Time-resolved Three-dimensional Pulmonary MR Angiography Using a Spiral-TRICKS sequence

J. Du[1], M. Bydder[1], R. M. Znamirowski[1], S. C. Rose[1], G. M. Bydder[1]
[1]Radiology, University of California, San Diego, San Diego, CA, United States

INTRODUCTION

Evaluation of the pulmonary circulation is important in the assessment of many disease processes, such as pulmonary embolism, hypertension, and vascular anomalies. Contrast-enhanced three-dimensional magnetic resonance angiography has emerged as a useful, noninvasive method for evaluating the pulmonary vasculature and its functionality (1, 2). However, the short arterial-venous transit time and complex contrast dynamics are challenging for single volume imaging. Time-resolved acquisition provides many advantages for pulmonary imaging, although there is a tradeoff of spatial resolution for temporal resolution. Here we report on a hybrid 3D spiral sequence which combines a spiral readout in-plane and Cartesian slice encoding through-plane in a TRICKS scheme (3), thereby providing both high spatial resolution and high temporal resolution.

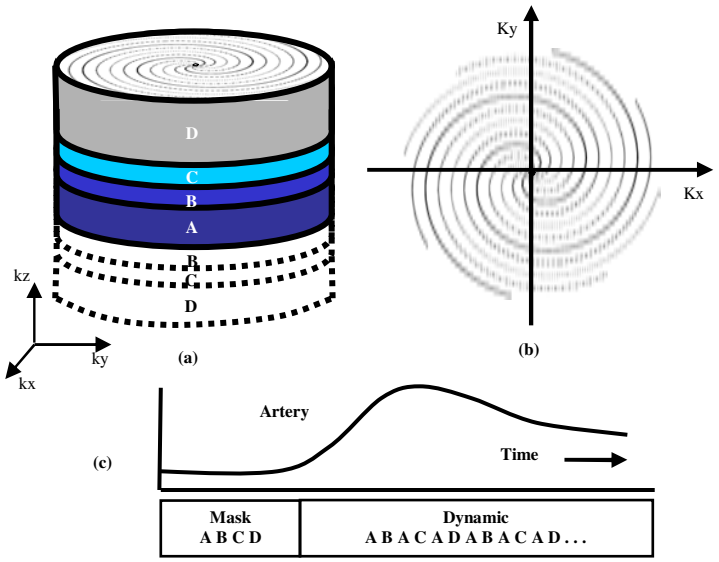

Figure 1. Pulse sequence diagram for 3D SPIRAL-TRICKS sequence: (a), Cartesian slice encoding was used through-plane, and divided into four regions: A, B, C and D; (b), spiral trajectory was used in-plane; (c), mask data acquisition was followed by dynamic imaging using TRICKS technique. Partial slice encoding (sampling half the slice encodings from B, C and D regions) was used to improve the temporal resolution. The spiral trajectory was interleaved for each repeatedly acquired region.

MATERIALS AND METHODS

A 3D SPIRAL-TRICKS sequence (Figure 1) was implemented on a 1.5 T Signa TwinSpeed scanner (GE Healthcare Technologies, Milwaukee, WI) with a maximum gradient performance of 40 mT/m and 150 mT/m/ms. This sequence integrated spiral trajectory in-plane and Cartesian slice encoding through-plane. The whole of k-space was divided into 4 regions: A, B, C and D along the slice encoding direction. The sampling scheme was shown in Figure 1. Partial slice encoding was used to speed up the acquisition. Homodyne reconstruction was used to maintain the slice resolution. The spiral trajectory was interleaved for each repeatedly acquired region. A sliding window reconstruction algorithm was used to improve image SNR and temporal resolution, and reduce artifacts (4). Degradation due to gradient distortion and eddy currents was minimized by fine-tuning the in-plane gradient anisotropy, followed by spiral trajectory measurement using Duyn's method (5). The measured k-space trajectory was used for re-gridding. A total of 30 ml of Gd-based contrast material was injected at a rate of 4ml/sec, followed by 20 ml of flush injected at the same rate. The acquisition parameters were: FOV = 30 cm, TR = 8.7 ms, TE = 0.6 ms, spiral projections = 42, BW = 62.5 KHz, readout = 512, number of slices = 36, slice thickness = 5 mm, scan time = 24 sec.

RESULTS AND DISCUSSION

Figure 2 shows the time-resolved maximum intensity projection (MIP) images of the pulmonary vasculature with 6 time frame images displayed in the axial plane. The pulmonary arteries and veins were well depicted with a high in-plane spatial resolution of 1.35×1.35 mm^2 (acquired) and a high temporal resolution of 1.2 seconds-per-frame. Further investigation will focus on protocol optimization, and its combination with parallel reconstruction to obtain subsecond temporal resolution.

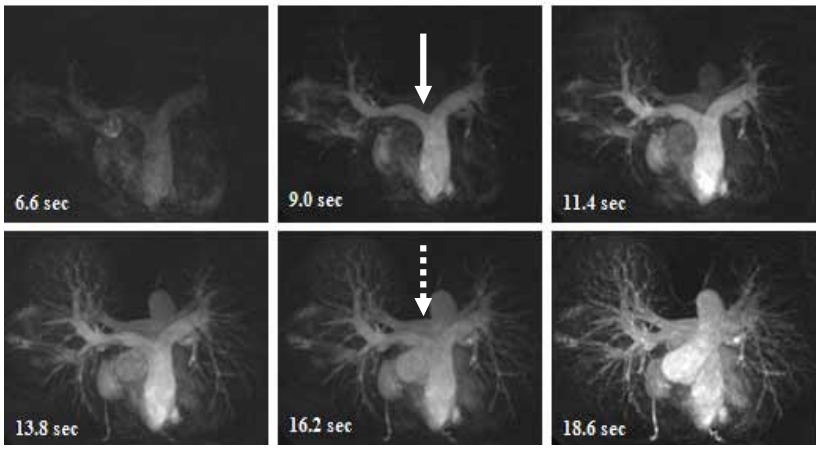

Figure 2. Alternate MIP images obtained from time-resolved pulmonary MR angiography showing sequential filling of the pulmonary arteries (solid arrow) and veins (dashed arrow). The imaging FOV = 30 cm, readout = 512, spiral projections = 42, #slice = 36, slice thickness = 5 mm, in-plane pixel size = 1.35×1.35 mm^2 (acquired). The total scan time was 24 sec, including the mask. The temporal resolution was 1.2 sec-per-frame.

CONCLUSIONS

The Spiral-TRICKS sequence is rapid and efficient for imaging the contrast dynamics in the pulmonary vasculature. This sequence may also be useful in carotid and renal imaging, where high spatial resolution and high temporal resolution are both desirable.

REFERENCES

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