Magnetic Nanoparticles for Magnetic Resonance Imaging

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Magnetic Resonance Imaging (MRI) is a major clinical imaging technique. It provides contrasted images of the body with a good resolution. Moreover, it does not use any ionizing radiation. For some specific applications, contrast agents composed of magnetic entities are needed. Magnetic nanoparticles are often used in this context.

1. Physico-chemical characterization of the particles

The efficiency of magnetic particles for biomedical applications is closely related to their physico-chemical properties, as the size, the structure, the magnetic organization, the surface composition... Moreover their biocompatibility and toxicity are also sensitive to these properties. Therefore, before any NMR or MRI experiment, a detailed study of these characteristics is necessary. This is achieved thanks to different techniques: transmission electron microscopy (TEM), X-ray diffraction, magnetometry and photon correlation spectroscopy (for the hydrodynamic size). Different examples are given below.

2. NMR relaxation and effect of magnetic particles on MRI

When placed in a static magnetic field (taken in the z direction), the protons of a patient acquires a nuclear magnetic moment. This moment can be excited by using radio waves with a suited oscillation frequency. A signal can then be measured by a detection coil. This the (very) basic principle of all NMR and MRI experiments. After the excitation, the proton magnetization returns to equilibrium in a process called relaxation.

The projection of the proton magnetization on the z axis (called the longitudinal magnetization) is undergoing longitudinal relaxation with a $T_1$ constant time. Its projection in the plane perpendicular to z, called the transverse magnetization, is undergoing transverse relaxation with a $T_2$ constant time. $T_1$ and $T_2$ are of paramount importance for MRI: they governs the contrast. When putting magnetic particles in the presence of the protons, on considerably shortens $T_1$ and $T_2$ which creates contrast on the MRI images.

The relaxation rates (1/ $T_1$ and 1/ $T_2$) normalized by the concentration in magnetic element are called the relaxivities. These latter are used to measure and compare the magnetic particles efficiency.

References


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