Refocused Turbo Spin Echo for Noncontrast MRA

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Introduction

There is increasing interest in non-contrast MRA methods because of the risk of NSF in patients with kidney disease [1]. RARE-type sequences are capable of generating contrast between blood and surrounding tissue based on T_2 differences, but conventional RARE sequences have a non-zero first moment at the RF pulses and at odd echoes, and are therefore susceptible to flow-related artifacts and signal loss. An alternative technique combines the increased signal provided by the 180° refocusing RF pulses of RARE and the better flow performance of the fully-refocused gradients and phase alternation of balanced SSFP. This method has been used for 2D cardiac edema imaging [2], but not for MRA. Here we apply a hybrid 3D refocused turbo-spin-echo (TSE) sequence to the lower limbs in an initial evaluation of its efficacy and applicability in peripheral angiography studies.

Purpose

To develop a 3D refocused TSE (rTSE) sequence for generating peripheral angiograms, and to compare angiograms of the thigh of normal volunteers generated by the rTSE sequence to those generated by a traditional TSE sequence.

Methods

A 3D dataset was first acquired on a Siemens 1.5-T Avanto scanner (Siemens Medical Solutions) with a standard TSE sequence: TR 3000 ms, TE 157 ms, echo spacing 3.1 ms, resolution 1.48 x 1.48 x 1.48 mm^3, refocusing flip-angle 180°, acquisition time 3.17 minutes. Immediately afterwards, a second 3D dataset was acquired with the same sequence parameters using the rTSE sequence. The rTSE sequence was identical to the TSE sequence except that the frequency-encoding gradient had a zeroth moment of zero, and the excitation and refocusing RF pulses were applied along the same axis with a 180° phase alternation along the echo train analogous to common implementations of balanced SSFP.

Image quality was compared based on SNR, contrast resolution, and vessel sharpness of transverse images across the 3D volume. Contrast resolution was calculated as the difference in intensity values between the femoral artery and vein divided by the sum of those intensity values. Vessel sharpness was quantified by calculating the two-dimensional magnitude of the image gradient and recording the maximum gradient across the femoral artery at three locations and orientations. The average maximum gradient value from these measurements was taken as a measure of vessel sharpness in the overall image.

Results

Figure 1 shows example coronal maximum-intensity-projections from the TSE and rTSE sequences. Artery-vein contrast is visibly increased using the rTSE sequence. The table below displays SNR, contrast resolution, and sharpness for each sequence. Image contrast resolution and sharpness were both greater using the rTSE sequence ($p < .01$).

Figure 1. Coronal MIP images from the TSE sequence (left) and the rTSE sequence (right). Note increased SNR and contrast between arteries and veins in the rTSE image.

Discussion & Conclusions

The use of balanced gradients and RF-pulse phase alternation in a TSE sequence resulted in images with comparable SNR to those generated without the use of balanced gradients but with higher contrast resolution and sharper vessels. The rTSE method is similar to balanced SSFP in that the zeroth moment for each gradient axis is zero between each pair of refocusing RF pulses, mitigating velocity-dependent artifacts. However, it differs in several important respects: First, 180° refocusing pulses provide a greater echo signal level than low-flip-angle balanced SSFP. The artery-muscle contrast subsequently obtained with rTSE is similar to that of a traditional TSE sequence and, for gated studies, does not require additional T2-prep pulses as in balanced SSFP. Second, because imaging is carried out during the initial transient, the well-known SSFP banding artifact is avoided. Stemming from this, longer echo spacings are achievable, which is desirable for high-resolution images. Additionally, since this technique does not rely on subtraction to remove static tissue and venous signal, longer echo spacings may also be desirable to increase artery-vein contrast in the final images [3]. Artery-vein contrast will be less of an issue in the coronaries, where we hope to apply this technique in the future for gated 3D coronary studies.

	SNR	Contrast Resolution	Sharpness
TSE	11.9 ± 1.11	-0.11 ± 0.08	0.33 ± 0.05
rTSE	9.52 ± 1.76	0.09 ± 0.07	0.46 ± 0.05

References
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