High-Resolution Magnetization Transfer Compensated Dynamic Angiography Imaging at 7 Tesla

Ann-Kathrin Homagk[1], Alexander Radbruch[2], and Wolfhard Semmler[1]

[1]Dept. of Medical Physics in Radiology, German Cancer Research Center (DKFZ), Heidelberg, Germany, [2]Dept. of Neuroradiology, University Heidelberg, Heidelberg, Germany

Introduction

Arterial spin labeling (ASL) is a non-invasive method to assess not only perfusion, but also dynamic flow patterns within the cerebral vasculature. Dynamic ASL has been applied to estimate the degree of flow in arteriovenous malformations (AVM) [1, 2]. For high resolution dynamic ASL imaging of the cerebral vasculature, a STAR sequence [3] has been adapted to meet the requirements of ultra-high magnetic fields [4]. To compensate for insufficient background suppression due to magnetization transfer effects, various techniques known as PICORE [5], FAIR [6] or FAIRER [7] have been developed. However, these sequences are considerably SAR-intense due to additional magnetization transfer pulses. In this work, we investigate the suitability of different pulsed ASL techniques for high resolution dynamic imaging of the cerebral vasculature at 7 T.

Materials and Methods

Dynamic angiography imaging was performed in three healthy volunteers on a 7T MR system (Siemens Magnetom, Erlangen, Germany) with a 24 channel receive head coil (Nova Medical, Wilmington, MA, USA). Five different techniques were implemented and optimized for the use at 7 Tesla: STAR, STAR_MT (STAR with additional magnetization transfer pulse in the control image), PICORE, FAIR and FAIRER. For all techniques, a segmented FLASH readout with first-order flow compensation and centric k-space re-ordering was used. The volunteers were imaged using the following parameters: TR = 8.4 / 10.2 ms (STAR / all other sequences), TE = 4 ms, α = 12°, Sl.th. = 40 mm, Inv.th. = 80 mm (STAR, STAR_MT and PICORE), FOV = 270 $\times$ 189 mm², matrix = 480 $\times$ 329, BW = 180 Hz/px, 14 phases with TI ranging from 50 ms to 960 ms, 25 segments, 6 averages, TA = 9 min – 11 min. As additional delay time had to be inserted for the STAR_MT, PICORE, FAIR and FAIRER sequences to meet SAR restrictions, the acquisition time was increased for these techniques.

Results and Discussion

Fig 1 shows dynamic angiography images of the cerebral vasculature of one volunteer acquired with the five sequences at three different TI. All images have an in-plane resolution of 0.57×0.57 mm². Due to the MT effect compensation in the STAR_MT, PICORE, FAIR and FAIRER sequences (Fig 1b-e), background signal from brain tissue is more efficiently suppressed, leading to an improved delineation of small vessels in the later phases (arrowheads) compared to the STAR images (Fig 1a). The best visibility of peripheral vessels was obtained with the FAIR and FAIRER sequences. Both techniques use only on-resonant inversion pulses and are hence most robust against MT effects. The acquisition time of the MT compensated sequences is increased by up to 20 %, but still applicable in vivo.

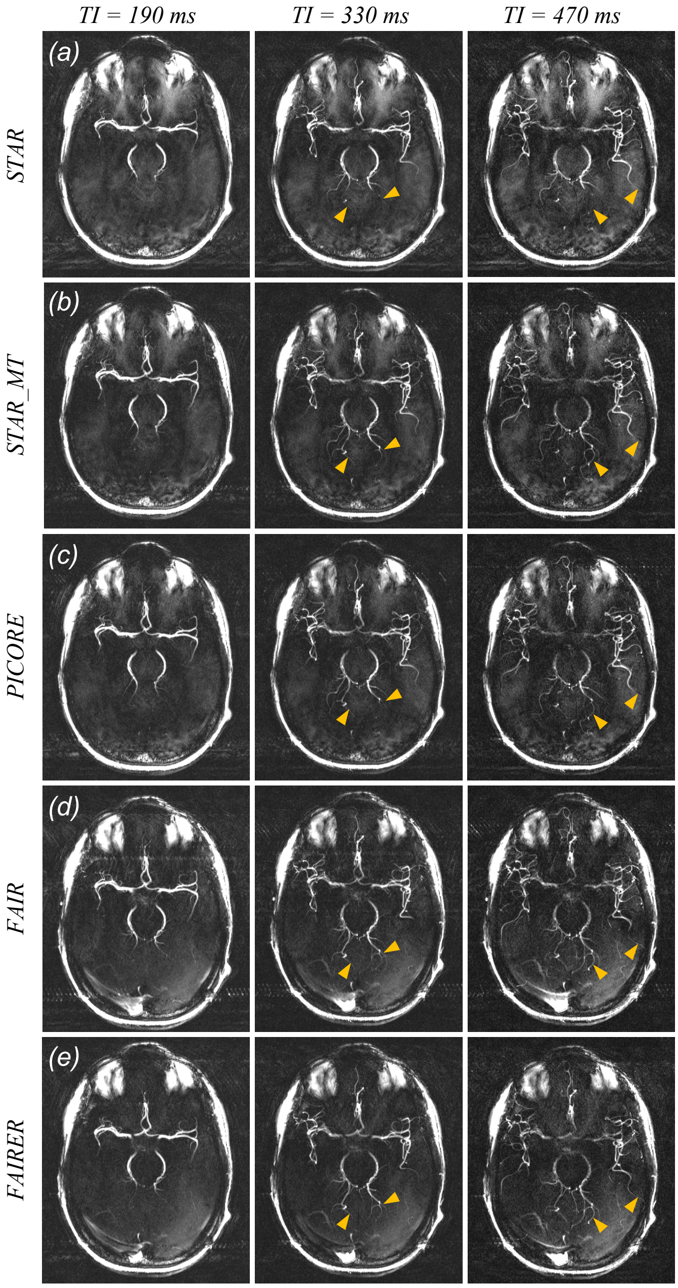

Fig 1. Dynamic angiography images of a healthy volunteer, acquired using the (a) STAR, (b) STAR_MT, (c) PICORE, (d) FAIR and (e) FAIRER sequence. The first column shows images acquired at TI=190 ms, second column: TI=330 ms, third column: TI=470ms. The use of additional MT pulses (b-e) results in a better visibility of smaller vessels, especially for the FAIR and FAIRER sequences (arrowheads).

Conclusion

This study shows that magnetization transfer compensated ASL techniques allow for a better dynamic visualization of the cerebral vasculature at 7 Tesla compared to the STAR sequence. A decrease in acquisition time for all sequences could be achieved by the use of VERSE pulses. Furthermore, a combination of a multichannel head coil with superior B_1 homogeneity and a separate neck labeling coil would improve the inversion profile as well as the saturation of remaining background signal from brain tissue.

References

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