Resolution recovery in Turbo Spin Echo using segmented Half Fourier acquisition

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Abstract

Turbo Spin Echo (TSE) is a sequence of choice for obtaining $T_2$-weighted images. TSE reduces acquisition time by acquiring several echoes within each TR, at the cost of introducing an exponential weighting in the $k$-space that leads to a certain image blurring. This is particularly important for short-$T_2$ structures, which can even disappear if their size in the phase encoding direction is comparable to the degree of blurring. This article suggests the use of a combination of Half Fourier (HF) and segmented (multishot) TSE (sHF-TSE) to recover the original resolution of the SE images. The improved symmetry of the dataset achieved by HF reconstruction is used to increase the resolution of the TSE images. The proposed combination, available in most clinical scanners, reduces the blurring artifact inherent to the TSE sequence without increasing the scan time or the number of acquisitions, but at the cost of a slight reduction of the signal-to-noise ratios (SNR). Qualitative and quantitative results are presented using both numerical simulation and imaging. Significant edge enhancement has been achieved for structures with short $T_2$, (narrowing of the full width at half maximum [FWHM] up to 45%). The proposed sequence is more sensitive to movement artifacts but has proven to be superior to the conventional TSE for imaging static structures. © 2004 Elsevier Inc. All rights reserved.

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1. Introduction

The most widely used clinical magnetic resonance imaging techniques for the diagnosis of parenchymal disease employ heavily $T_2$-weighted sequences to detect long $T_2$ components in tissue. But tissues also contain short $T_2$ components that are not detected or only poorly detected with conventional sequences. These components are the majority species in tendons, ligaments, menisci and other related tissues, and the minority in many other tissues that have predominantly long $T_2$ components [1]. In this work we propose to use the properties of the segmented Half Fourier Turbo Spin Echo (sHF-TSE) sequence as a strategy to increase the spatial resolution of $T_2$ weighted images and, in particular, the conspicuity of short $T_2$ structures.

Turbo or Fast Spin Echo (TSE, FSE) [2], formerly RARE (Rapid Acquisition with Relaxation Enhancement), is a faster alternative to the classical spin echo (SE) sequence [3] proposed by Hennig et al. [4] for the acquisition of $T_2$-weighted images. The TSE sequence shortens the acquisition time by filling in several lines of the $k$-space in each shot or repetition time (TR). The number of echoes ($k$-space lines) acquired within each TR is called echo train length (ETL) and typically ranges from 3 to 30 [5]. The $k$-space thus becomes divided into segments, each one containing the echoes acquired at the same TE [6,7]. The number of segments corresponds to the number of echoes in the ETL.

The particular phase encoding strategy followed in TSE can significantly influence the quality of the images, since the echo amplitude is modulated as a function of its position in the $k$-space: each segment becomes weighted according to the TE of their constituent echoes. The effects of this modulation in TSE imaging are ghosting and blurring artifacts that lead to a resolution loss in the phase encoding direction. These problems are particularly severe for