Session: Imaging Bone Architecture & Composition

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Highlights

- The general principles of free induction decay (FID) imaging will be explained
- Pros and cons of the different sequences used to image spins with ultra-short T_2 values will be discussed

Title: Free Induction Decay Imaging of Short-lived Signals

Target audience: Clinicians and MR physicists

OUTCOME/Objectives: Understand the fundamental principles of the common pulse sequences used to preserve signals from fast relaxing spins in hard tissues like bone

In bone, a majority of the water protons cannot easily be visualized using conventional MRI methods due to the ultra-short transverse relaxation time of these spins (T_2 < 1 ms). In standard MRI methods, which are usually gradient echo (GRE) or spin echo (SE) sequences, signal excitation and signal acquisition events are separated by an echo time (*TE*) that cannot easily be less than ~1 ms due to the time needed to switch gradient pulses on and off. As a result, it is challenging to detect ultra-short-lived signals with these methods. During the past two decades, pulse sequences that acquire the free-induction decay (FID) instead of a gradient or spin echo have been shown to offer improved capabilities for imaging spins with ultra-short T_2. However, the translation of FID-based MRI methods into routine preclinical and clinical use has been slowed to some extent by the need for specialized hardware (e.g., fast switching between transmit and receive modes) and the technical challenges associated with reconstructing images from FID projections. Despite these increased technical demands, interest in FID-based imaging methods has steadily increased in recent years, due in large part to the many pioneering works by Graeme Bydder and others who have demonstrated the utility of FID-based sequences to capture important short-lived signals in tissues like cortical bone. Examples of early FID-based sequences have various acronyms and names, but the main ones are UTE, BLAST, RUFIS, WASPI, and ZTE. With these methods, MRI signal is excited by using a short constant-frequency pulse. An alternative newer approach called SWIFT uses frequency-modulated (FM) pulses to excite signals while detecting signal simultaneously or almost simultaneously using time-shared excitation and acquisition scheme. With all of these FID-based methods, time domain data (*k*-space) are created from FIDs acquired in a radial manner (i.e., with spokes radiating out from k = 0). T_1-weighting can be produced by appropriately setting the flip angle and repetition time (*TR*), like in GRE imaging. However, bias from T_2 or T_2*-weighting can be essentially eliminated because the acquisition delay is so short. Various sequence modifications can yield images exclusively of the short T_2 species. An example of using such an approach to enhance image contrast at the interface between bone and cartilage is shown in Fig 1. With FID-based imaging, phase contrast can also be obtained despite the lack of echo. In summary, FID-based sequences provide the important capability to visualize bone and other hard tissues with MRI.

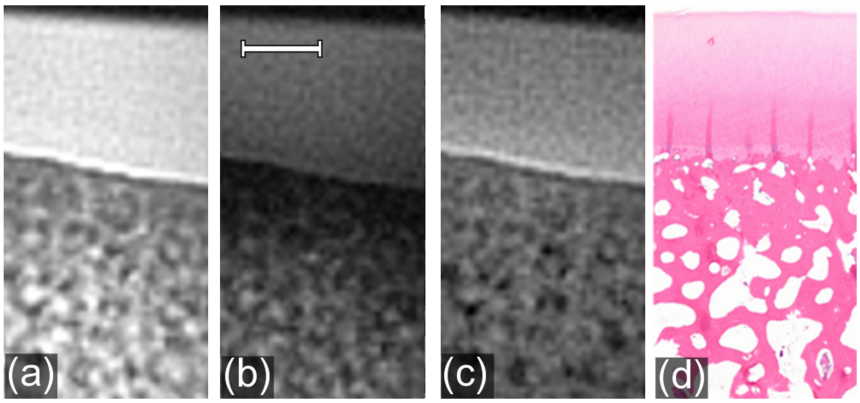

Fig. 1: Selected slices from a 3D SWIFT image of a bone-cartilage specimen from an 18-month old pig, acquired at 9.4 T. (a) normal SWIFT image; (b) SWIFT image with short T_2 spins saturated, c) subtraction image to reveal the short T_2 fraction, and d) Safranin-O stained microscopic image of the same specimen. Scale bar indicates 1 mm. Reproduced from Garwood et al, *Encyclopedia MR*, 2012.