Interleaved multi-slab 3D gradient and spin echo for arterial spin labeling

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Introduction: The cerebral blood flow (CBF) quantification with conventional ASL methodology has a limitation in the coverage or resolution in the slice direction. In order to overcome this drawback of the conventional ASL methodology including multi-slice 2D or the single slab 3D acquisitions, we performed an interleaved multi-slab 3D acquisition for a single ASL preparation. Single-slab multi-shot 3D acquisitions are suitable for minimizing the difference in arterial transit delay, providing spatially homogeneous perfusion mapping, but are time-consuming. The purpose of this study was to demonstrate the feasibility of the proposed multi-slab 3D GRASE ASL method in measuring the baseline CBF of healthy subjects. The conventional multi-shot, single slab 3D acquisition was also performed for comparison.

Methods: MRI acquisitions: Five healthy subjects (three males and two females) were scanned on a 3T Magnetom Trio scanner (Siemens Healthcare, Erlangen, Germany) with a 8-channel head coil. A gradient and spin-echo (GRASE) sequence was used for 3D image acquisition [1, 2]. A centric phase-encoding order in the slice direction was used to reduce ghost artifacts. Acquisition parameters were: TR=3 s, TE=9.1 ms, resolution=4x4x5 mm^3, matrix size=64x64, 25 partitions without partial Fourier sampling. EPI factor (echo train length)=13; bandwidth=3584 Hz/pixel, a refocusing pulse flip angle of 162 deg.

Pulsed arterial spin labeling (PASL) method was used with PICORE and Q2TIPS technique [3]. The post-labeling delay (arterial inflow) times (TI) were 0.8, 1.2, 1.6, 2.0, and 2.4 s. The duration for Q2TIPS saturation pulses (T_{q2tips}) was 700 ms. The post-inversion saturation pulses were also applied to avoid aliasing in the slice encode direction [1]. Five averages for 5 different TIs were acquired giving a total scan time of 6 min for the interleved multi-slab acquisition, and 15 min for the single slab acquisition.

The absolute value for CBF was calculated on a voxel-by-voxel basis according to the equation [4] :

$$\Delta S = CBF * M_{zBlood} * T_{q2tips} * \exp(-TI/T_{1Blood}) * \exp(-TE/T_2{*}_{Blood})$$

The resulting CBF images were spatially normalized into the standard space, in order to apply automatic region of interest (ROI) for cerebral and cerebellar cortices. The averaged CBF values across the whole gray matter voxels in the cerebrum were calculated for each measurement condition.
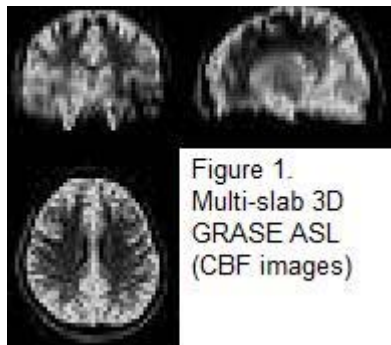

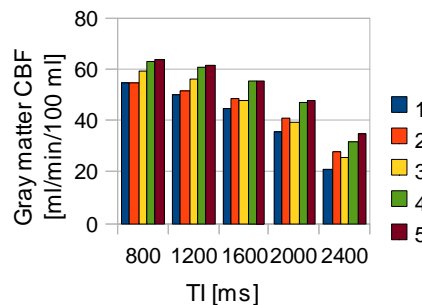Figure 1. Multi-slab 3D GRASE ASL (CBF images)
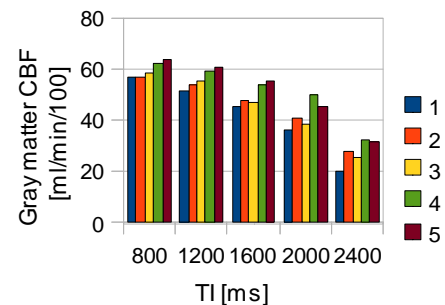

Figure 2. Multi slab

Figure3. single slab

Results: Figure 1 shows an example of the merged CBF quantification images from a subject which were obtained using the proposed multi-slab 3D GRASE sequence (displayed by three orthogonal sections). Image artifacts in the slice encoding direction do not increase even when multi-slab technique is applied. By using the multi-slab 3D acquisition approach, the total scan time could be shortened to 2/5 compared to the single slab approach. Statistical analysis showed no significant difference in the accuracy of the CBF quantification between the single slab acquisition and the multi-slab acquisition (Figure 2, 3).

Discussion:
We have shown that the ASL imaging based on a multi-slab 3D GRASE sequence provided equivalent results in the absolute quantification of the CBF to that of the single slab sequence. Therefore, the feasibility of the proposed multi-slab 3D acquisition approach was demonstrated by its better time efficiency and equivalent quantification accuracy. In order to quantify the CBF accurately in multi-slab acquisition, we must consider that TI differs with different slab. And, according to the assumption which we used for calculating the CBF values [4], the estimated CBF values changed systematically with TI (Figure 2, 3). Thus, the multiple TI imaging (with repetitions) must be necessary to correct estimation of the CBF.

Conclusion: We proposed the new 3D ASL acquisition using multi-slab 3D GRASE, which shortened scanning time without sacrificing measurement accuracy. The potential clinical applications of this ASL method should include high-temporal resolution monitoring of CBF and vascular reserve in patients with neurovascular diseases. Future work will include an application of this proposed method for neuronal activation study.

References: [1] Gunther et al., MRM 54:491-8, (2005); [2] Fernadez-Seara et al., MRM 54:1241-7 (2005); [3] Luh et al., MRM 41:1246-54 (1999); [4] Wong et al., MRM 55:1334-41 (2006)