

# A Novel ECG-gated MRA for Simultaneous Imaging of the Left Atrium and Esophagus in Patients with Atrial Fibrillation

Eugene G. Kholmovski<sup>1,2</sup>, Sathya Vijayakumar<sup>1,2</sup>, Douglas Sheffer<sup>3</sup>, Lowell Chang<sup>2,3</sup>, Krishna N. Velagapudi<sup>2,3</sup>, Christopher J. McGann<sup>2,3</sup>, and Nassir F. Marrouche<sup>2,3</sup>  
<sup>1</sup>UCAIR, Department of Radiology, University of Utah, Salt Lake City, Utah, United States, <sup>2</sup>CARMA Center, University of Utah, Salt Lake City, Utah, United States, <sup>3</sup>Department of Cardiology, University of Utah, Salt Lake City, Utah, United States

**Purpose:** Atrial fibrillation (AF) is the most common cardiac arrhythmia affecting more than 5 million people in Europe and North America. Radio-frequency (RF) ablation of the left atrium (LA) is effective for symptomatic, drug refractory AF patients.<sup>1</sup> Detailed description of anatomy of LA and pulmonary veins (PVs) is required for planning and execution of the procedure. Information about esophagus and its position relative to LA and PVs is essential to reduce risk of potentially lethal atrio-esophageal fistula in patients undergoing RF ablation.<sup>2</sup> It is desirable that images of LA, PVs, and esophagus are acquired by the same scan to simplify their usage in electro-anatomical navigation systems used for RF ablations. Typically, anatomy of LA and PVs is visualized using contrast enhanced (CE) MR angiography (MRA). Conventional CE-MRA of LA is performed using non-gated sequences with data acquisition during contrast first-pass. The sequences require long breath-hold and precise timing of data acquisition with contrast injection. Such scans can be challenging in sick or sedated patients. Boundaries of anatomical structures may be severely blurred in non-gated MRA because data are acquired continuously during whole cardiac cycle. Furthermore, esophagus cannot be imaged by conventional CE-MRA. The main goal of this study was to develop and validate an ECG-gated CE-MRA sequence for simultaneous imaging of LA and PVs, and esophagus.

**Methods:** A novel ECG-gated CE-MRA sequence for LA, PVs, and esophagus imaging has been developed. The sequence was compared with conventional CE-MRA sequence in patients study. Eighty patients with AF underwent either conventional non-gated (40 patients) or ECG-gated (40 patients) MRA on a 3T scanner (Verio, Siemens Healthcare, Erlangen, Germany). MRA studies were performed using contrast injection (0.1 mmol/kg of Multihance (Bracco Diagnostics Inc., Princeton, NJ)).

An ECG-gated MRA was implemented using 3D saturation recovery prepared GRE sequence with respiratory navigation. Saturation pulse was applied every heart beat and fat saturation was performed immediately before data acquisition. Data acquisition was limited to 20% of cardiac cycle and was performed during LA diastole. Additional scan parameters were: axial imaging volume, FOV=400x400x110, voxel size=1.25x1.25x2.5 mm, TR/TE=2.8/1.3 ms, flip angle=15°, TI=200 ms, phase encoding (PE) direction: left-right, phase-encoding scheme: centric in PE direction and linear in slice encoding direction. Typical scan time was 3-6 minutes depending on patient respiration pattern. Contrast injection protocol for this ECG-gated MRA scan consisted of two stages: fast contrast injection (half dose, rate of 1.0 mL/sec) immediately before the MRA scan and followed by slow infusion (half dose, rate of 0.1 mL/sec) during the scan.

Conventional non-gated MRA was performed with contrast injection rate 2.0 mL/sec and continuous data acquisition during single breath-hold (14 sec.). Scan parameters were: axial imaging volume, FOV=400x263x120 mm, voxel size=1.25x1.25x2.5, TR/TE=2.8/1.1 ms, flip angle=27°, PE direction: anterior-posterior, and 3D centric phase encoding scheme. Scan time was 14 seconds.

All MRA studies were randomized and quality scores were determined by two experienced readers for the following categories: contrast (value and uniformity), border sharpness, details of the PVs, LA, and LA appendage (LAA), visibility of esophagus, and overall image quality: 1=poor, 2=acceptable, 3=good, 4=excellent. Mean and standard deviation (SD) for each category were calculated. Comparisons between MRA techniques were made by two-tailed paired Student's t-test.

