Comparison of Temporal and Spatial Undersampling Techniques for Time-Resolved Contrast-Enhanced MR Angiography

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Introduction

Compared to timed contrast-enhanced MR angiography, time-resolved acquisitions are intended to have a sufficient frame rate to capture the peak arterial frame without the need for a dose timing scan. In addition, high temporal resolution allows for better study of flow-based pathologies involving shunting or retrograde filling, and can generate multiple peak arterial frames when asymmetric filling is present (1). In order to achieve sufficient SNR and spatial and temporal resolutions, undersampling is necessary in either the spatial or temporal dimensions. In this study, we compare a novel temporal undersampling strategy, dubbed TREAT (Time-Resolved Echo-shared Angiographic Technique), to a similar temporal undersampling strategy, TRICKS (Time-Resolved Imaging of Contrast KineticS) (2), and to a spatial undersampling strategy involving parallel imaging, GRAPPA (GeneRalized Autocalibrating Partially Parallel Acquisition) (3) for imaging the carotid arteries.

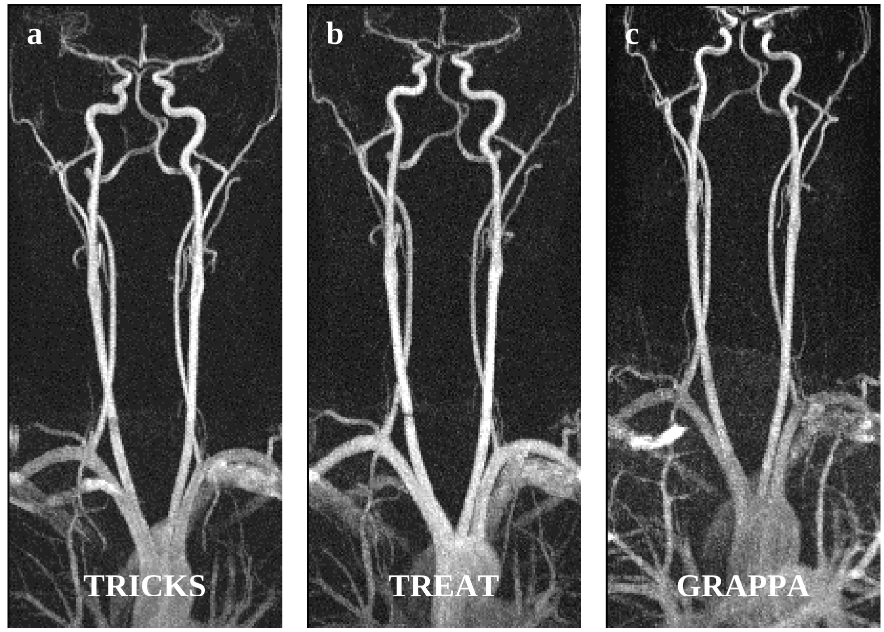

Figure 1

Materials and Methods

Simulations compared the TRICKS and TREAT schemes by sampling a continuous-space, continuous-time expression for a vascular phantom image and measuring artifact power. Images were acquired from 6 healthy volunteers using each of the 3 techniques on a 1.5 T whole body MR scanner (Avanto, Siemens Medical Solutions, Erlangen, Germany) with a 4-channel head coil and 2-channel neck coil (Siemens Medical Solutions, Erlangen, Germany). 2 patients with confirmed pathology were also scanned using one of the techniques. A coronal 3D multi-phase FLASH pulse sequence was used with a Cartesian *k*-space trajectory, centric reordering, and partial Fourier undersampling (FOV = $300 \times 135 \times 64$ mm, image matrix = $320 \times 144 \times 64$, spatial resolution = $1.0 \times 1.0 \times 1.0$ mm, phases = 10, temporal resolution = 6.0 s/frame, TR/TE = 2.4/0.9 ms, flip = 25º, bandwidth = 980 Hz/pixel, R-L/A-P partial Fourier factors = 0.75/0.75). 3 equal size segments were used for both the TREAT and TRICKS scans. The GRAPPA scans had an undersampling factor of 2 and 36 reference lines such that the number of acquired lines was the same for all scans. A single dose of a gadolinium-based contrast agent (Magnevist, Berlex, Wayne, New Jersey) was administered in an antecubital vein at an injection rate of 4.0 ml/s, starting simultaneously with the imaging protocol. Images were qualitatively scored by board-certified radiologists.

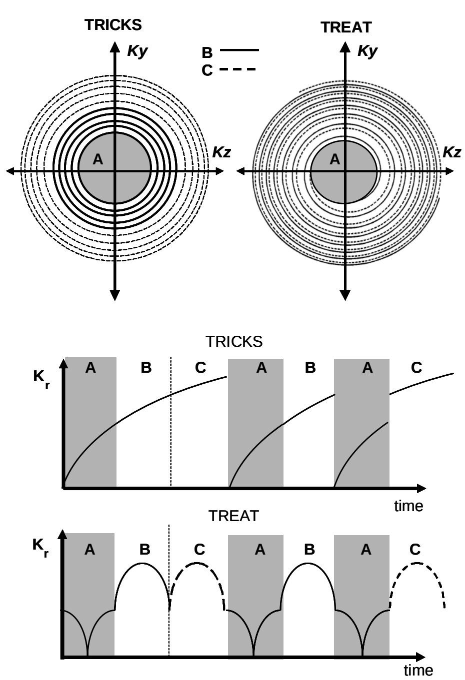

Figure 2

Results

Simulations showed no difference in artifact power between TRICKS and TREAT. **Figure 1** shows representative coronal magnitude subtraction MIP's using **(a)** TRICKS, **(b)** TREAT, and **(c)** GRAPPA in the same volunteer at the same temporal resolution of 6.0 s. TREAT images showed improvement over TRICKS and GRAPPA images, according to both qualitative image scoring and quantitative SNR measurement. In patients, a carotid stenosis and an arteriovenous shunt were both better demonstrated with time-resolved acquisitions than timed acquisitions.

Discussion/Conclusion

The difference between the TRICKS and TREAT schemes is depicted in **Figure 2**. With TREAT, a central segment ("A") is acquired for every time frame. The remainder of *k*-space is divided into several interleaving segments ("B" and "C"), unlike TRICKS which does not have interleaved segments. As a result, TREAT acquires a wider spectrum of lines in each time frame. Additionally, lines are acquired with TREAT such that no discontinuities in k_r occur in order to suppress artifacts from eddy currents, which may explain why imaging showed a difference between these techniques whereas simulation did not. In choosing an acceleration strategy for time-resolved imaging, several options are available, including parallel imaging and temporal echo sharing, and all techniques evaluated here are acceptable, with TREAT producing the most superior results. TRICKS/TREAT may still be combined with parallel imaging strategies for even greater undersampling factors.

References

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3. Griswold MA, et al. MRM 2002;47:1202-1210.