Clinical Applications of Contrast Inflow Dynamics MRA (CIDA): Novel Approach for ECG-Gated Dynamic Contrast Enhanced MRA

M. M. Fung[1], E. J. Schmidt[2], M. N. Hood[3], G. Holmvang[4], R. Y. Kwong[5], and V. B. Ho[3]

[1]Global Applied Science Lab, GE Healthcare, Bethesda, MD, United States, [2]Global Applied Science Lab, GE Healthcare, Boston, MA, United States, [3]Radiology, National Naval Medical Center, Bethesda, MD, United States, [4]Cardiology, Massachusetts General Hospital, Boston, MA, United States, [5]Cardiovascular Medicine, Brigham and Women's Hospital, Boston, MA, United States

PURPOSE

ECG-gated 3D contrast enhanced MRA (ceMRA) provides high spatial resolution and minimal pulsation artifacts in the visualization of cardiac and pulmonary vasculatures [1,2]. Imaging during the optimal dynamic phase of the bolus is a critical determinant for selective vascular depiction using ceMRA. Time-resolved ceMRA techniques[3] may improve the likelihood of capturing the optimal phase but the application of time-resolved gated ceMRA has been limited, due to the required increase in scan time associated with ECG-gating. Spatial and temporal resolution, or alternatively anatomic coverage, are often compromised to meet the breathhold limitation. In this work, we present the clinical applications of a novel multiple-dynamic-phase ECG-gated 3D MRA approach[4] that can obtain high-spatial resolution and temporally-selective contrast-enhanced images without neccesitating an increase in scan time. Automatic triggerring is also incorporated to better pin-point the time range of the desired dynamic phases.

METHODS

12 healthy subjects (11 male, 1 female, age 42±11 years) volunteered for participation in this IRB-approved study. The conventional ECG-gated ceMRA technique acquires data only in a portion of the cardiac cycle, resulting in relatively low scan efficiency. In the proposed **C**ontrast **I**nflow **D**ynamics MR**A** (CIDA) technique, multiple cardiac phases were acquired within the cardiac cycle in a 3D acquisition. By altering the slice ordering of each cardiac phase, the center of k-space of each 3D dataset was adjusted to occur at a different time point, following a single contrast media injection, thus providing images of multiple dynamic phases along the contrast arrival curve in a single breathhold acquisition (Fig 1). A variable-center slice ordering scheme that minimized k-space discontinuity was developed to increase the flexibility in temporal selectivity. The automatic triggering sequence continuously monitored for contrast arrival in a user-specified ROI (SVC for pulmonary artery, RV for the pulmonary veins) and triggered the CIDA scan, thus eliminating the need for a separate timing-bolus injection. 3 to 4 temporal phases were acquired, with a 3-4 second delay between each phase. Each phase had an acquisition window of ~250-275ms and was separated by ~250ms in the cardiac cycle. View sharing of the outer k-space was utilized if the acquisition window overlapped. Contrast-enhanced CIDA MRA [3D SPGR, TR/TE/θ=4.3/2.0ms/40°, SENSE 2, 70% partial-kz, 0.5-1NEX, 1.3x1.6x3mm^3 resolution, 2 phases, scan time=20 heartbeats / 25 slices] was performed on 12 patients, using a 1.5T MRI with an 8 channel cardiac coil (GE Healthcare, USA). Acquisitions were performed with first pass contrast (0.2 mmol/kg gadoteridol (ProHance; Bracco Diagnostics, New Jersey, USA), 2cc/sec injection rate).

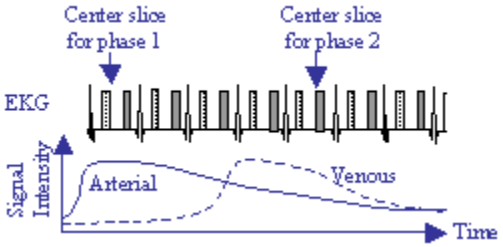

Figure 1. CIDA technique. A variable center-slice ordering scheme adjusted the center of k-space of the systolic and diastolic phases to coincide with the contrast arrival at the desired anatomy.

RESULTS

CIDA MRA was successfully completed in all subjects. Figure 2 shows results from a patient; High spatial resolution ECG-gated 3D MRA of 4 dynamic phases (effective temporal separation of 3 seconds) were obtained in a single 21-second breathhold, and utilizing a single injection. Filling of the aorta was visualized and phase 4 showed the optimal dynamic phase with complete filling. CIDA eliminates the need for a timing bolus or the acquisition of a second phase with another breathhold, thereby increases the robustness of ceMRA and streamlines workflow. Furthermore, more flexibility in the temporal resolution can be achieved (minimum achievable temporal separation of 1 heart beat) compared to other time resolved techniques (e.g. TRICKS or multiphase acquisition) as the various temporal phases are collected in a parallel manner. This enables the separation of arterial and venous system with short temporal separation (Figure 3). Alternatively, this technique can also be used to study the morphology of the cardiac structures at multiple cardiac phases. Figure 4 shows results where the morphology of the left atrium can be visualized in both systole and diasystole.

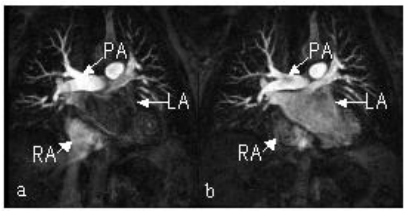

Figure 3. CIDA performed on a patient with 6 seconds delay between the 2 phases. The first phase(a) shows pulmonary artery enhancement while the second phase(b) shows left atrial enhancement.

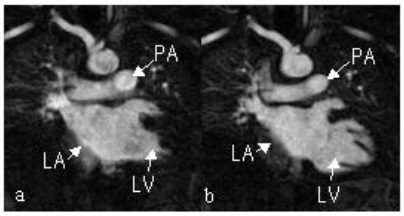

Figure 4. CIDA performed on a patient with multiple cardiac phases. The morphological changes of the left atrium between (a)systole and (b)diasytole can be visualized.

CONCLUSION

We have shown that the CIDA technique has three main clinical advantages: 1. increases the likelihood of capturing the optimal dynamic phase, 2. increases temporal selectivity of the arterial and venous system, 3. enables morphological study at multiple cardiac phases. Cardiac motion artifacts were suppressed, as the data for each phase was collected within a consistent window in the cardiac cycle. The CIDA technique can, furthermore, be combined with other time-resolved MRA techniques, such as TRICKS, to provide a cardiac motion-suppressed time-resolved MRA, without significant penalty in scan efficiency.

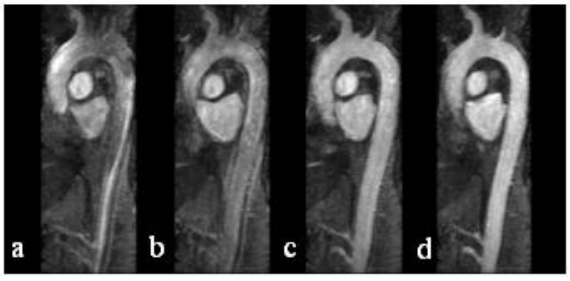

Figure 2. CIDA with automatic triggering performed on a patient. Figure 2a-d show 4 dynamic phases of the aorta during the contrast injection with a 3-second temporal delay between each phase. The optimal contrast enhancement at the aorta can be visualized in the fourth phase (d).

REFERENCE:

[1] E. Groves, ISMRM 2006, Proceeding: 506
[2] M. Katoh, ISMRM 2006, Proceeding: 507
[3] F. Korosec, MRM 1998 36:345-351
[4] M. Fung, 19th Intl. Conf. on MRA