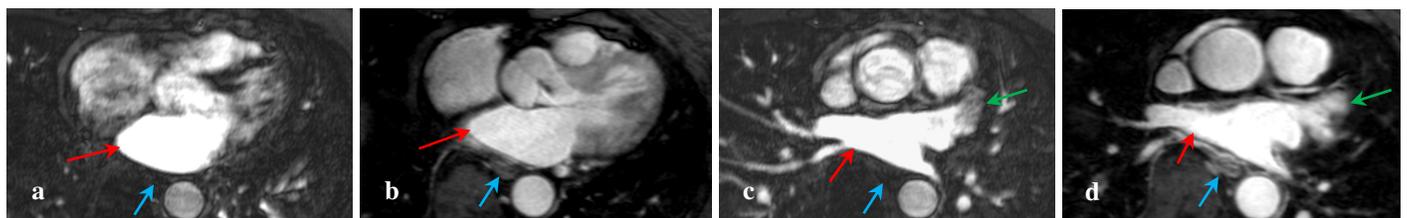
**Results:** Typical images acquired using non- and ECG-gated MRA sequences are shown in Figures 1 and 2. Non-gated MRA (Fig. 1a, 1c) suffers from blurring and reduced border sharpness of the LA structures and PVs. In comparison ECG-gated MRA (Fig. 1b, 1d) shows better border detail and overall scan quality. Esophagus is barely visible in non-gated scans (Fig. 2a), whereas, it is clearly observed in ECG-gated scans (Fig. 2b). Quantitative analysis (Table 1) demonstrates that ECG-gated MRA scored significantly higher than non-gated MRA in all categories. One ECG-gated scan had poor quality because of patient motion. Two non-gated scans were scored as poor. One of them was because of poor breath-hold, the other one was because of wrong timing of data acquisition with contrast injection.

| Table 1       | Contrast  | Sharpness | PVs       | LAA       | LA        | Esophagus | Overall Quality |
|---------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------------|
| Non-gated MRA | 2.63±0.66 | 2.35±0.71 | 2.35±0.69 | 2.25±0.72 | 2.35±0.70 | 1.21±0.31 | 2.66±0.65       |
| Gated MRA     | 3.18±0.78 | 3.08±0.81 | 3.04±0.82 | 3.11±0.84 | 3.08±0.81 | 3.37±0.52 | 3.16±0.75       |
| p-value       | <0.00001  | <0.00001  | <0.00001  | <0.00001  | <0.00001  | <0.00001  | <0.00001        |

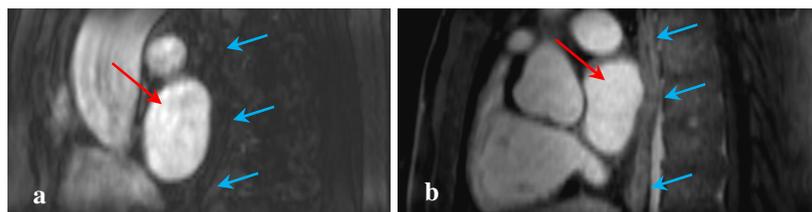
**Discussion and Conclusion:** A novel sequence for simultaneous visualization of LA and PVs, and esophagus has been developed and validated. The sequence is less dependent on patient compliance and yields better clarity of LA and PVs anatomy (border sharpness and anatomical details) and accurate depiction of esophagus than conventional non-gated MRA. These advantages may translate into improved diagnostics and treatment of AF patients including planning and execution of RF ablation, detection of PV stenosis, and following LA remodeling post-ablation. This new sequence may also be used to simplify and improve segmentation of LA wall from late gadolinium enhancement (LGE) scans of LA performed for visualization and quantification of pre-ablation fibrosis and post-ablation scar.<sup>3-5</sup>

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**References:** 1. Calkins H, et al., *Europace* 2012;14:528-606. 2. Pappone C, et al., *Circulation* 2004;109:2724-2726. 3. Peters D, et al., *Radiology* 2007;243:690-695. 4. McGann CJ, et al., *JACC* 2008;52:1263-1271. 5. Oakes RS et al. *Circulation* 2009;119:1758-1767.



**Figure 1.** Non-gated (a, b) and ECG-gated (c, d) MRA of the same patient acquired four days apart. Notice non-uniform intensity and blurred boundaries of cardiac structures in non-gated MRA. These structures including origin of coronary artery and esophagus are nicely visualized by ECG-gated MRA. Red arrows indicate LA, green arrows – LAA, and blue arrows – esophagus.



**Figure 2.** Esophagus imaging by non-gated (a) and ECG-gated MRA (b). Sagittal slices reformatted from the corresponding axial image volumes are shown. Notice excellent visualization of esophagus in ECG-gated scan. Esophagus is practically invisible in non-gated scan. Red arrows indicate LA, blue arrows – esophagus.