

# High-Resolution Dynamic Angiography Imaging at 7 Tesla

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## 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]. In theory, the increase in SNR at ultra-high magnetic fields allows for ASL images with higher spatial resolution. However, SAR limitations and changes in relaxation times imply that standard imaging protocols are only of limited use and have to be adapted to the higher field strength. In this work, we present how the challenges of acquiring dynamic angiography images at 7 Tesla can be overcome.

## MATERIALS AND METHODS

For dynamic ASL imaging of the cerebral vasculature, a STAR sequence [3] was implemented with the following adaptations: for effective suppression of unwanted background signal, a 20 mm thicker region than the imaging slice was saturated before data acquisition. The selective spin labeling in an upstream slice was accomplished by an adiabatic hyperbolic secans inversion pulse  $B_1(t)=[A_0\text{sech}(\beta t)]^{1+i\mu}$  with optimized parameters  $\beta$  and  $\mu$ . To minimize artifacts caused by eddy currents, gradients were applied in all directions during the inflow time  $TI$ . Data were then acquired with a segmented FLASH readout with first-order flow compensation and centric k-space re-ordering. To minimize the total scan time, images with different  $TI$  were acquired in an interleaved fashion. After pre-saturation and ASL inversion pulses,  $n_{ips}$  lines per segment were sampled, which was repeated  $n$  times. Thus,  $n$  images with different inflow times  $TI_1=TI$ ,  $TI_2=TI+n_{ips}\cdot TR$ , ...,  $TI_n = TI+(n-1)\cdot n_{ips}\cdot TR$  were acquired. As the  $T_1$  decay and the previous data readouts at shorter  $TI$  lead to lower signal intensities for long  $TI$ , the flip angles of the imaging readout pulses were increased for each phase.

Dynamic angiography imaging was performed on a 7T MR system (Siemens Magnetom, Erlangen, Germany) with a 24 channel receive head coil (Nova Medical, Wilmington, MA, USA) or a single channel head coil (Invivo, Orlando, FL, USA). The single channel coil was used for comparison as it provides a more homogenous  $B_1$  and a larger coverage in caudal direction. Three volunteers were imaged using the following parameters:  $TR = 10$  ms,  $TE = 4$  ms,  $\alpha = 13^\circ$ ,  $\alpha_{sat} = 150^\circ$ ,  $\alpha_{inv} = 340^\circ$ ,  $Sl.th. = 40$  mm,  $Inv.th. = 80$  mm,  $\beta = 800$  1/s,  $\mu = 10$ , 14 phases with  $TI$  ranging from 50 ms to 960 ms,  $BW = 180$  Hz/px,  $FOV = 270 \times 184$  mm<sup>2</sup>, matrix =  $480 \times 324$ , 25 segments, 6 averages,  $TA = 6:45$  min.

## RESULTS AND DISCUSSION

Fig 1 shows dynamic angiography images obtained from one of the volunteers. The images in the upper row were acquired with the 24ch coil, whereas the single channel coil was used for the lower row. All images have an in-plane resolution of  $0.56 \times 0.57$  mm<sup>2</sup>. In the 24ch coil images, background signal from brain tissue and the eyes (arrows) is not effectively suppressed due to the  $B_1$  inhomogeneity of the coil. Furthermore, the limited transmit coil coverage in the lower parts of the head impairs the spin labeling. Yet small peripheral vessels could be visualized in the later phases (arrowheads). The single channel coil provides a lower SNR, however background signal is suppressed more efficiently, especially in the anterior parts of the head (arrow).

This study shows that high-resolution dynamic angiography imaging at 7 Tesla is feasible within an appropriate acquisition time using a modified STAR sequence. A combination of a multichannel head coil with a superior  $B_1$  homogeneity and a separate neck labelling coil would improve the inversion profile as well as the saturation of unwanted background signal.

## REFERENCES

[1] Yan L et al, Radiology 256(1), 2010. [2] Essig M et al, Magn Reson Ima 14(3), 1996. [3] Edelman R et al, Magn Reson Med 31(2), 1994.

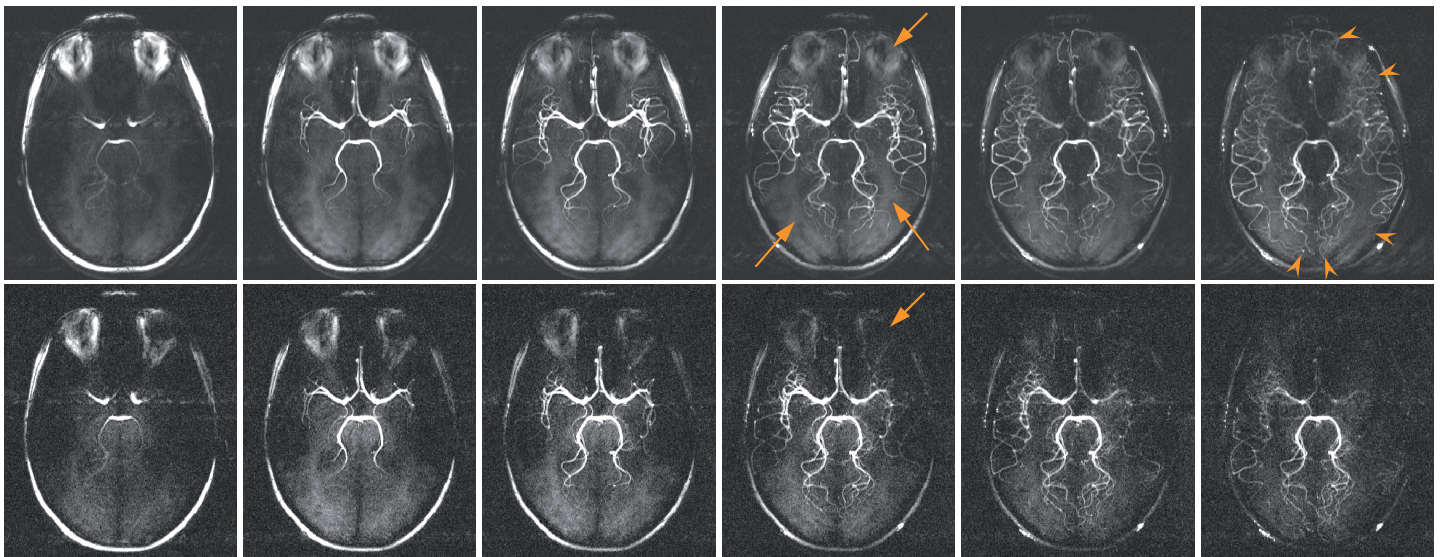


Fig 1. Dynamic angiography images of a healthy volunteer, acquired with the 24ch/1ch head coil (upper/lower row), at  $TI = 50/190/330/540/750/960$  ms. In the 24ch coil images, background signal from brain tissue and the eyes (arrows) is not fully suppressed due to the  $B_1$  inhomogeneities. Yet, small peripheral vessels could be visualized (arrowheads). The 1ch coil provides a lower SNR, however background signal is suppressed more effectively, especially in the anterior parts of the head (arrow).