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Novel Contrast Agents in Magnetic Resonance Imaging): From Future Perspective

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ABSTRACT

The choice of MRI contrast agent is typically determined by two factors: the biocompatibility and degradability of the material. In our context, PEG has garnered significant interest, despite the availability of numerous other polymers. PEG, a partially acetylated glucosamine biopolymer, possesses various biological and chemical properties, such as film-forming capability, biocompatibility, mechanical robustness, non-toxicity, high water permeability, susceptibility to chemical modification, cost-effectiveness, among others.

1. INTRODUCTION:

Magnetic resonance imaging (MRI) has become a widely used method for medical imaging due to its non-invasive nature and absence of harmful radiation, as found in X-rays. Compared to other diagnostic technologies used in clinical settings, it has various advantages. These include the absence of ionizing radiation, high precision in determining location, the ability to easily manipulate images, non-invasiveness, and the ability to produce clear distinctions in soft tissues[1].

Although magnetic resonance imaging (MRI) has some benefits, it is crucial to note that it has a lower sensitivity compared to other imaging techniques. Nevertheless, in the past few decades, numerous experiments and research endeavors have been conducted to enhance its sensitivity and image quality. These achievements have been made by employing different magnetic ions and magnetic nanoparticles (MNPs) as contrast agents. The global introduction of gadopentetate dimeglumine in 1988, as the first gadolinium-based contrast agent, was a key milestone in clinical practice. Subsequently, an additional eight gadolinium chelates were created and enhanced on a global scale[2].

MRI contrast compounds enhance the sensitivity of in vivo imaging, allowing rapid detection of illnesses and lesions. The utilization of MRI has significantly risen due to the advancements and modifications in contrast materials. MRI, widely recognized as a crucial imaging technique, is employed in around 30 million surgeries, with estimates indicating around 300 million procedures performed (data on record Bayer Healthcare)[3].

This paper aims to present an analysis of the utilization of novel contrast agents in MRI, while also emphasizing ongoing technological advancements and potential clinical challenges. This study does not involve any novel examinations on humans or animals; instead, it relies on preexisting research[4].

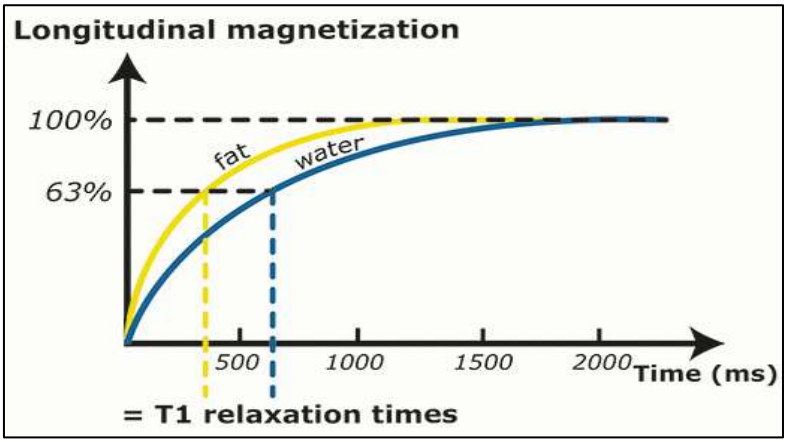
2. Basic Principle of MRI:

Bloch pioneered the field of nuclear magnetic resonance (NMR) in 1946, and Bloembergen and Purcell subsequently advanced this work in 1978. The fundamental process involves applying a high-frequency magnetic field to the body, which leads to the stimulation of proton nuclear spin. The spin of the proton, filled with excitement, undergoes rotation in reaction to the magnetic field that is exerted upon it. Upon the flip of the spin, it generates a radio frequency signal known as the magnetic resonance signal. The intensity of this signal is dictated by the quantity of protons in the voxel, along with their relaxation properties.[5].

