Free-Breathing 2D Time-of-Flight Pulmonary MRA at 3T

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INTRODUCTION

Contrast-enhanced pulmonary MRA (PMRA) has been widely used in clinical diagnosis. However, such technique is not desirable for certain patients with difficult in holding breath or cooperating during MRI scan. In non-contrast-enhanced PMRA, 2D time-of-flight (TOF) approach has not been widely employed in PMRA due to low SNR. At high field such as 3T, increase in signal intensity and T_1 increase may offset this disadvantage. This study aims to optimize and evaluate a free-breathing 2D TOF PMRA protocol at 3T. The protocol is based on a coronal T_1-weighted turbo field echo (TFE) sequence with static tissue suppression using magnetization transfer (MT) plus selective inverse recovery (SIR), spectral fat saturation, cardiac VCG gating, respiratory navigator gating, and parallel imaging (SENSE).

METHOD

The proposed 2D TOF PMRA sequence is shown in Fig.1. The diagram represents one cardiac cycle. After triggering delay (TD) adjusted to the individual heart rate, a slice selective 180° pulse is applied to invert the magnetization of the stationary tissue within the slice. The inversion delay (TI) is chosen to null the static tissue signal approximately at the start of TFE acquisition. Meanwhile, an off-resonance MT irradiation is performed to suppress static tissue signal. Because MT reduces the effective T_1 of the thoracic and cardiac muscle [1], shorter TI is needed for IR nulling. Optimal TI also allows adequate TOF inflow of non-inverted fresh arterial and venous blood into the imaging slice. Then a 2D coronal T1-weighted segmented TFE acquisition is performed during the relatively stable terminal diastole phase to minimize blood spin dephasing and motion-induced discontinuities between consecutive 2D slices. To suppress fat tissue, a frequency selective adiabatic inversion pulse (SPAIR) is applied prior to each TFE shot. In addition, the pencil-beam navigator gating is employed by detecting the spatial position of locomotory diaphragm.

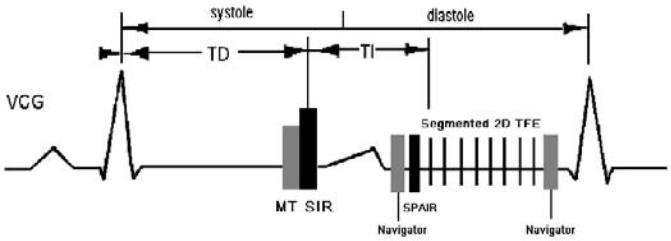

Fig. 1 Timing diagram of proposed 2D TOF pulmonary MRA sequence. It is based on segmented 2D TFE sequence with static tissue suppression using magnetization transfer (MT) plus selective inverse recovery (SIR), spectral fat saturation, cardiac gating, navigator, and SENSE parallel imaging.

All experiments were performed on a 3 T Philips Achieva system with the peak gradient amplitude of 80mT/m and the gradient switch rate of 200mT/m/s. 12 healthy volunteers (age 20-67, 8 men, 4 women) were studied with informed consent. A 6-element synergy coil was used for SENSE parallel acquisition. The 2D coronal T1-weighted segmented TFE sequence had the shortest TR/TE=3.4ms/1.45ms and partial echo to minimize the strong T2* effect in lung; TFE factor=30. FOV=370mm with 80% rectangular FOV; acquisition matrix of 256×218; in-plane spatial resolution=1.45mm×1.84mm; number of acquisitions (NSA) =2-4; and SENSE factor of 2. Data was collected with centric reordering and 3/5th partial Fourier phase encoding. For respiratory compensation, the leading type of navigator echo technique was implemented by positioning the 2/3 of beam within the right diaphragm dome and 1/3 on the lung, navigator length of 50mm and the acceptance window of 4 mm.

