Magnetic Resonance Imaging: Improved Visualization of Bone with Ultrashort TE (UTE) Pulse Sequences

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INTRODUCTION

With all magnetic resonance (MR) sequences used in routine clinical practice signal from cortical bone in the mature skeleton is not detectable. Trabecular bone is present in lower concentration than cortical bone and signal from this tissue is not directly detectable either. Bone of this type is only seen indirectly as regions of low of signal within yellow or red bone marrow. Subchondral compact bone also produces no detectable signal. Its presence is inferred from low signal adjacent to bone marrow but it is not distinguishable from the adjacent deep (calcified) layer of articular cartilage which also produces no signal with conventional sequences.

It is possible to detect signal from cortical bone using ultrashort TE (UTE) pulse sequences which detect MR signals from tissues with short T_2s before they have decayed to very low levels (1, 2). To date, however, only cortical bone has been demonstrated with sequences of this type and this has been at low resolution and only in the tibia. In this study we demonstrate imaging of cortical bone with high spatial resolution and conspicuity as well as direct visualization of trabecular bone and subchondral compact bone.

METHODS

The tibia, knee and skull were examined in four normal volunteers using fat suppressed conventional UTE pulse sequences (1), (TR=500, TE=0.08 msec) and fat suppressed inversion occurring sequences (TR=500, TI=30-200, TE=0.08 msec) using a 512x512 matrix and FOV of 100-160mm. The inversion pulses varied in duration from 0.5 to 12.75 msec. Subtraction of later echo images from the first was also used.

RESULTS & DISCUSSION

High resolution and high conspicuity images of cortical bone were obtained in each case (Fig. 1). Trabecular bone was apparent in the skull (Fig. 2) and phalanges. Subchondral bone was seen in the femur at the knee joint. Improved image quality for trabecular and cortical bone was obtained using longer inversion pulses.

Visualization of compact bone was improved with inversion pulses which were primarily used to invert and null the long T_2 components of surrounding muscle. This improved the contrast to noise ratio for bone. The typical TI of 200 msec meant there was a high level of longitudinal recovery associated with the short T_1 (e.g. 130 msec) of bone. Additionally, the short T_2 of bone meant that inversion pulses did not significantly invert the magnetization from bone, although they saturated it to varying degrees. This is supported by the absence of a null point when TI was varied over a range from 30 msec to 200 msec. With a longer inversion pulse (12.75 msec vs 0.5 msec) less of the bone signal was saturated and higher resolution images were obtainable.

To visualize trabecular bone directly it is necessary to reduce the signal from fat. This can be done with frequency based fat suppression pulses but there may be concern that at interfaces with bone fat was not suppressed as a result of local susceptibility effects which change the resonance frequency in the immediate vicinity of bone. It is possible to use a TI value to null fat but this does not effectively null muscle and therefore makes a more limited contribution to conspicuity.

Subchondral compact bone is present in a relatively thin layer. It is possible to distinguish calcified cartilage from compact bone because of its longer (but still relatively short) T_2. This gives a lower signal on subtraction images from the cartilage. Conventional x-ray densitometry reflects the crystalline component of bone where as the signal for MR probably comes from the organic matrix and fluid components and may provide complementary information.

Fig. 1 Compact bone: High signal is seen in the compact bone of the tibia. (IR500/0.08/200 msec)

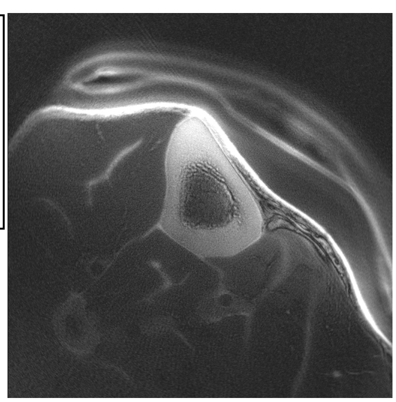
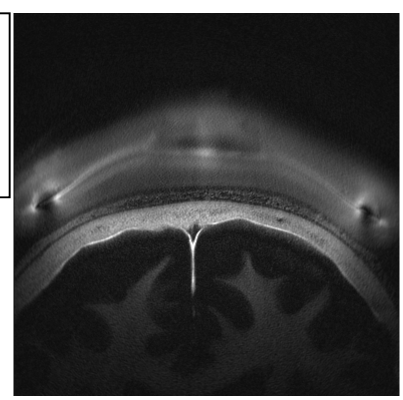


Fig. 2 Trabecular bone: Signal is seen between the inner and outer tables of the skull (IR500/0.08/200msec)



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