Angularly Undersampled PR-TRICKS for the Determination of Pulmonary Transit Time

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Introduction

Angularly undersampled projection-reconstruction (PR) imaging has been shown to allow for high quality 3D time-resolved contrast-enhanced MR angiography, especially when combined with the TRICKS segmentation scheme [1,2]. In contrast to traditional Cartesian sampling, decreasing the number of echoes for radial k-space trajectories results in the introduction of a angular undersampling, or "streaking," artifact instead of blurring. Consequently, if additional artifact can be tolerated, angularly undersampled PR is ideal for applications with high spatial and temporal resolution demands. One such application is capturing the dynamic passage of contrast through the pulmonary vasculature to determine transit time [3,4]. Clinically, pulmonary mean transit time (PMTT) combined with phase-contrast flow measurement yields total pulmonary blood volume (PBV). Noninvasive assessment of PMTT and PBV could potentially be used to diagnose and monitor patients with cardiopulmonary disorders, such as congestive heart failure. We have implemented the PR-TRICKS pulse sequence to acquire the high temporal resolution 3D volumes necessary for transit time measurement.

Materials and Methods

Images were acquired from healthy volunteers on a 1.5 T whole body MR scanner (Sonata, Siemens Medical Solutions, Erlangen, Germany) with a phased-array cardiac coil (Siemens Medical Solutions, Erlangen, Germany). A coronal 3D multi-phase FLASH pulse sequence was used with a radial k-space trajectory, linear ordering, and angular undersampling in the in-plane dimensions, and a Cartesian k-space trajectory, centric reordering, TRICKS segmentation, and partial Fourier undersampling in the through-plane dimension (FOV = 300 x 300 x 96 mm, image matrix = 128 x 128 x 8, phases = 20, temporal resolution = 1.3 s, TR/TE = 3.80/0.61 ms, flip angle = 15º, bandwidth = 1220 Hz/pixel, angular undersampling factor = 0.75, TRICKS segments = 3, slice-encoding partial Fourier factor = 0.8, where the angular undersampling factor is defined as the fraction of views to read-out points, and the number of TRICKS segments includes the central segment acquired at every phase, plus the additional segments acquired at alternating phases). A single dose of a gadolinium-based contrast agent (Magnevist, Berlex, Wayne, New Jersey) was administered in an antecubital vein at an injection rate of 5.0 ml/s, starting simultaneously with the imaging protocol. Volunteers were in a supine position with arms over their head, and held their breath during the scan. Magnitude subtraction, MIP, and ROI analysis were performed offline using commercially available image processing software (MATLAB, MathWorks, Natick, Massachusetts). Pulmonary arterial and venous signal intensity curves were calculated as the mean of a 3 x 3 matrix of adjacent pixels in an optimal subtracted slice. ROI's were chosen from one of the two pulmonary arteries and one of the four veins.

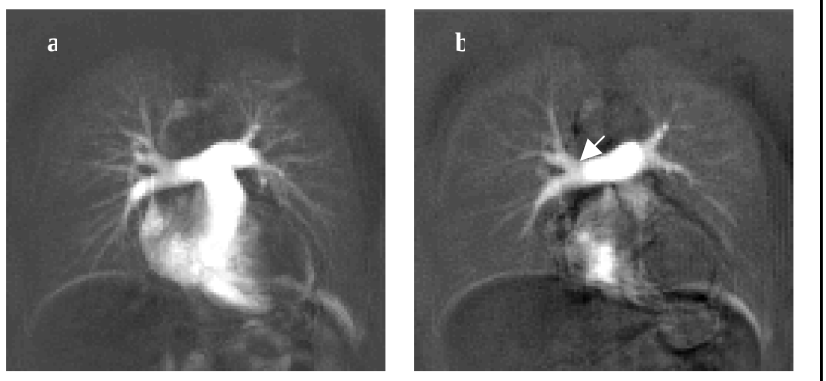

Figure 1 **a)** Coronal MIP image after magnitude subtraction at peak arterial phase. **b)** Subtracted slice at same time frame as a) demonstrating the pulmonary arteries. The arrow indicates the location of the ROI for arterial signal intensity curve determination.

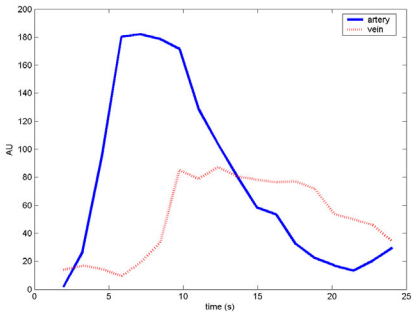

Figure 2 Typical arterial and venous signal intensity curves as a function of time. The ratio of areas of the arterial and venous curves is approximately 2:1. The temporal resolution is 1.3 s/frame.

Results/Discussion

Figure 1 shows a coronal MIP image after magnitude subtraction at the peak arterial phase. Only coarse resolution was necessary in order to maximize the frame rate. Also shown is a typical subtracted slice for placing the arterial signal intensity curve ROI. Figure 2 shows signal intensity (reflecting contrast agent concentration) as a function of time for ROI's in a typical pulmonary artery and vein. The temporal resolution of 1.3 s/volume adequately captured the dynamic passage of contrast. Pulmonary transit times can be inferred based on both the delay in arrival of contrast and the amount of signal intensity blurring in time between the vessels.

Angular undersampling produced no significant artifacts, nor did undersampling from the TRICKS and partial Fourier schemes. Therefore, undersampling enabled higher frame rates while minimizing lost physiological information.

Conclusion

The angularly undersampled PR-TRICKS pulse sequence allows for the high temporal resolution necessary to acquire 3D volumes of the pulmonary vasculature for determination of pulmonary transit times. Angular undersampling and the TRICKS segmentation scheme sample k-space data in a fashion that maximizes the acquisition of physiologically relevant information. Pulmonary transit time is a component in the total characterization of cardiopulmonary hemodynamics.

References

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