Fast, artifact-free T_2 mapping with fast spin echo using the extended phase graph and joint parameter reconstruction

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Target Audience

Scientists and clinicians interested in fast T_2 mapping.

Purpose

Fast spin-echo (FSE) can be used for fast and robust T_2 mapping, using either a variable TE spin-echo preparation or by acquiring multiple FSE images with different effective echo times. However, this approach is sensitive to T_2- and refocusing flip angle (B_1)-dependent image blurring and ghosting artifacts[1]. T_2-dependent artifacts have been reduced using joint reconstruction of T_2 and equilibrium magnetization (M_0)[2], and B_1 errors have been compensated in multiple spin-echo imaging by directly fitting echo signals with the extended phase graph (EPG) algorithm[3]. This study combines these two approaches, resulting in a Cartesian FSE T_2 mapping protocol that jointly reconstructs artifact-free T_2, M_0, and flip angle maps.

Methods

Single-slice, 16-echo, 4-shot FSE acquisitions (64 x 64) from a phantom were acquired at 4.7T using 120° prescribed refocusing pulses and with a total of 8 different effective echo times varied according to three acquisition schemes: 1) changing echo number used to sample k=0, while minimizing amplitude modulation from line to line across k-space, 2) a multiple spin-echo preparation period, and 3) one which rotated the acquisition modulo the echo train length, to minimize covariance between T_2 and high spatial frequency information. Fourier-reconstructed magnitude images from the first two strategies were fitted to B_1, T_2, and M_0 maps using the EPG algorithm. Complex k-space data from the third strategy were Fourier transformed in the read-direction (columns), then jointly fitted row-by-row to B_1, T_2, and M_0 using the EPG algorithm and a least-squares cost function. An analytical expression for the signal's Jacobian matrix was derived to expedite computation. This analysis was repeated using only 4 and 2 different effective echo times. In the latter case, B_1 was constrained to the prescribed value, as there were too few images to fit the third parameter.

Results

Figure 1 shows the three T_2 maps created using 4 effective echo times. The proposed method's map (bottom) contains less artifact than that from the first strategy (top) and is sharper than that from the second strategy (middle) at the cost of increased noise. Similar results were garnered by using 8 images and 2 images, excepting systematic bias caused by the erroneous constraint of B_1.

Discussion & Conclusion

The proposed joint reconstruction generated T_2 maps that were sharpened relative to voxel-by-voxel fitted FSE data. In addition to using a fast pulse sequence, the joint reconstruction allowed for low-power RF pulses by directly accounting for stimulated echoes in the signal equation. This makes the technique an excellent candidate for clinical translation. Future studies include extending this to larger image matrix sizes, which will increase computation time and may affect computational stability.

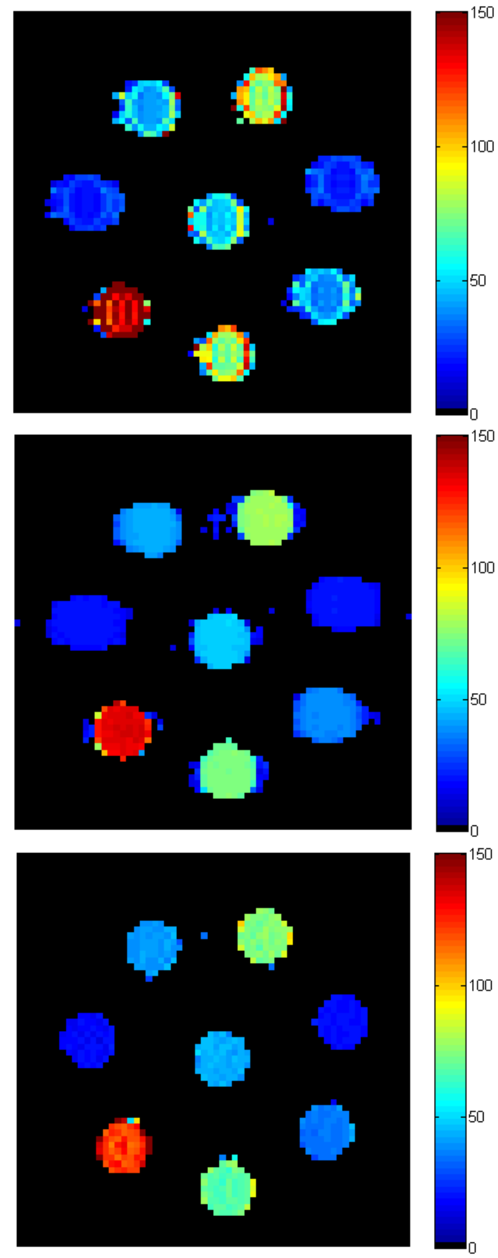

Figure 1. T_2 Maps. T_2 in units of ms.
Top: variable k-space ordering.
Middle: multi-echo prep.
Bottom: proposed method.

References

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