RESULTS

The proposed pulmonary MRA protocol was performed with free-breathing comfort in all 12 volunteers. The data acceptance rate in respiratory navigator was ~50% on average. TI, flip angle, and acquisition parameters were experimentally optimized. The optimal TI and flip angle were found to be ~300ms and 30°, respectively (see Figs. 2 and 3). With these optimized parameters, satisfactory pulmonary MRA were achieved. Fig. 4 shows a typical front MIP view of these pulmonary MRA images. Note that such image quality permitted the routine visualization of pulmonary arterial branches up to high orders in all subjects (N=12) with good definition.

CONCLUSION AND DISCUSSION

A free-breathing 2D TOF pulmonary MRA protocol has been demonstrated at 3T. The protocol is robust and clinically relevant for patients who are unable to provide long breath-holds during MRI scans. In the sequence proposed (Fig. 1), the selective inverse recovery (SIR) pulse serves to suppress the background static tissue in conjunction with the off-resonance MT irradiation. T1 of muscle increases by 30-40% from 1.5T to 3T. At 3T, MT rate of muscle is close to 90% [2]. Thus the optimal TI for effective static tissue suppression found in this study is similar to that reported by Jakob [1]. On the other hand, long TI is desired for strong inflow effect, but long TI will reduce the upper limit on the patient heart rate (HR) that can be accommodated by this PMRA protocol. At 3T, we found that TI of ~300ms provides an appropriate balance between these factors. It provides satisfactory pulmonary MRA contrast and can accommodate patient HR up to 140 bpm. Future work in this direction includes the separation of pulmonary arterial and venous vessels.

REFREENCE.

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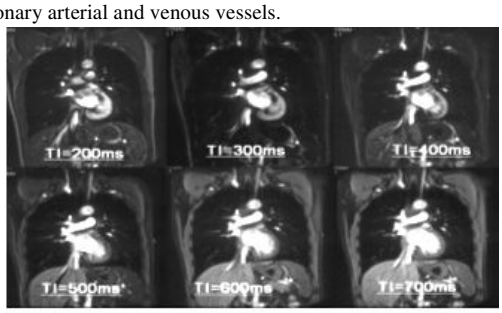

Fig. 2 TI optimization. TI of ~300ms is optimal for th proposed sequence to achieve both static tissue suppressio and adequate inflow effect.

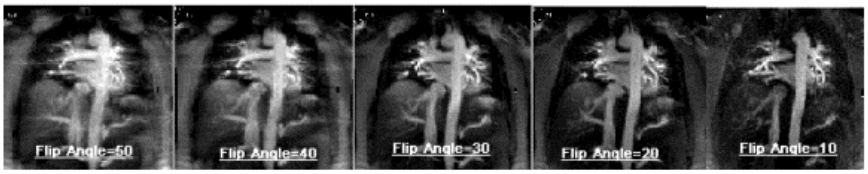

Fig. 3 Effect of varying flip angles in TFE. ~30° provides the optimal contrast (56-yr female).

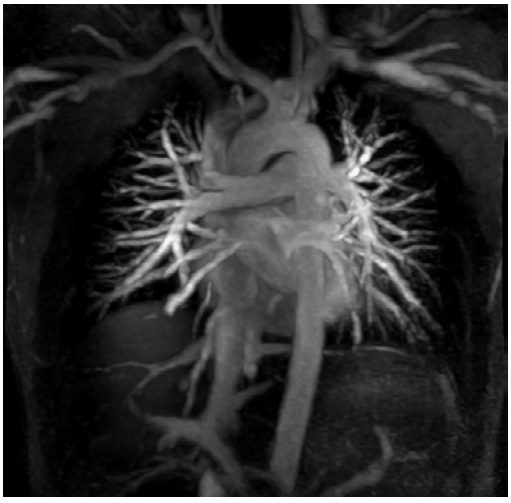

Fig. 4 Typical pulmonary MRA acquired with the proposed protocol (28-yr male, HR 80 bpm, slice thickness 2mm, 80 slices, TI 300ms, TD 300ms, and flip angle 30°).