Advances in T2-weighted axial moving table acquisitions

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INTRODUCTION

Axial continuously moving table (or move during scan, MDS) MRI was limited so far to the use of rapid imaging techniques like TrueFISP [1] or single shot techniques like EPI[2] or single shot TSE [3]. Their use in MDS MRI is straight forward: 1. They are fast to cover the total body within a reasonable scan time. 2. Maximum inplane and through plane homogeneity in the images is achieved by acquiring all slices consecutively in the isocentre of the magnet. 3. They are highly suited for free breathing imaging. The disadvantage of these techniques is the limitation in the resolution achievable with single shot sequences and the limited diagnostic value of T2/T1 weighted contrast for tumor diagnostic. The aim of this work is to develop and evaluate a multi shot T2-weighted TSE sequence that allows high resolution imaging for MDS tumor screening, while maintaining the advantages of the single shot technique in terms of speed and motion insensitivity.

METHOD

Basic sequence setup: The choice of the contrast and SNR determining basic sequence parameters shown in table 1 was based on the following competing requirements: 1. The duration of a single echo train must be as short as required in order not to sacrifice resolution and/or SNR due to late echoes and in order to limit respiration related shifts of slice content during the echo train. 2. The number of excitations NEX per image is minimized to reduce breathing artifacts and to achieve reasonable scan times. To keep within SAR limits without compromise in scan efficiency varying flip angles (TRAPS) were applied that varied between 60° and 180° along the echo train.

	Multi shot	Single shot
Echo train length ETL	45	90
Echo spacing ESP	4.5 ms	4.5 ms
NEX	3	1
TR/TE	3s/100ms	420ms/100ms
Base matrix size	384x384	256x256
Acq. phase encodes	85%	81%
Half Fourier	yes	yes

Tab. 1: used sequence parameters

Spatial sequence setup: In terms of moving table MRI the spatial-temporal order of acquisition steps changes basically going from single to multi shot acquisitions: For time efficiency the 3-shot TSE sequence applies an interleaved multislice acquisition pattern with 15 slices in TR. With a slice distance of 6mm this slice package extends to D=90mm thickness. To acquire all data for image reconstruction in each slice, the table moves by D/NEX=30 mm per repetition. Either the scan positions in the scanner are moved by the same distance with each TR to follow the same anatomical slices or the slice package met in the patient is shifted by –D/NEX each TR. However, as the slice packages in the patient overlap NEX times, after a number of repetitions there are enough shots on each anatomical slice to collect the full data set for image reconstruction. The first technique extends the scan range used in the scanner during NEX*TR to 2*D=180mm, while the latter technique uses the same scan range for each TR. This scan range is further reduced to D*(1-1/NEX)=60mm if successively excited slices are spatially ordered opposite to the table motion direction. For the shown images here, the second technique was applied. During the echo trains the refocusing pulses were applied to the same anatomical slice shifting the frequency of the refocusing pulses accordingly to the table motion.

Scanner setup: All experiments were performed on a 1.5 T Siemens Avanto scanner with 32 receive channels and a total of 60 local coil elements covering the total patient (TIM®-system). During scan it was switched dynamically between different subsets of the coil arrangement according to the current table position.

RESULTS

Single shot and 3-shot images of different body parts are compared in Fig. 1. The single shot images (A.1 – A.4) have a nominal resolution of 2mm*2.4mm per pixel (base matrix size = 256x256 pixels). However, the actual resolution is reduced due to moderate blurring. The images were acquired at a table speed of 14mm/s (1.8m in 2min 10s) covering the total body with axial slices (thickness = 5mm) each 6mm. The nominal resolution in the 3-shot images (B.1 – B.4) is 1.3mm*1.5mm per pixel (base matrix size = 384x384 pixels). Almost no blurring is observed in the 3-shot images, which were acquired at a table speed of 10mm/s (1.80m in 3min). The reduction in table speed corresponds to the increase in the base matrix size. SNR was determined dividing the signal intensity in ROIs in different tissues by the mean background signal intensity. The loss in the SNR in the 3-shot images compared to the single shot images was between 10% and 25% for muscle, liver, kidney, white matter and intra abdominal fat. Normalized to the voxel size, which is about double in the single shot images this corresponds to a relative gain in SNR of about 50% due to the shorter echo train duration. Contrary to the single shot images the multi shot images show residual breathing artifacts (B.2) and ghosting due to a limited TR as no dummy scan was applied preceding the first excitation of each slice (B.1, B.4).

DISCUSSION

An axial T2-weighted MDS technique is presented that covers the total body without gaps in as little as 3min. The achieved image properties are drawing equal with the image properties gained in conventional stationary imaging in terms of contrast, image resolution and SNR. Overcoming the limitation in resolution of previously presented single shot techniques the table speed is only moderately reduced to 10mm/s. Multislice acquisition strategies could be integrated into axial MDS imaging without scarifying image quality due to gradient field related inhomogeneities along the scanners z-axis. For the first time, dynamic coil switching during the scan enabled the acquisition of the total body with local surface coils that are fixed to the patient and dedicated to the different body parts. The major drawbacks of the presented technique are residual breathing and ghosting artifacts due to the 3 shot acquisition. However, it was shown, that multi shot techniques can be made more robust against motion effects by simultaneously using parallel imaging techniques and multiple averages [4,5]. The combination of parallel imaging with our technique is highly promising as acceleration factors of 3 seem to be realistic in clinical routine using dedicated coil setups like TIM®. In this ideal case the advantages of single shot techniques in terms of motion robustness and ghosting would be completely restored as an image is reconstructed from each shot.

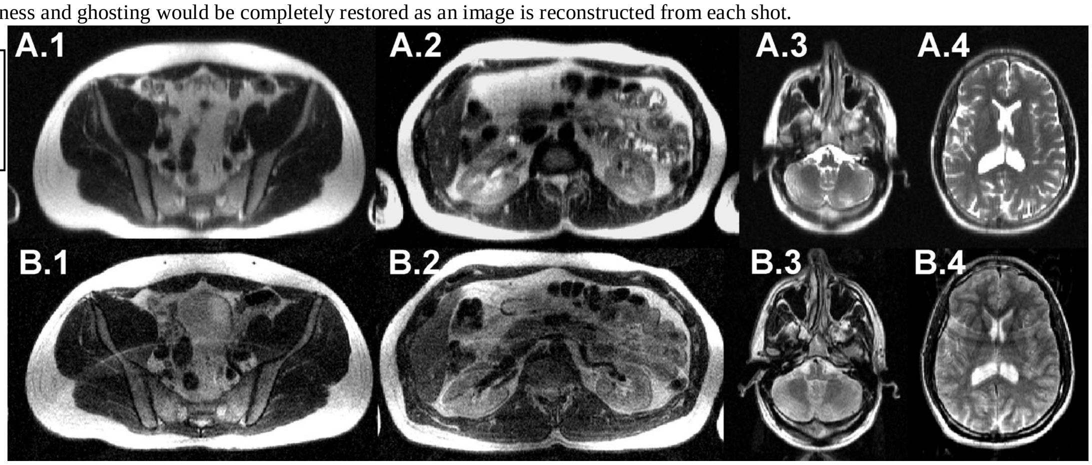

Fig.1: cropped images acquired with a single shot (top) and a 3 shot (bottom) sequence during continuous table motion.

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