High Resolution Breath-hold Contrast-Enhanced 3D FIESTA Coronary Artery Imaging

T. K. Foo1, V. B. Ho2, L. Cheng3, H. Sakuma4, D. L. Kraitchman5, K. C. Wu5, D. C. Bluemke2

1GE Medical Systems, Baltimore, United States, 2Uniformed Services University of the Health Sciences, Bethesda, MD, United States, 3PLA General Hospital, Beijing, China, People's Republic of, 4Mie University, Tsu, Japan, 5Johns Hopkins University, Baltimore, MD, United States

Synopsis

A method for high spatial resolution breath-held 3D volume imaging of the coronary arteries using contrast-enhanced FIESTA is presented. With FIESTA, contrast enhancement persists for over 30 minutes using conventional extra-cellular Gd chelate contrast agents. This approach allows images of each coronary artery distribution to be acquired in a single breath-hold and can be integrated into a comprehensive cardiac examination that includes function, perfusion, and delayed hyper-enhancement. Using this approach, 12 partitions can be acquired in a short 24 heartbeat breath-hold.

Introduction

Three-dimensional coronary MR imaging can be achieved using either free-breathing navigator scans (1) or breath-held acquisitions. Due to the long scan times of navigator acquisitions, the overall success rate for achieving evaluable arterial depiction has been between 72 and 84 % (2,3). Breath-hold volume acquisitions (4,5) are limited by shorter scan time considerations that result in compromises in the overall spatial coverage (number of slice partitions) or spatial blurring (from the use of multiple echoes per rf excitation pulse).

We propose the use of a variable temporal sampling (VAST) technique (6) using an ECG-gated fast imaging employing steady-state acquisition (FIESTA) technique (more generically known as steady-state free precession or SSFP) to image each coronary artery distribution in a single breath-hold. We demonstrate that this approach is compatible within a comprehensive cardiac examination that includes a first pass perfusion (7) examination and a delayed hyper-enhancement evaluation for myocardial viability (8,9). We take advantage of the persistence in Gd-chelate contrast enhancement in FIESTA pulse sequences to further improve the vessel image S/N (10).

Materials and Methods

All experiments were conducted on 1.5 T CV/i and TwinSpeed scanners equipped with high performance gradient subsystems (40-50 mT/m and 150 T/m/s). Both animal experiments and human studies were conducted. The animal experiments allowed the evaluation of the different spatial resolutions achieved with a variety of segmentation strategies. For the human subject studies, 12 patients (11 male, 1 female, mean age = 60 +/- 19 years), who were already scheduled for a myocardial viability study, were consented for an additional coronary artery evaluation.

An initial first pass perfusion coronary artery examination (7) was performed using 0.1 mmol/kg of Gd contrast followed by a second 0.1 mmol/kg dose for a cumulative 0.2 mmol/kg contrast media dose. At the 20-minute mark after administration of the contrast media a 3D breath-hold delayed enhancement study was performed (6). In the intervening period, targeted volume 3D coronary artery studies were performed for as many coronary artery distributions as possible.

The coronary artery imaging acquisition was an ECG-gated 3D FIESTA pulse sequence with a spectrally selective inversion pulse applied for fat suppression. Imaging was performed in diastole and all scans completed in no more than 24 heartbeats. Image acquisition was segmented across 2 RR intervals for each slice partition encoding value. An interleaved view acquisition order was used with 40 views in the first R-R interval and 80 views in the second R-R interval.

Note that the central 80 views were acquired within the same temporal window. Imaging parameters were: 24-26 cm image FOV; 2-2.4 mm partition thickness; 10-12 partitions; 256 x 192 – 256 x 224 matrix; TE/TR = 1.5-1.7/3.9-4.4 msec; 65-degree flip angle.

The resulting images were scored by 2 observers who rated each coronary artery segment (proximal, middle, distal) on a 4-point scale (1 = poor [coronary vessel not seen or barely seen]; 2 = marginal [visible but not adequate]; 3 = good [coronary artery adequately visualized]; and 4 = excellent [coronary artery well depicted]). Each coronary segment was defined as a 3cm vessel segment.

Results

From the patient studies, 11 right coronary artery (RCA), 10 left anterior descending artery (LAD), 10 left main (LM) and 9 left circumflex artery (LCx) distributions were imaged. Of these, 30/33 RCA segments were graded as 3 or better (mean score), 15/30 LAD segments (with 10/30 segments not seen), 9/10 LM segments, and 12/30 LCx segments (with 14/30 segments not seen). A majority (84 %) of all vessel segments observed were noted to have a qualitative score of 3 or better (RCA : 91%; LM : 90%; LAD : 75%; LCx : 75%). Of all 103 possible segments, 24 (mostly LAD and LCx distal segments) were not visualized. All proximal coronary vessels were well visualized. The mean breath-hold period for 12 partitions was 22 +/- 5 sec. The short breath-hold period was well tolerated by all patients.

In the animal experiments, the normalized vessel profile of the right coronary artery was measured and compared between the VAST and symmetric segmentation. Even with a longer acquisition window period for the high spatial frequency for VAST (164/377 msec) than with a symmetric acquisition (271 msec), the vessel profiles matched well for 160, 224, and 256 view encoding values.

Conclusion

We have demonstrated that the proposed segmentation scheme is able to yield coronary artery images of high S/N. A substantial fraction of the proximal and middle segments were well visualized and noted as diagnostic. The ability to exploit the persistence of contrast enhancement using conventional extra-cellular contrast media allows a longer time window to image the coronary arteries with increased vessel S/N. The proposed 3D acquisition technique makes maximum utility of the dead time between the contrast media administration and the myocardial delayed enhancement study, providing the opportunity to complete a cardiac examination in 30-45 min that yields functional, viability, and proximal-mid coronary artery assessments.

References
