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MR Basics and PET/MR Interferences

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Abstract. In this talk, two topics involved in multimodality imaging are covered: The basics of Magnetic Resonance (MR) Imaging, as well as the possible cross-modality interferences in combined PET/MR systems. MR has evolved in the second half of the 20th century from a purely analytical tool used in chemistry to a powerful medical imaging modality. Its major strengths are the use of non ionizing radiation as well as the multitude of contrasts it offers. However, compared to PET the sensitivity of MR is relatively low, only in the millimolar range. MR utilizes the intrinsic property of certain nuclei to possess an observable spin. The spin itself is a fundamental property of nature like mass or electric charge. Most MR experiments use the 1H (hydrogen) atom, which is due to its high abundance in biological tissue, an excellent candidate for MR imaging. When 1H nuclei are placed in an external magnetic field of the strength B0 (the main magnetic field of the MR scanner), they can absorb photons of the frequency f. This frequency is called the Larmor Frequency, and depends on the gyromagnetic ratio (γ) of the nuclei used. We can calculate the Larmor Frequency by: f=γ*B0, one of the fundamental equations in MRI, in case of 1H γ=42.58 MHz/T, i.e. a 1 T MR scanner operates at 42 MHz, a 7 T machine at 300 MHz. By using radiofrequency pulses of these frequencies we can transfer energy to the spin system and manipulate it. A 90° radiofrequency (RF)-pulse (B1-field) flips e.g. the spins (in a classical physics view) by 90° from their equilibrium position. After the RF-pulse is turned off, the spins tend to relax back into their original equilibrium, during this process a small RF-signal is emitted from the nuclei which is collected by RF-coils. This relaxation process has two time constants. The spin-lattice relaxation time, also called the longitudinal relaxation time, or T1, measures how long it takes till all spins are in their original position parallel to the external B0-field. The spin-spin relaxation time, also called transverse relaxation time T2, measures how long it takes till the spins dephase once they have been excited. Both relaxation times are different between different tissue types such as water, fat, or cancer –therefore they can be used to generate the MR image contrast. The MR image itself is formed by the use of gradients, these are small (milli Tesla-range) additional magnetic fields, that can be switched on and off over time, and are overlaid to the strong (Tesla-range) B0-field. To combine PET and MR in one device, various issues that arise from the operation within a strong magnetic field as well as from the MR RF-field and gradients need to be solved. Interferences from the MR to the PET include: operation of PET detectors in a strong B0 field, and induction of currents by the gradients as well as by the MR RF-pulses. On the other hand, if we have a PET installed inside a MR we need to be careful about: The B0-field homogeneity, electromagnetic radiation from the PET electronics, eddy currents and susceptibility artefacts. A clever PET design and the use of dedicated PET detectors can solve most of these problems. Combined PET/MR is therefore a technically challenging but definitely worthwhile goal in multimodality imaging.

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