A Technique for Rapid Single-Echo Spin Echo T2 Mapping

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INTRODUCTION

Measurement of T_2 relaxation times can provide valuable quantitative information in a variety of conditions, including brain disorders, tumors, and cartilage degradation [1-3]. Rapid T_2 mapping is normally achieved using multi-echo spin-echo (MESE). However, this approach is associated with several limitations: stimulated echoes generated by the echo train that can bias T_2 measurement [4], heat deposition, and limited availability. For these reasons, the traditional and widely available single-echo spin-echo (SESE) approach is used, despite its limited clinical value due to long repetition times (TR), and hence long acquisitions, to ensure T_2 accuracy. In this abstract, we present a SESE technique that uses short TRs to provide rapid and accurate T_2 mapping.

$$M_{xy}^{ss} \approx \left[1 - 2e^{-\frac{(TR-\frac{TE}{T2})}{T1}} + e^{-\frac{TR}{T1}}\right] e^{-\frac{TE}{T2}} \quad \textbf{[1a]}$$

$$\approx e^{-\frac{TE}{T2}} \quad ; \quad TR >> T1 \quad \textbf{[1b]}$$

THEORY

The steady-state signal (M_{xy}^{ss}) of a spin-echo sequence is given by Eq.[1a] if TR>>T_2. With conventional T_2 mapping, we impose TR>>T_1 to achieve the familiar form of monoexponential T_2 decay (Eq.[1b]). With the new method, the long TR requirement is replaced by TE<< T_1 only, which reduces Eq.[1a] to Eq.[2a]. If we further impose TR-TE=constant, Eq.[2a] is simplified again to a pure monoexponential decay (Eq.[2b]). This modification enables the use of short TRs to significantly reduce acquisition time.

$$M_{xy}^{ss} \approx \left[1 - e^{-\frac{(TR-TE)}{T1}}\right] e^{-\frac{TE}{T2}} \quad \textbf{[2a]}$$

$$\approx k e^{-\frac{TE}{T2}} \quad ; \quad TR - TE >> constant \quad \textbf{[2b]}$$

METHODS

Phantom and *in-vivo* experiments were performed to validate the constant TR-TE technique. Phantoms were prepared using MnCl2 or Gd-DTPA to cover a range of T_2 (20-320 ms) and T_1 (24-3040 ms). Three different SESE methods were compared: 1) gold standard TR=3000ms, 2) short TR=320ms, 3) TR-TE=320ms. The same TEs were used in all sequences (TE=10,15,22,33,49,73,108,160ms).

In-vivo T_2 maps of the knee cartilage and brain of a healthy volunteer were also acquired. The total scan time for a 256×256 matrix, constant TR-TE acquisition with eight echoes was 12 minutes.

RESULTS

Phantom T_2 measurements (Fig.1) using the proposed constant TR-TE method agreed with gold standard measurements over a much larger range of T_2 values compared with the short but constant TR counterpart. Discrepancy for the new method is observed only at the largest T_2 (320ms) due to violation of the TR>>T_2 condition. In human knee cartilage (Fig.2), T_2 measurements agreed with previous reports, and the characteristic gradient from the deep to superficial surface of cartilage was observed. In the healthy human brain (Fig.3), the constant TR-TE method provided improved T_2 accuracy over the constant TR method when using short TRs. The greatest discrepancy is seen near the CSF, where long T_2 values (~2s) result in violation of the TR>>T_2 requirement even for long-TR scans. In fact, the new constant TR-TE approach is more accurate in these regions (grey matter where partial volume with CSF is present), as it reduces signal from long-T_1 species. Table 1 shows that for both grey and white matter, T_2 measured using the constant TR-TE method are most consistent with literature values.

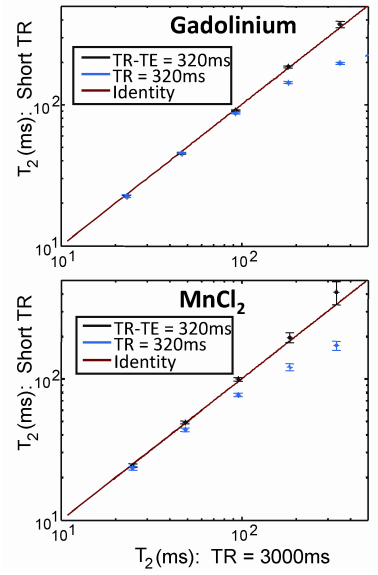

Fig. 1. Phantom T_2 measurements.

CONCLUSIONS

The proposed constant TR-TE SESE approach allows accurate T_2 measurement with a considerably reduced scan time compared to conventional methods. It is immune to limitations associated with other rapid alternatives, such as stimulated echoes in MESE and static field effects in gradient-echo methods. Moreover, it offers flexibility in the choice of echo number and spacing and is readily implemented on all clinical scanners.

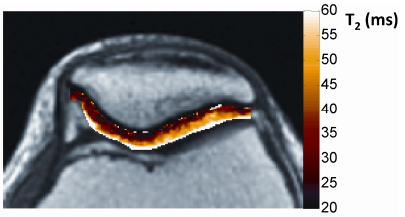

Fig. 2. *In-vivo* T_2 map of healthy knee cartilage.

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Table 1. Comparison of brain T_2 measurements with literature values

Tissue	Long-TR Spin Echo	Short-TR Spin Echo TR-TE = 320 ms	Literature
White matter	79.8 ± 2.7	72.1 ± 2.9	72 [Ref 5] 69 [Refs 6,7]
Gray matter	111.1 ± 6.5	92.4 ± 3.0	92 [Ref 7] 95 [Refs 5,8]

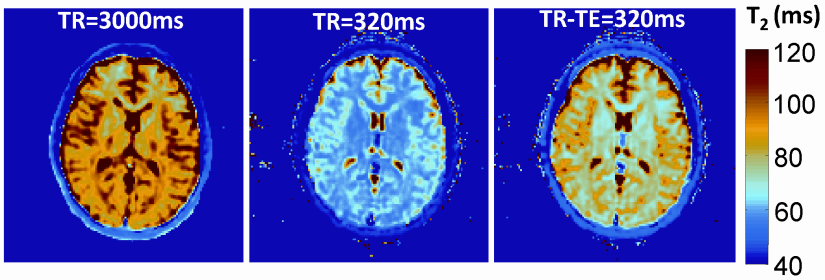

Fig. 3. *In-vivo* T_2 map of healthy human brain.