VCATS, MR Coronary Angiography using Breath-hold Volume Targeted Acquisitions

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Introduction
High performance gradient systems have opened the doors to 3-D volumetric imaging of the heart using segmented echo planar imaging (EPI) techniques1 with good temporal resolution and adequate in-plane spatial resolution. The latest developments along these lines have attempted the acquisition of the entire cardiac anatomy in a single breath-hold with isotropic resolution2,3. We sought of combining this single breath-hold volumetric image acquisition to prescribe optimal orientations within a multiplanar reformation (MPR) platform. This is done to set up a small volume scan oriented along the coronaries or VCATS (Volume Coronary Arteriography using Targeted Scans) so that the coronary arteries can be assessed with the highest in-plane resolution possible within the context of breath-hold imaging (balancing gradient performance and signal-to-noise) and still provide contiguous slices that avoid the misregistration problems present with previously documented 2-D single slice approaches.

Material and Methods
Ten volunteers and twenty patients were referred after conventional coronary arteriography. A 1.5T Magnetom Vision platform (Siemens Medical Systems, Erlangen, Germany) was used. All subjects were positioned supine with a 4-channel quadrature body phased array coil placed over the thorax. The measuring protocol for coronary screening considered two 3-D MR pulse sequences with two clearly defined objectives: localization and targeting, respectively. The localizer measurement attempts to scan the entire heart volume and provide the necessary data for input for the targeted scans of the coronaries (VCATS).

The localization procedure and evaluation of the coronary segments can be summarized in the following steps:
1. Use a single end-expiration breath-hold 3-D localizer (using fat-suppressed multi-shot 3-D segmented EPI) to cover the entire heart.
2. The volume localizer is evaluated in a multi-planar reconstruction platform, focusing on one coronary segment at a time (see table 1).
3. The optimal double oblique plane and slab position that contains the coronary segment of interest is recorded.
4. Slab position and double oblique plane orientation are used for the end-expiration breath-hold VCATS (fast-suppressed 3-D segmented turbo FLASH).
5. The process is repeated (steps 2-4) until all coronary segments are evaluated.

<table>
<thead>
<tr>
<th>Volume</th>
<th>Coronary segments evaluated</th>
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<tbody>
<tr>
<td>1</td>
<td>Transverse scan containing the left main (LM), proximal circumflex (LCX) and proximal left anterior descending (LAD) coronary arteries</td>
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<tr>
<td>2</td>
<td>Transverse scan of the proximal segment of the right coronary artery (RCA)</td>
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<td>3</td>
<td>Double oblique scan along the distal portion of the RCA</td>
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<tr>
<td>4</td>
<td>Double oblique plane of the aortic root and proximal RCA and LM</td>
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<td>5</td>
<td>Double oblique scan of the distal LAD</td>
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<tr>
<td>6</td>
<td>Double oblique plane on LCX</td>
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<tr>
<td>7</td>
<td>Double oblique scan along the RCA</td>
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</table>

Table 1: Denomination of routine coronary segments evaluated. Order of volume acquisition is indicated by volume number.

Results and discussion
Consistent results were obtained in all volunteers and 15 patients that were able to withstand a breath-hold acquisition of 18 to 22 heartbeats. The volume localizer is used not only to prescribe optimal visualization orientations for VCATS but can be rendered to demonstrate the course of the coronaries over the heart (Figure 1) on a patient with proximal stenosis of the LAD on conventional coronary angiography (Figure 2). The heart volume localizer was completed in 18 heartbeats and was segmented and displayed accordingly. VCATS results are demonstrated in Figures 3 and 4 demonstrating the proximal segments of the RCA, LM and LAD, with orientations that were prescribed from the MPR of the volume localizer. As in all techniques previously described, the quality of the data will depend on the ability to perform a good fat suppression over the cardiac volume targeted. The use of intravascular contrast agents inducing high relaxivity in blood will contribute to reduce artifacts and augment the signal-to-noise even further.

Conclusions
We present an alternative approach to fast 3-D localization and targeted imaging of the coronary arteries. This breath-hold protocol enables rapid scanning of the coronary anatomy in several breath-holds (whenever possible) and permits suitable localization of the coronary arteries, interactive positioning for optimal viewing, fast feedback and a nearly operator independent evaluation.

Figure 1: Potential use of the 3D MSEPI volume localizer. Volume rendering of patient of Fig. 2.

Figure 2: LAD stenosis (arrow). Conventional X-ray arteriogram of patient.

Figure 3: 12 center slices of a double-oblique view of the aortic root showing proximal segments of RCA, LM and LAD acquired with VCATS in 21 heartbeats. Patient with stenosis in mid RCA segment.

Figure 4: 12 center slices of a transverse view of LM, and proximal LCX and LAD acquired with VCATS in 21 heartbeats.

References