Magnetic resonance angiography of the mouse cerebrovascular system at 17.6 T

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Introduction

Many neurodegenerative diseases including Alzheimer's disease are linked to abnormalities in vascular system. Visualization of the changes in vascular structure is important for early diagnosis and treatment. Blood vessels can be imaged non-invasively by magnetic resonance angiography (MRA) [1]. In this technique shortening of the effective T_1 of moving blood provides the vessel contrast with stationary tissue [2]. Improvement of this technique by increasing the vessels contrast and signal to noise ratio is possible by using higher magnetic fields [3]. In this study we investigated the feasibility of performing 3D time-of-flight magnetic resonance angiography (3D TOF MRA) at 17.6T to image the cerebral vasculature of mouse. Our results show that MRA significantly benefits from ultra high magnetic field (17.6 T) especially to visualize smaller vessels.

Methods

C57bl6J mice (9 month old) were used in this study. All measurements were conducted on a vertical wide bore 9.4 T and 17.6 T Bruker spectrometer, with a 1000 mTm^{-1} actively shielded imaging gradient insert (Bruker). A birdcage radio-frequency (RF) coil (inner diameter 2 cm) was used. The 3D time-of-flight (TOF) gradient echo sequence was applied with effective echo time = 1.86 ms, FOV=15mm and matrix size=128. Flip angle and repetition time were optimized to obtain best image quality in a reasonable imaging time. For this optimization varying FA (5, 10, 15, 20, 30, 40, 50°) and varying RT (15,20,30,40 ms) were used. To compare 3D TOF MR angiography at 9.4T and 17.6T, all imaging parameters were kept same except RT at 17.6 T was kept 5 ms longer to keep acquisition time (9 min 12 s) same at both fields. Imaging parameters were effective echo time = 1.86 ms; repetition time =15 ms (or 20 ms); flip angle = 25°. While inside the probe, the respiration rate of the mouse was constantly monitored (BioTrig BT1 monitoring software and acquisition module). For the quantitative evaluation of four vessels and their branches, the difference in signal intensity between region of interest (sROI) of a vessel point and signal intensity of surrounding non vessel background (sBG) were measured. The CNR of each region was calculated as: CNR=(sROI-sBG) /σ. Signal to noise ratio (SNR) was calculated as: sROI/σ.

Results and Discussion

In this study, 3D TOF MRA sequence was optimized at 17.6 T to visualize cerebral vessels in living mouse. The following vessels were evaluated: ACA (anterior cerebral artery), MCA (middle cerebral artery), PPP (pterygo portion of pterygopalatine). Figure 1 shows the effect of flip angle and repetition time on CNR. The best CNR was observed at FA between 20-40 especially for larger vessels such as the main part of anterior cerebral artery (ACA) and middle cerebral artery (MCA). However, smaller vessels such as ACA1 were better visualized using smaller flip angle. Fig. 2 compares the MIP of angiogram of same mouse imaged at 9.4T and 17.6T. MIPs from 17.6T MR angiography depict branches of ACA vessels more clearly than did those from 9.4T MR angiography. Fig. 2c show that CNR and SNR was higher in all the vessels at 17.6 T as compared to 9.4T. Our results show that MRA at 17.6 T revealed enhanced visualization of smaller vessel. Visualization of smaller vessel in mouse brain can be invaluable for early diagnosis and treatment using transgenic mouse models of various brain disorders.

References: [1] Beckmann et al. J. Neurosci. (2003) 23:8453-8459; [2] Hu and David Annu. Rev. Biomed. Eng. (2004) 6: 157-84; [3] Fushimi et al. Radiology (2006) 239:233-237

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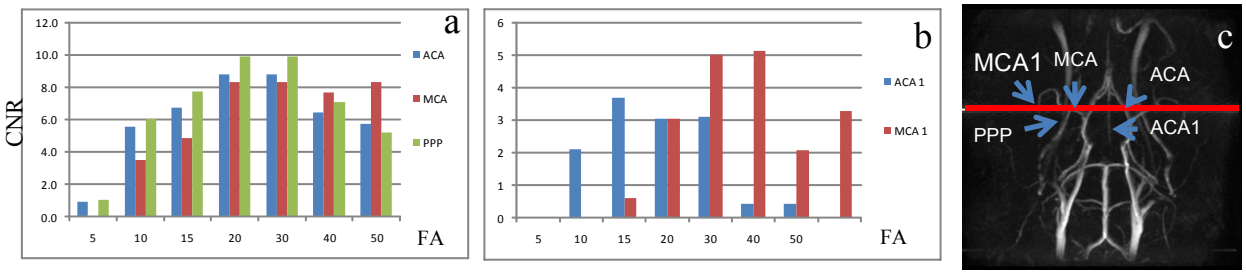

Fig. 1: Effect of flip angle (FA) on CNR: (a) ACA, MCA, PPP (b) branches of ACA and MCA; ACA1, MCA2: blood flow is slower in branches of ACA and MCA. The flip angle between 10 and 30 gave higher CNR for ACA1. For MCA1, FA between 20 and 40 gave higher CNS. (c) MIP of 3D TOF MRA of mouse.

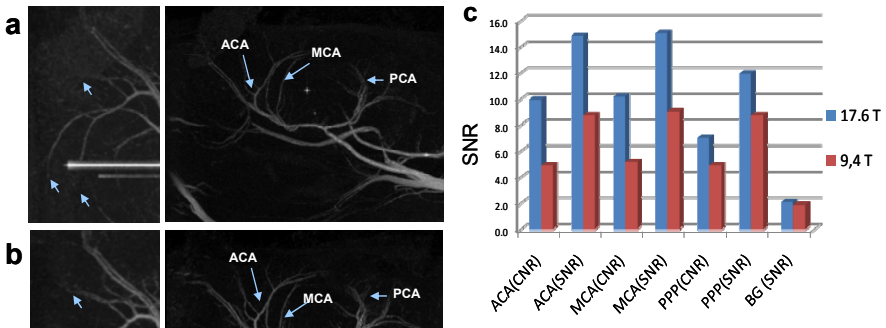

***Fig 2:** MIPs from 3D TOF MR angiography in 9 month old wild type mouse at 9.4 T (a) and 17.6 T (b). More vascular branches of ACA are visible in 17.6 T. (c) Overall increase in signal intensities from all vessels was observed at 17.6T as compared to 9.4T.*