Relaxation, in this context, denotes the process by which excited nuclei shift from a state of high energy to a state of lower energy, thereby emitting energy into the surrounding environment. Relaxation refers to the process of magnetization returning to its original condition along the main magnetic field[6]. The relaxing technique is characterized by two primary parameters: Two entities referred to as T1 and T2. T1, also referred to as longitudinal relaxation time, represents the duration needed for magnetization to revert to 63% of its initial value. It is alternatively known as "spin-lattice relaxation." T2 represents the time interval during which the transversal component has a decrease of 63% in its energy from the excited state. The occurrence of this loss is a result of the transfer of energy between neighboring spins, which is referred to as "spin-to-spin interaction." Magnetic Resonance Imaging (MRI) fundamentally relies on the distinction between the durations of longitudinal and transverse relaxation.[7].

3. T1 Relaxation:

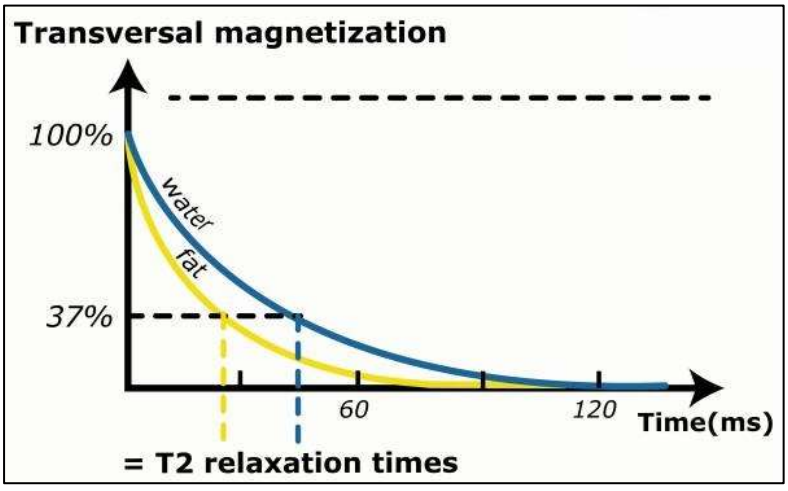
This phenomenon can be described as the opposite of excitation, when protons strive to revert back to their initial equilibrium condition by emitting energy in the form of radiofrequency (RF) waves. The net magnetization undergoes reversal and reorients itself parallel to the z-axis. The emergence of the term "spin-lattice relaxation" is attributed to the energy release occurring in the surrounding tissue. T1 relaxation predominantly takes place within the proton compartment following a 90º excitation pulse, and it differs across different types of tissue. As an illustration, H1 atoms exhibit strong bonding in fat, but have a less secure attachment in water. Protons that are strongly bound release energy at a higher rate compared to protons that are weakly bound. The dynamics can be graphically depicted by a curve.



According to this graph, at the initial time t=0, immediately after the RF pulse, there is an absence of magnetization in the z-direction. However, shortly thereafter, the z magnetization commences its restoration. T1 relaxation is a time constant that represents the duration required for the longitudinal magnetization to recover to 63% of its initial magnitude. The diverse emission of energy by different tissues at different rates contributes to the exceptional differentiation capability shown in MRI[8].

4. T2 Relaxation

The process of T2 relaxation is little more intricate. It is crucial to comprehend that T1 and T2, albeit distinct, happen concurrently. T1 pertains to events occurring in the z-axis, while T2 delineates occurrences in the X-Y plane. The net magnetization is the collective sum of the magnetic fields generated by all protons, which are aligned along the z-axis. Each proton rotates on its own axis. While they rotate at a regular rate, they are not synchronized with each other[9].



The graph illustrates that initially, all spins are synchronized, but shortly thereafter, they commence to lose synchronization. T2, similar to T1, is a temporal constant that can be defined as the duration required for the spins to lose 63% of their initial value.

5. CONCLUSIONS:

Various types of nanoparticles are employed based on their intended function. For scientific purposes, metals including gold, silver, and cobalt, as well as metal oxides such as Fe_2O_3, TiO_2, and SiO_2, are utilized.

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