Non-Contrast Time Resolved Pulmonary MRA with ECG-Triggered 3D HASTE

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Introduction:

Non-contrast enhanced MRA using an ECG-triggered 3D-HASTE sequence has been used for 3D MRA to distinguish arterial and venous blood flow [1-2]. A time resolved version of such method, with continuous acquisition of multiple cardiac phases, was developed and tested in the lung. 4D data-sets were acquired with different trigger delay times to provide hemodynamic information in the pulmonary circulation with high signal-to-noise (SNR) and high spatial resolution. This new sequence allows the separation of pulmonary arteries and pulmonary veins without the use of exogenous contrast agents. Though requiring a slightly longer scan time, double triggering with 2D PACE (Prospective Acquisition Correction) can potentially resolve the image mismatch across different ECG phases. Our aim was to test the feasibility of this approach for time-resolved pulmonary MRA.

Material and Methods

The sequence diagram of the Non-contrast enhanced 3D-HASTE sequence is shown in Figure 1. Before the acquisition, an inversion recovery pulse is used to suppress the fatty tissue and attenuate the background signal. The fast arterial blood flow during systole accounts for incomplete spin rephasing and therefore low signal intensity. Signal intensity is maintained at higher level during the diastolic phase due to considerably lower velocities. The implementation of different trigger delay times over multiple measurements provides the opportunity for simultaneous assessment of systolic and diastolic phases.

All examinations were acquired with a 1.5 T scanner (SIEMENS Magnetom Avanto, Germany) using the phased array body coil. Seven MRA datasets in coronal orientation were sampled with a double triggered 3D HASTE sequence. Integrated Parallel Imaging Technique (iPAT) was applied to reduce the acquisition window and speed up data acquisition. The following acquisition parameters were used: FOV 450mm x 450 mm, TR = 1 respiratory cycle, effective TE = 49 ms, echo spacing = 5.3 ms, bandwidth = 978 Hz/pixel, matrix 320x256, 60 partitions of 1.2 mm thickness, phase encoding direction head to feet, iPAT acceleration factor 2 with GRAPPA reconstruction, double triggering with 2D PACE. The seven cardiac phases were acquired with a 100 ms incremental delay, starting from no trigger delay after the R wave detection. The readout spoil moment was adjusted to 10% of the readout gradient. The total acquisition time was about 15 minutes. The 4D data-sets were generated by dynamic subtraction of the first systolic data set from subsequent images.

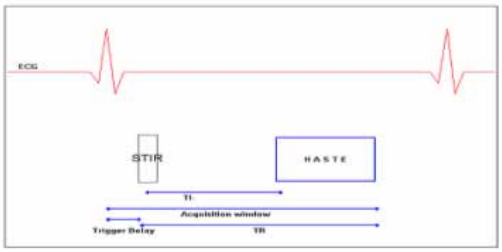

Figure 1: Relationship between trigger delay time, acquisition window, TR, inversion recovery pulse and R-R wave.

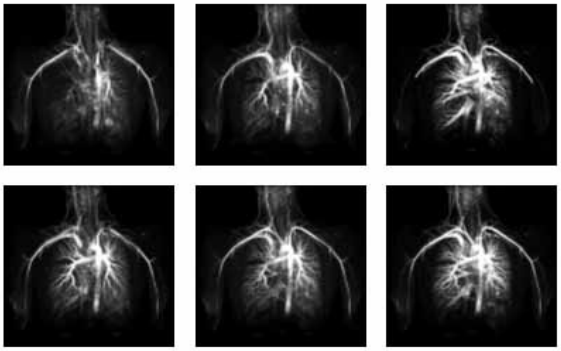

Figure 2: Time Resolved Pulmonary MRA with different trigger delay time, from 100msec to 600msec, increment 100msec.

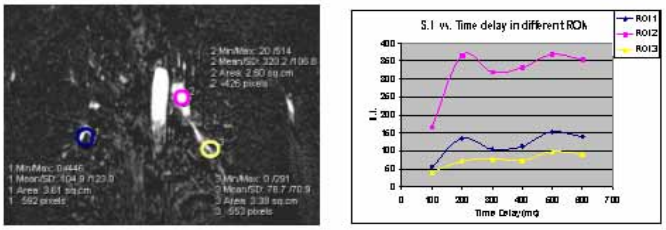

Figure 3: Signal intensity (SI) vs. time delay in selected regions of interests of the lung.

Results

Three volunteers were examined to evaluate the feasibility of the non-contrast MRA technique in terms of obtaining dynamic flow information in 3D reconstruction. The time resolved pulmonary MRA images for six ECG phases are shown in Figure 2. The first phase (not shown), with trigger delay time of 0 ms, was used as a mask for the all other images. The mask separates arterial and venous vessels, and smaller vessels can be clearly delineated. The vascular anatomy can be visualized in detail and in conjunction with its time dependent function. The incremental trigger delay time of 100 ms was used to sufficiently differentiate hemodynamic phases. Shorter increments and more ECG phases would improve the temporal resolution, but prolong the total scan time. Time-resolved Maximum Intensity Projection (MIP) images demonstrate the time dependent blood flow via the collateral arteries. In Figure 2, progression from the main pulmonary arterial to small pulmonary artery branches can be observed. Signal intensity is plotted versus time for the three regions of interest in Figure 3 (right); ROIs were drawn using the raw data (left).

Conclusions

Non-contrast time resolved MRA with ECG-Triggered 3D HASTE was successfully demonstrated for 3D pulmonary MRA permitting observation of hemodynamic information without the application of a contrast agent. The 3D approach has the potential to allow precise evaluation of thromboemboli and complicated collaterals and vascular malformations. The 4D acquisition is linked to a comparatively long scan time due to the number of hemodynamic phases observed. Due to the misregistration of images during different cardiac phases in case of patient motion or incompliance, double triggering with Prospective Acquisition Correction can potentially resolve the problem, although this requires a longer total scan time.

Reference

1. Mitsue Miyazaki et al. Radiology 2003; 227:890-896. 2. Mitsue Miyazaki et al. JMRI 2000; 12:776-783.