Continuous Arterial Spin Labelling Perfusion Measurements Using Single Shot 3D GRASE at 3T

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Introduction

A single shot 3D GRASE sequence has been previously employed for perfusion measurements at 1.5T using a pulsed ASL technique (1). This sequence acquires a combination of spin and gradient echoes in a CPMG train, with a refocusing pulse applied before every phase-encoding step in the slice direction. This makes it a good candidate for imaging areas affected by background gradients caused by susceptibility differences in air-tissue interfaces, such as orbito-frontal cortex. In this study, a CASL pulse was added prior to the single shot 3D GRASE read-out and quantitative perfusion measurements were carried out at 3T. The sequence performance was evaluated by comparison with a CASL sequence with EPI read-out.

Materials and Methods

Experiments were performed using a Siemens Trio scanner operating at 3T. Sagittal images of the brain of five volunteers were acquired with the CASL 3D GRASE and with a CASL 2D EPI for comparison. A bird-cage head coil (Bruker) was used for signal transmission and reception. The imaging parameters for GRASE were: resolution = 3.9 x 3.9 x 6 mm, FOV (read direction, HF) = 250 mm, FOV (phase-encoding direction, AP) = (156-187) mm (function of head size), slab thickness = 120 mm, nominal 20 partitions with 10% oversampling, 5/8 partial Fourier encoding was used on the partitioned slice-axis, so the number of measured phase-encodings was reduced to 14, matrix size = 64 x (40-44-48), BW = 2790 Hz/pixel, ramp sampling was used to reduce the echo spacing to 0.4 msec and the time between refocusing pulses to 22msec, total read-out time = 300 msec. The flip angle of the refocusing pulses was set to 162° and a TR of 4.5 sec was used to keep the SAR within acceptable limits. A 2 sec CASL pulse with amplitude modulated control optimized for high field (2) and a post-labelling delay of 1.2 sec were played prior to the 3D GRASE read-out. 30 pairs of measurements were averaged to obtain CBF maps. The imaging parameters of the 2D EPI read-out were the same, except for the BW which was set to 3004 Hz/pixel to keep the echo spacing at 0.4 msec and the number of slices which was reduced to 16. The inversion plane was offset 8 cm from the center of the FOV in the HF direction (see Figure 1). The effective TE was 68msec for 3D GRASE and 15msec for EPI. EPI and GRASE images were realigned using SPM2 and segmented to separate gray and white matter. CBF was then computed in these regions, as well as whole brain mean CBF, using the equations described in (2). An anatomical image data set was also acquired with a MPRAGE sequence and used for coregistration and normalization with a standard template brain. Mean EPI and GRASE images were then coregistered and normalized. The normalized mean images were masked using an intensity threshold and a paired-T test was used to compare the extent of brain coverage of the two sequences. Mean and variance maps were obtained from the normalized CBF images of the five subjects, for both sequences.

Results and Discussion

The use of reduced flip angle refocusing pulses and a TR of 4.5 sec allowed acquisition of perfusion measurements at 3T using a CASL single shot 3D GRASE sequence, within acceptable SAR limits. Whole brain mean CBF values measured using GRASE and EPI read-outs are comparable (Table 1). Mean CBF values in gray matter obtained with GRASE are lower than those obtained with EPI, while mean CBF values in white matter are higher for GRASE than for EPI. This may be due to the smoothing of the GRASE images in the slice encoding direction caused by decay of the signal during read-out (see simulated point spread function (PSF) in Figure 2). The difference in TE for both sequences may also have an effect, since the current simplified model for CBF calculation does not account for T_2 differences between gray and white matter. Signal coverage of the GRASE sequence is significantly better in orbito-frontal areas as shown in Figure 3c. The variance of the CBF values in this area is reduced when the measurement is performed using 3D GRASE, due to the signal recovery (variance maps in Figure 3).

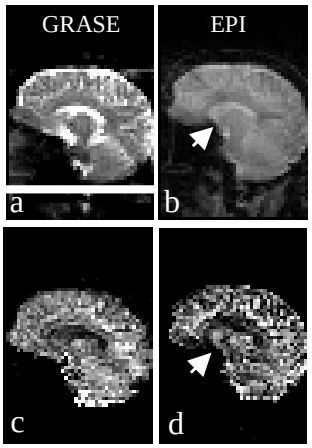

Figure 1: Sagittal brain images acquired using (a) 3D GRASE, (b) EPI. Notice the signal loss in orbito-frontal area in the EPI image (white arrow). CBF maps computed from (c) 3D GRASE, (d) EPI data. The white line in (a) indicates the inversion plane location.

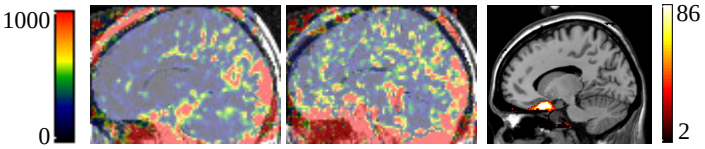

Figure 3: CBF variance maps overlaid on an anatomical image (a) 3D GRASE, (b) EPI, showing reduced variance for CBF measurements done with GRASE in orbito-frontal region. (c) Statistical overlay of signal enhancement in GRASE compared to EPI (p<0.001).

Table 1: Mean ± standard deviation of CBF across subjects (n=5) in ml/100g/min

	Whole brain	Gray matter	White matter
EPI	35.4 ± 3.5	52.1±6.1	22.9±2.0
3D GRASE	36.3 ± 6.1	39.9±6.4	32.3±4.6

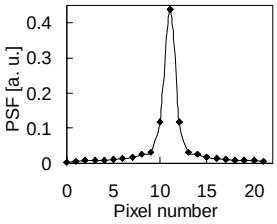

Figure 2: Slice direction PSF, obtained by simulation of the decay of the vascular signal, including stimulated and spin echoes, (T_2=200 msec, T_1=1.5sec)

Conclusions

Perfusion measurements at 3T are feasible using a CASL 3D GRASE single shot sequence and provide improved coverage in high susceptibility regions such as orbito-frontal cortex as compared with EPI. The resolution of the 3D GRASE could be improved by the use of parallel imaging techniques. The single shot version of the sequence would facilitate the implementation of background suppression for perfusion measurements.

Bibliography

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Acknowledgments

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