Off-resonance Projection Imaging of USPIO-enhanced Bone Marrow

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Introduction

Administration of ultrasmall superparamagnetic iron-oxide (USPIO) particles has been suggested for functional bone marrow imaging, i.e. imaging of the phagocytotic activity of monocytes and macrophages present in normal bone marrow [1]. A possible clinical application is differentiation between hematopoietic bone marrow and neoplastic infiltration, which is unreliable when using standard pulse sequences and contrast media [2]. Iron-oxide particles are usually detected by their effect on proton relaxation times, more precisely their T_1 and T_2* shortening.

Recently, several imaging techniques have been presented that detect USPIO uptake by the shift of proton resonance frequencies in the vicinity of the particles [3,4]. We examined, if off-resonance spin echo (ORSE, [3]) is a useful tool in iron-oxide enhanced imaging of bone marrow.

Materials & Methods

ORSE was implemented on a 1.5 T MR scanner (MAGNETOM Avanto, Siemens Medical Solutions). Both pulses in this spin echo sequence have a spectral bandwidth of 1 kHz with 0.1% stopband ripple and an adjustable frequency offset. The pulses are played out in the absence of gradients to specifically excite and refocus frequency-shifted protons. Because of non-selectivity, only 2D projection imaging is feasible in-vivo in acceptable acquisition durations.

New Zealand white rabbits received USPIO particles (SHU555C, Bayer Schering Pharma) given in a dosage of 100 µmol Fe/kg. Imaging was performed 16 hours thereafter using a TR of 800 ms, TE 15.3 ms, a readout bandwidth of 130 Hz per pixel and +800 Hz frequency offset. Each 256x256 projection image took 3:25 min to acquire. Projections from different directions were obtained in a sequential fashion.

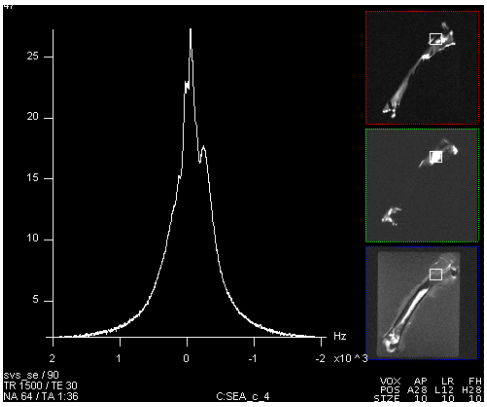

Figure 1: Proton spectrum of USPIO-enhanced bone marrow.

Results & Discussion

Figure 1 shows an ex-vivo proton spectrum (spin echo) of a single voxel containing mostly marrow. Apparent is the broad distribution of resonance frequencies in the range of about ±1 kHz. Excitation at +800 Hz frequency offset (0 Hz = water) reaches a considerable fraction of protons. Figure 2 displays in-vivo projection images acquired using ORSE. They show excellent background suppression, except for some faint signal from areas of insufficient shim, e.g. at the abdominal wall. Although the particles are also taken up by liver and spleen, they cannot be seen because T_2 values are too short in these tissues. For the same reason, iron uptake in lymph nodes might not be noticeable too. This enables functional bone marrow imaging of the complete skeleton without overlay by other organs in a short examination time.

A difficulty remains: As with other off-resonance techniques, the appearance of a rod-shaped marrow region is dependent on its orientation with respect to B_0. The field disturbance may extent into adjacent tissue, e.g. the intervertebral disks where no iron has been taken up (cf. figure 2). While it is an interesting new method for bone imaging, potential applications for off-resonance imaging of iron enhanced bone marrow still need to be determined.

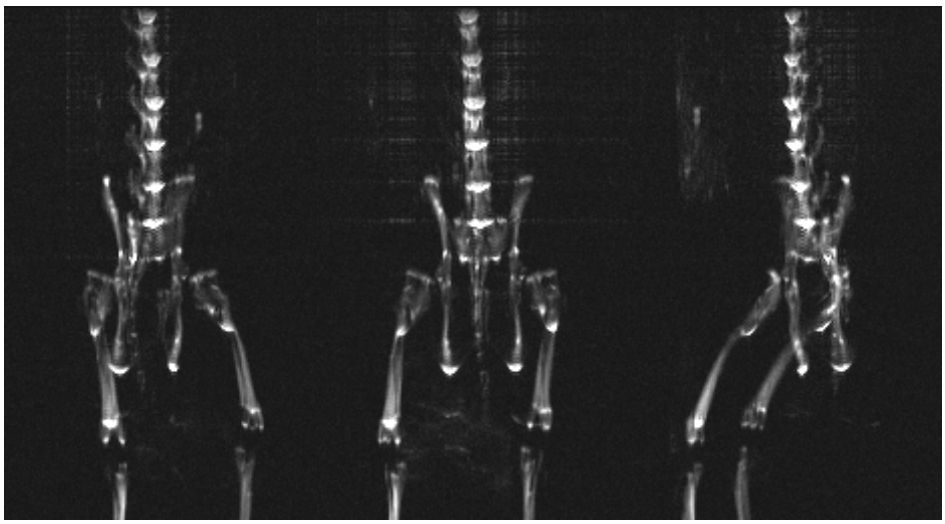

Figure 2: In-vivo ORSE projection images of a New Zealand white rabbit 16h after application of 100 µmol Fe/kg SHU555C.

References

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