Improved 3D TFEPI ASL with Flip Angle Sweep

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INTRODUCTION

Arterial spin labeling (ASL) techniques have proven to be an excellent tool to study perfusion non-invasively [1, 2]. Many different approaches have been proposed for labeling of the inflowing blood and for the image readout. Due to the intrinsic low SNR, EPI-based ASL requires several signal averages to achieve a reliable measurement. A possible approach to overcome this SNR issue is based on using single-shot 3D EPI. Since the echo train reads out all slices together, a larger number of signals are sampled per voxel, granting to the 3D imaging an intrinsic higher sensitivity compared to 2D imaging [3]. Further than that, 3D image readout provides that the whole imaging volume is acquired at a single post-labeling delay. However, the ASL signal evolves during the data acquisition and this can result in image blurring if not taken into account. In the present study we present an optimization for a 3D gradient echo EPI acquisition scheme by exploring a modulation of the flip angle of the MR acquisition to keep the ASL contrast constant over the 3D image readout.

MATERIALS AND METHODS

Six healthy adult volunteers were scanned in a 3T Achieva system (Philips Medical Systems, The Netherlands) equipped with gradients capable of 80mT/m amplitude and 200mT/m/ms slew rate and an 8-channel head coil. All subjects were free of neurological disorders. A standard 2D GE-EPI ASL sequence was acquired for comparison using the following parameters: TR/TE=3000/15ms, FOV=240x240mm^2, matrix=64x64, slice thickness=5mm, EPI direction = AP, with SPIR fat saturation. A set of 40 ASL acquisitions was acquired for signal averaging. 3D ASL images were acquired with a single shot TFEPI readout matching the position and resolution of the 2D ASL sequence and using the following parameters: TFE shot duration=3000ms, TFE factor=34, turbo direction RL and EPI direction FH. The 3D TFEPI sequence includes a non selective inversion pulse with a delay of 210ms to suppress fat and reduce the static tissue signal. Two sets of 3D TFEPI images were acquired using either a constant flip angle of 15 degrees or a flip angle sweep based on simulation of the longitudinal and transversal magnetization during the ASL train for both control and labeling conditions with the constraint condition of maintaining the signal difference between control and label constant as we described earlier [4]. The effective flip angle for this condition ranged from 9 to 60 degrees over the turbo train of 34 excitations. All acquisitions used STAR labeling scheme [5] with a labeling slab of 200mm located right below the imaging slab with 1500ms delay time for the 2D reference acquisition and a slightly longer delay of 1700ms in the 3D acquisitions in order account for the longer labeling delays of the last slices obtained with the 2D sequence.

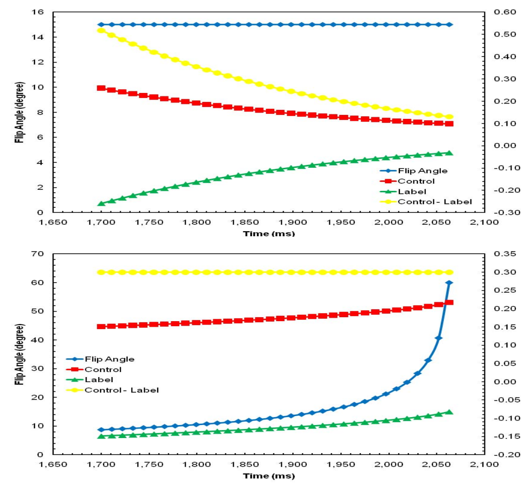

Figure 1: The results of simulations using a constant flip angle for a 3D ASL experiment (top row) and using a flip angle modulation (bottom row).

RESULTS

Fig. 1 shows the typical evolution of the transverse magnetization during the control (red line) and the labeling (green line) condition during the ASL 3D image readout. When a constant flip angle (blue line) is employed (top row), the signal of the difference between both conditions decreases with the increase of the number of excitations. On the bottom, Fig. 1 reveals how the signal difference between label and control images can be constant if the flip angle used for MR acquisition is modulated. Fig. 2a shows perfusion-weighted images obtained from a representative volunteer using the standard 2D ASL. Fig. 2b shows the respective perfusion-weighted images obtained using 3D ASL with a constant flip angle of 15 degrees. This figure shows that the image resolution is compromised in the turbo direction (RL) due to reduced ASL signal in the later turbo acquisitions, located at high k-space profiles. Fig. 2c shows perfusion-weighted images acquired from the same subject using 3D ASL with flip angle sweep. The improved resolution, as compared to the data acquired with a constant flip angle, is reflected by the improved effective resolution, and an increased SNR is attained as compared to the 2D ASL reference, especially at the basis of the brain.

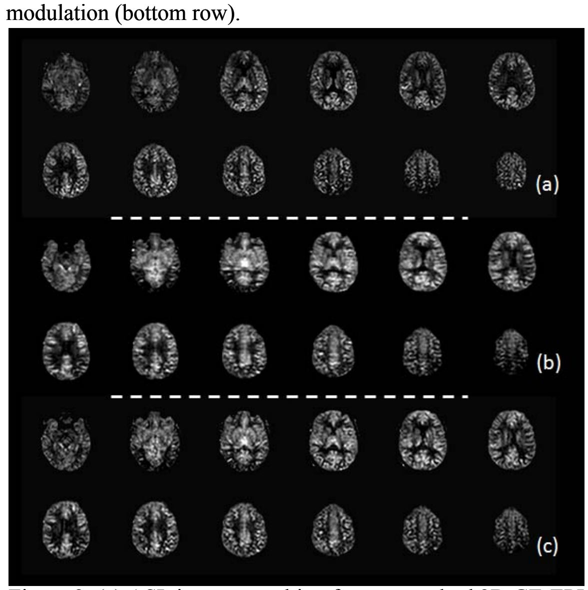

Figure 2: (a) ASL images resulting from a standard 2D GE-EPI acquisition, (b) 3D TFEPI acquisition with constant flip angle of 15 degrees and (c) 3D TFEPI with flip angle sweep (sweep from 9-60 degrees).

DISCUSSION AND CONCLUSIONS

In this study, the combination of flip angle sequencing and 3D image readout for ASL revealed the advantages of the implementation to evaluate tissue perfusion. In addition to the intrinsic SNR improvement and reduced in-plane distortions, the 3D readout implementation shows lower distortions in FH direction due to short EPI train and has the advantage that the whole volume is acquired at the same post-labeling delay. With the conventional implementation, which employs a constant flip angle, the spatial resolution of the perfusion maps was compromised due to the low ASL signal remaining in later turbo acquisitions. This was circumvented here by introducing flip angle sequencing, which has proved to be a useful improvement for 3D EPI ASL implementation.

REFERENCES

[1] Detre JA et al, *NMR Biomed* 1994; 7:75-82. [2] Golay X et al, *Top Magn Reson Imaging* 2004;15:10-27. [3] Gunther MK et al, *Magn Reson Med* 2005; 54: 491−498. [4] Paiva FF et al, *ISMRM* 2010; 1743. [5] Golay X et al, *Magn Reson Med* 2005; 53:15-21.