MR Basics and Clinical Applications

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The physical effect of nuclear magnetic resonance (NMR) was discovered by F. Bloch and E. Purcell in 1946, for which discovery and both were awarded the Nobel Prize in 1952. The main application for NMR since then was in analytical chemistry, until P. Lauterbur suggested in his famous paper in 1973 a technique for the acquisition of sectional images with NMR. His work with Sir Peter Mansfield was awarded the Nobel Prize in 2003.

NMR- or as today dubbed MRI (magnetic resonance imaging) - makes use of the property spin of the atomic nuclei. The nucleus of hydrogen (H-1) consists of one particle: the proton. The spin of the proton lets it behave like a bar magnet with North and South Pole. In the environment of a strong magnetic field we observe a strict alignment of these nuclear magnets. The alignment is actually a precession around the main field direction. The distribution with and against the direction of the main magnetic field is almost even with a small excess of particles pointing with the field having no compensating counterpart.

This excess portion forms the "net magnetisation" of a probe. Its size scales linearly with the strength of the external magnetic field. The higher the field, the larger the available magnetization.

Irradiating radiofrequency (RF) pulses of a certain frequency let the magnetization of the probe turn away from the direction of the main field, e.g. 90 or 180 degrees. The RF pulses drive the zillions of tiny bar magnets into a coherent alignment as they rotate around the main field direction. After the excitation, e.g. of 90 degrees, the rotating magnetization induces a signal in the receiving coils. But this signal diminishes after a short period characterized by the exponential factor T2 analogue to the radioactive decay. Parallel to the T2 decay the magnetization tends to align again with the outer magnetic field. This process is described by the exp. factor T1. Both "relaxation times" are in the range of a few milliseconds (ms) to a few seconds in living tissue. Molecular structures influence the T1 and T2 times and thereby enable different contrasts between tissue types.

The basic idea for MR imaging has been the utilization of additional magnet coils, which superimpose linearly rising field deviations in all 3 directions over the homogeneous main magnetic field. These gradient fields are necessary for slice selection and spatial encoding of the MR signals.

As in computed tomography (CT) one needs more than one projection of the object to reconstruct a full image. For an image with a 256 square matrix at least 256 recorded and encoded signals are necessary for the analysis with the Fourier Transformation (FT). The FT inspects the digitized MR signals for their frequency and phase content and their amplitude. The measurement process in MRI was initially slow. But many techniques ("pulse sequences") were developed to accelerate this procedure, producing in turn a wide range of acronyms (7).

References:

1. Nitz, Runge, Schmeets. The Physics of Clinical MR Taught Through Images. Thieme 2013.
2. Hashemi, Hashman, Bradley. MRI: The Basics. LWW 2010
3. A.D.Elster: Questions and Answers in MRI. http://www.mri-q.com/index.html
4. Magnets, Spins and Resonances. Siemens 2003.
5. Magnets, Flow and Artefacts. Siemens 2004
6. MRI Glossary. Siemens 2008
7. MRI Acronyms. Siemens 2015
8. 4-7http://www.healthcare.siemens.de/magnetic-resonance-imaging/magnetom-world/publications/mr-basics