Dynamic Spin Labeling Thick-slab Angiography: Off-resonance Correction of Spiral Acquisitions by Vessel-Selective B_0-Fieldmapping

C. Warmuth[1], B. Hamm[1], M. Taupitz[1]
[1]Department of Radiology, Charité Medical School, Berlin, Germany

Introduction

Dynamic spin labeling angiography (DSLA) is a technique that enables depiction of the influx of magnetically labeled blood into the vessels with high temporal resolution [1]. DSLA of the cerebral vasculature has proven to be useful for the characterization of carotid artery stenoses and quantitative determination of flow [2, 3]. Gradient echo readout using spiral k-space sampling is very attractive for DSLA, because the long T_2* of blood makes it very SNR efficient [4]. A drawback is that spiral acquisitions suffer from off-resonance blurring in regions of B_0 inhomogeneities. This blurring can be corrected for, if the local off-resonance frequency may be determined, e.g. in a prior multi-echo fieldmap scan. However, in angiographic thick slab 2D projection acquisitions this is not possible, as the position of a vessel in slice direction within each anisotropic voxel is a priori unknown. Hence, the off-resonance frequency must be averaged over the whole slice thickness which is not adequate in regions of large through-plane B_0-gradients, e.g. near the frontal sinus. Here we present a method to acquire vessel selective B_0-fieldmaps for inline off-resonance correction of spiral DSLA images.

Materials & Methods

The basic idea is to acquire spin labeling images at two different echo times (1.5 & 4 ms) and to subtract label and control images before calculation of the fieldmap. All imaging studies were performed at 1.5 T on a Siemens Magnetom Sonata system. Labeling was accomplished by alternating slice selective/global inversion (FAIR) using a 10 ms hyperbolic secant inversion pulse. Before and after the inversion, saturation pulses plus spoiling destroyed any remaining magnetization in the 60 mm image slab. Thereafter, 45 phases were acquired with 28 ms temporal resolution using a 10° TONE pulse for excitation and distal saturation pulses to suppress venous blood. The spiral readout consisted of 17 interleaves of 15 ms length. A slewrate of 150 $Tm^{-1}s^{-1}$ and 18 mT/m maximum gradient enabled acquisition of 256x256 images in a 250 mm FOV. Four averages were done in combination with ECG triggering; a measurement took 544 heartbeats to complete. Image reconstruction was done as follows: At first, complex label and control images were subtracted, leaving only the blood signal. Afterwards, complex phase subtraction of the two echoes was carried out and all acquired time points were averaged resulting in a single fieldmap image of the vessels. At last, this fieldmap was post-processed by using a threshold of 10% to suppress noise voxels and a 3 voxel region growing with next neighbor interpolation. All spiral images were finally off-resonance corrected by multi-frequency interpolation reconstruction of the gridded k-space data.

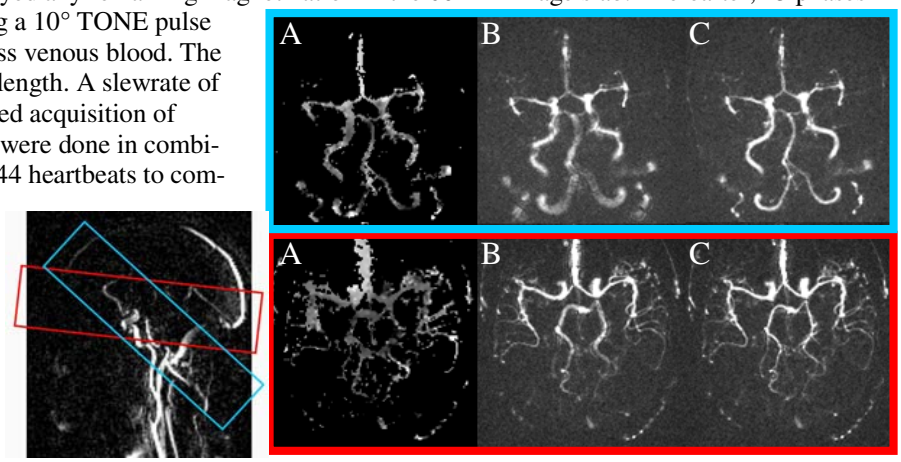

Figure 1. Left: Sagittal phase contrast vessel scout shows the slice positioning. Right: (A) vessel selective fieldmaps,(B) uncorrected and (C) off-resonance corrected images of the two thick slabs

Results & Discussion

Spin labeling angiograms of the cerebral arteries of a volunteer are shown in figure 1. The vessel selective fieldmaps have sufficient SNR. In the more coronal slab (blue in fig. 1) off-resonance frequencies ranged from -150 Hz in the neck to +50 Hz in the frontal lobe. The uncorrected images were affected by heavy blurring, which could be completely removed with our method. In its current implementation, scan time is doubled because the two echo times are measured sequentially. It is just as well possible though, to measure the echoes in an interleaved fashion, i.e. odd phases with TE_1 and even phases with TE_2. In this way, an acquisition with submillimeter inplane resolution may be finished after 34 inversions with the spiral trajectory we chose. At 1.5 Tesla however, the SNR of such a short acquisition is insufficient, and several measurements must be averaged. In this case a 3D acquisition of e.g. 8 partitions instead of 4 averages of 2 echoes might be the better choice. It provides at least the same SNR and may easily be off-resonance corrected using a pre-acquired fieldmap, but is not impaired by the major limitation of our projection method: the fieldmap may be incorrect if vessels cross in a voxel. In this case the average off-resonance frequency of the vessels is determined and both are deblurred suboptimal. On a 3 Tesla system the SNR but also off-resonance blurring are twice as high. Here, the presented technique would enable to measure dynamic angiograms in the shortest possible scan time.

References

[1] Wang SJ, Magn Reson Med. 1991 Jan;17(1):244-51
[2] Warmuth C, Am J Neuroradiol. 2005 May;26(5):1035-43
[3] van Osch MJ, Med Image Anal. 2005 Jun 8
[4] Amann M, Proc. ISMRM 2002 Honolulu, #629