Active Head Coil Detuning: A Method to Reduce SAR in CASL at 7T

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Introduction: Continuous arterial spin labeling (CASL) has been demonstrated as a non-invasive technique to measure cerebral blood flow (CBF) [1]. CASL at 7T has the dual benefit of increased spin polarity and the increased T_1 of arterial blood (~2100 ms [2]) [3]. Two major limitations of CASL at 7T are the Specific Absorption Rate (SAR) limit and increased B_1 inhomogeneity. One method to reduce the SAR deposition and improve the B_1 homogeneity is by employing a separate labeling coil in the neck with an actively detuned head coil [4,5]. These features eliminate magnetization transfer (MT) effects in the head coil during labeling, thereby removing the need for RF power during the control pulse train. Removing the control RF reduces the ASL-preparation SAR deposition by 50% allowing for shorter TRs, and increases the labeling efficiency by removing the need for RF modulation during control [6]. The work presented here demonstrates the utility of this novel coil system for reducing the SAR-limited TR in high-resolution CASL at 7T [5].

Methods: Data were acquired from five consenting healthy volunteers on a Siemens Magnetom 7T scanner (Siemens Healthcare, Erlangen, Germany). We developed a dedicated 7T ASL coil system for data acquisition with 8 ch Tx/Rx head, 2 ch Tx/Rx labeling [5]. The 8-channel head coil was actively detuned during the labeling train. The optimal labeling plane was selected using an axial FLASH-based localizer to ensure proper B_1 penetration in the common carotid and vertebral arteries (Fig. 1). The CASL labeling duration was 1500 ms (50-ms square pulses at 99% duty cycle with 40-Volt reference voltage, and 2.5 mT/m labeling gradient). The EPI acquisition parameters were 220-cm FOV at 128×128, 4 slices at 5-mm slice thickness, TE of 17 ms with a GRAPPA factor of 3. Initial data sets were collected to determine the SAR-minimum TR with and without control RF to confirm no MT effects during labeling. Three separate data sets were collected with 60 Label/Control pairs at the shorter SAR-minimum TR without Control RF with post-label delays of (1) 1000 ms, (2) 1500 ms, and (3) 2000 ms. Motion correction was performed using SPM8 (Wellcome Trust Centre for Neuroimaging, UCL, London, UK), and ASL analysis was performed using MATLAB (MathWorks, Natick, MA). Percent difference images were generated.

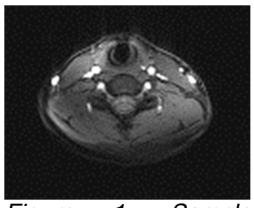

Figure 1: Sample FLASH image from a healthy volunteer used to select CASL labeling plane.

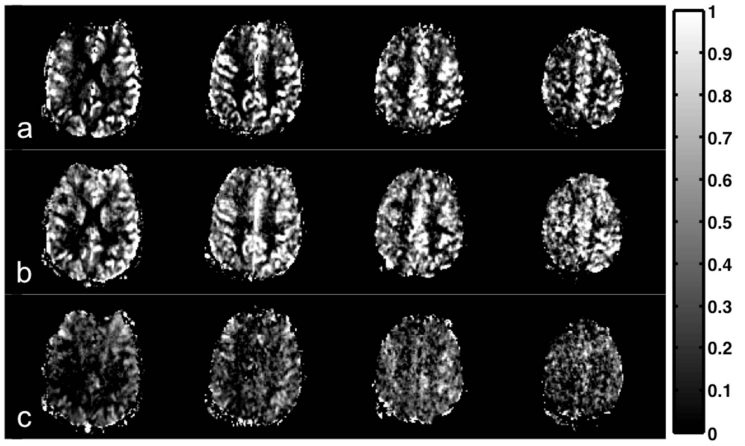

Figure 2: Sample 7T CASL 4-slice ΔM% images from a second healthy volunteer with 1500 ms of labeling, and post-label delays of (a) 1000 ms, (b) 1500 ms, and (c) 2000 ms. As expected, the data collected with a 1500-ms post-label delay shows a large percent signal change in GM.

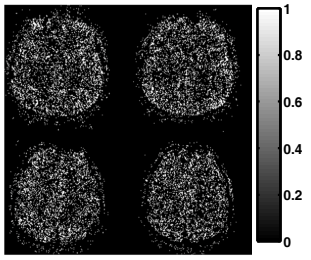

Figure 3: Sample data set from a third healthy volunteer showing the percent difference between Control RF on and Control RF off data sets. The minimal differences observed between Control RF On and Control RF Off indicate proper MT control, thus allowing for reduced SAR-minimum TR.

Results: Sample percent difference images from one healthy volunteer are shown in Fig 2. The 1.7×1.7×5 mm^3 resolution allows for adequate segmentation of gray matter (GM) and white matter (WM). No significant difference was observed between the SAR-minimum long-TR control RF on/off (TR = ~11,500 ms (Fig. 3), depending on subject weight), indicating that no MT effects are present during labeling. The SAR-minimum TR without RF control was found to be ~6200 ms, depending on subject weight. The percent signal change in GM from the data collected with short-TR without control RF with a 1500-ms post-label delay shows the highest percent difference in gray matter (Fig. 2).

Discussion and Conclusions: The receive capability of this 2-channel labeling coil system allows for optimal selection of the labeling plane. The non-uniform perfusion observed in GM (Fig. 2) may be related to B_0 inhomogeneity in the tagging plane. By properly accounting for MT effects, we were able to reduce the SAR-minimum TR by eliminating the RF during control. The high spatial resolution at 7T reduces the partial voluming between GM and WM in the percent signal change images. Future work will accurately measure the labeling efficiency in order to absolutely quantify the CBF. In conclusion, we have demonstrated the utility of this novel coil system for CASL at 7T with a reasonable SAR-minimum TR of under 6.5 seconds.

References: [1] Detre, *MRM* 1992;23:37. [2] Dobre, *MRI* 2007; 25:733. [3] Teeuwisse, *IJIST* 2010;20:62. [4] Talagala, *MRM* 2004;52:131. [5] Woo, *ISMRM Perfusion Workshop* 2012;P.26. [6] Alsop, *Radiology* 1998;208:410.