels Bohr in the 1920s, who discovered distinct lines in the absorption spectra of atoms which were theorized as being due discrete magnetic moments of elementary particles. Several other physicists in the 1920s and 1930s studied the effect of nuclear spin on magnetic moments. The field of nuclear magnetic resonance proper likely originated with the studies of Isidor Isaac Rabi and coworkers at Columbia University and Hunter College in New York, who in a single-page publication described a sharply focused resonance peak of a beam of LiCl molecules in a constant and an oscillating magnetic field placed a right angles [1]. The sharp dip in beam intensity at a specific radiofrequency is perhaps the first direct demonstration of the phenomenon nuclear magnetic resonance (NMR), in which the spinning protons in the lithium and chloride nuclei absorbed radiofrequency magnetic signals at a specific wavelength, known as the resonant frequency. The strength of the constant magnetic field used by Rabi, 6 Gauss, was about 0.01%

of the strength of the magnetic field generated by the most advanced clinical MRI machine (7 T).

In the ensuing decade, several discoveries, in particular the first recording of ¹³C spectra by Paul Lauterbur and Holm, paved the way for development of the first commercial NMR spectrometer in 1961, a quantum advance in the field of organic chemistry, since the unambiguous structure of organic compounds could be deduced from NMR spectra, undoubtedly facilitating the development of therapeutic organic compounds.

In 1971, Raymond Damadian published a highly prescient paper describing the first medical use of MR scans, in which he reported that spin–lattice (T_1) and spin–spin (T_2) magnetic relaxation times differed between normal and malignant tissues [2], the fundamental basis underlying MR-based tumor diagnosis, well described in the accompanying review. Lauterbur [3] first demonstrated MR imaging in 1973, in which he published NMR images of two tubes of water. In the same year, Sir Peter Mansfield published a paper in which NMR was used for the detection of the structure of solids, forming much of the basis for current-day functional MRI [4]. These three brief papers with a combined total of four authors and 10 printed pages provided most of the theoretical framework for the paradigm shift that eventuated in the development of the clinical MR scanners in current clinical use. As noted later, these articles, although published in highly visible journals, drew little contemporaneous attention, with no evidence of fanfare, press conferences, or other publicity noted at the time [4].

Eventually, the scientific community realized the importance of this translation of fundamental particle physics into applications useful to chemists and physicians. Indeed, the development path of MR imaging is littered with Nobel Prizes, seven to my count but likely more, and even a marked controversy, since Damadian, who first reported the utility of NMR in detecting tumor tissue, was denied the Nobel prize that was awarded to Lauterbur and Mansfield [5]. Damadian launched strident protests that at the time divided the scientific community [6–8]. As noted in the accompanying article, he ‘cried all the way to the bank’ in that his share

✉ Jonathan D. Kaunitz
jake@ucla.edu

¹ Departments of Medicine and Surgery, UCLA School of Medicine, Greater Los Angeles VA Healthcare System (GLAVAHCS), 11301 Wilshire Blvd, Bldg. 114/217E, Los Angeles, CA 90073, USA

of the MR imaging company he founded, FONAR, is worth several multiples of the Nobel Prize, at least from a monetary perspective.

Although I discourage political grandstanding in this journal, I will emphasize the point that some of the greatest advances in medicine are the results of flashes of insight by scientists imaginative enough to envision a new concept, perspicacious enough to understand its value, and courageous enough to pursue their ideas among skeptical colleagues and an intrinsically conservative scientific establishment. I certainly hope that society will continue to nurture these types of investigators so that science and medicine can continue to progress. Deciphering the secrets of the universe followed by transforming them into medical technologies that benefit millions is an achievement on par with other magnificent and marvelous accomplishments of humanity, be it in art, architecture, science, music, or literature. Such endeavors affirm the potential of humankind to improve the lives of Earth's inhabitants.

I encourage you to read over and ponder the accompanying paper, since it provides a unique glimpse for gastroenterologists into the rather arcane world of MR imaging that is

not only fascinating and highly comprehensible, but useful to clinical practice.

References

1. Rabi II, Zacharias JR, Millman S, Kusch P. A new method of measuring nuclear magnetic moment. *Phys Rev.* 1938;53:318.
2. Damadian R. Tumor detection by nuclear magnetic resonance. *Science.* 1971;171(3976):1151–1153.
3. Lauterbur PC. Image formation by induced local interactions: examples employing nuclear magnetic resonance. *Nature.* 1973;242:190–191.
4. Wehrli FW. On the 2003 Nobel Prize in medicine or physiology awarded to Paul C. Lauterbur and Sir Peter Mansfield. *Magn Reson Med.* 2004;51(1):1–3.
5. Mansfield P, Grannell PK. NMR 'diffraction' in solids? *J Phys C Solid State Phys.* 1973;6:L422–L427.
6. Macchia RJ, Termine JE, Buchen CD, Raymond V, Damadian MD. Magnetic resonance imaging and the controversy of the 2003 Nobel Prize in Physiology or Medicine. *J Urol.* 2007;178:783–785.
7. Weiss R. Prize fight. *Smithsonian magazine*; 2003.
8. Treacy PJ. The great Nobel Prize controversy about the discoverer of MRI. *Linkedin.com*; 2014.