Very fast 3D Perfusion Measurement with High Signal-to-Noise Ratio using Single-Shot 3D-GRASE: application to improve perfusion quantitation

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Introduction:

Arterial spin labeling (ASL) can be used to measure perfusion without the use of contrast agents. A major difficulty in obtaining quantitative perfusion values is that, in principle, the exact time when the labeled blood reaches the capillary exchange site (the so-called arterial transit time ATT) needs to be known for each imaging voxel. One solution is to reduce the sensitivity to different ATTs of the sequence by either delaying the image acquisition to longer TI [1] or by limiting the length of the labeled blood bolus (QUIPSSII [2]). However, these techniques rely on the unproven assumption that the ATTs fall within a certain range which might not be the case for all people and even less likely in patho-physiology of stroke or tumoral vascularity. The low signal-to-noise ratio (SNR) of ASL sequences makes it time-consuming to estimate the ATT for multiple slices, and many different sequences with different TIs typically can not be acquired in a clinically acceptable time. In this work, we present a single shot 3D imaging technique whose SNR is high enough to acquire 16 to 20 slices at each TI in less than a minute. This large reduction in imaging time results from the enormous improvement in data acquisition efficiency since the whole 3D image set is acquired after each ASL preparation. A highly quantitative coverage of ATT and perfusion is feasible in less than 5 minutes.

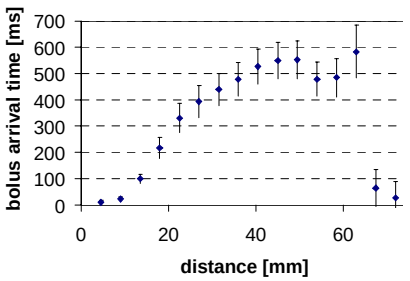

Fig. 2: Average bolus arrival time for all slices.

Material and Methods:

A clinical 1.5T scanner (Magnetom Sonata, Siemens, Erlangen, Germany) was used for imaging. Maximum gradient strength was 40mT/m with a slew rate of 200mT/m/ms. Arterial spin labeling was achieved with subtraction of two data sets with preceding non-selective and slice-selective inversion pulses, respectively. The imaging slab was saturated directly after application of the inversion pulse. The inflow of the labeled blood was sampled by a single shot 3D-GRASE sequence at different inflow times TI (250ms, 450ms, 850ms, 1050ms, 1650ms, 1950ms). Ten repetitions per TI were applied (acquisition time: 50 s). The whole experiment took 5 min.

The resolution relevant parameters of the single shot 3D-GRASE sequence were: matrix size 64x41, reconstructed to 128x80, field-of-view 250mm x 160mm, nominal 16 partitions with 13% oversampling, partition thickness 4.5 mm, 5/8 Fourier encoding was used to reduce the number of measured partitions to 11. Thus, an almost isotropic resolution of 4 mm $\times$ 4 mm $\times$ 4.5 mm was achieved. Other parameters include: echo time TE=33 ms, repetition time TR=2500ms, total echo train length: 451 echoes acquired within 410 ms, inter RF-spacing = 33 ms, bandwidth = 2170 Hz, off-resonance fat saturation pulse.

The whole data set of perfusion-weighted images at 6 TIs was used for post-processing to estimate the arrival time of the labeled blood for each slice after Gauss-filtering (σ=1pixel) along the TI-axis. A non-linear least-square fit (Marquardt-Levenberg) was applied to estimate cerebral blood flow (CBF) and arterial transit time (ATT).

Results:

Figure 1 shows perfusion-weighted images at different inflow times for slices 4-10 out of 16 slices along with calculated CBF and ATT maps. The average bolus arrival time for all slices is displayed in Fig.2. A plateau is reached at about 550 ms.

Discussion and Conclusion:

A method was presented to improve the acquisition of perfusion data by using a single-shot 3D-GRASE. Since the sequence is based on a true single-shot readout the SNR of the resulting perfusion-weighted images is optimal in terms of efficiency. In fact, the SNR is higher compared to conventional EPI or spiral-sequences, since the readout time per voxel is up to six times longer (400ms compared to 70ms). Measurement times of under a minute per TI allow sampling of the inflow of the labeled blood at multiple time points which can improve perfusion quantification tremendously, since ATT is taken into account instead of minimizing its effect. The proposed method allows fast isotropic acquisition of perfusion of almost the whole brain in under 5 min.

Acknowledgments:

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References:

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2. E.C. Wong, MRM 39, 702-708, 1999

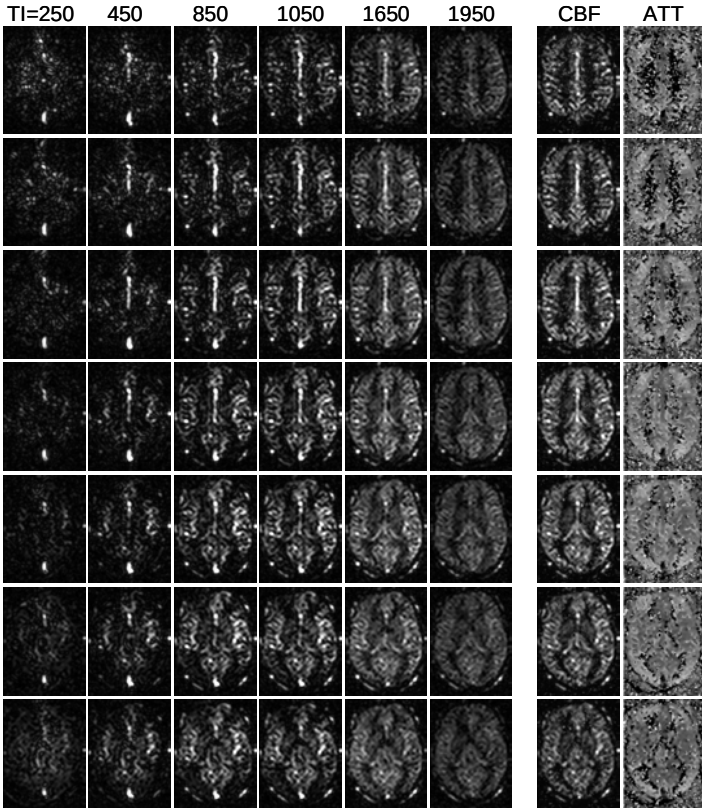

Fig.1: Seven slices out of 16 at 6 different inflow times TI. Calculated CBF and ATT values are shown in the two right columns. The acquisition time for the complete data set was 5min.