Multiphase-multistep 3D gadolinium-enhanced MRA of the abdominal aorta and run-off vessels

Stefan O. Schoenberg1, Frank Londy1, Paul Licato2, David Williams1, Thomas Wakefield2, Thomas L. Chenevert1
1Department of Radiology, 2Department of Surgery, University of Michigan, Ann Arbor, Michigan, USA

Introduction
With the introduction of the moving-table technique, complete assessment of the aorta and lower extremities with 3D gadolinium-enhanced MRA (3D-Gd-MRA) has become feasible by sliding the field-of-view during contrast infusion (1). Several problems of the moving-table technique arise as the diagnostic requirements from the aorta to the calves are not uniform. For the small arteries in the calves, high-resolution imaging with long scan times is required which is limited by signal-to-noise and venous overlay (2). In the aorta, aneurysms or dissections can substantially alter the contrast kinetics resulting in delayed and non-uniform vessel fill-in (3). Long scan times degrade the evaluation of the renal arteries due to parenchymal or venous overlay (4). In addition, the different course of the arteries in the lower extremities require various orientations and dimensions of each scan volume for maximum coverage. To account for all these problems, a combination of different hardware and software features are necessary that address fundamentally different requirements for temporal and spatial resolution in a single automated exam.

Materials and Methods

Multiphase-multistep 3D-Gd-MRA
Measurements were performed on a clinical 1.5T MR system (GE Medical Systems, gradient strength 23 mT/m, rise time 180 µs). A clinical prototype of the Smartstep technique was used, which features automated table movement and freely variable acquisition parameters for each anatomic location. The area from the abdominal aorta to the feet was covered with a specially designed 12-element phased array coil (U.S.A Industries). 3 separate 3D MRA volumes were individually prescribed in the abdomen, thighs and calves. To optimize the scans in terms of vascular enhancement kinetics, anatomic coverage and spatial resolution, a fast dual-phase acquisition in the abdomen (top station) was followed by a single scan for the thighs (middle) and a single, high-resolution scan in the calves (bottom) with a voxel size of 1.7mm³. Elliptical-centric k-space acquisition was used to maximize arterial enhancement and minimize venous overlay. To cover the most anterior and posterior vascular structures, the margins of the 3D volumes were tilted accordingly. Scan time was shortened using the half-Fourier algorithm (table 1).

Table 1: Parameters for multiphase-multistep 3D-Gd-MRA
<table>
<thead>
<tr>
<th>station</th>
<th>scan time (s)</th>
<th># scans</th>
<th>TR/TE (ms)</th>
<th>matrix</th>
<th>spatial res.(mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>top</td>
<td>27</td>
<td>2</td>
<td>4.0/1.4</td>
<td>192x320</td>
<td>2.5x1.5x2.0</td>
</tr>
<tr>
<td>middle</td>
<td>14</td>
<td>1</td>
<td>4.0/1.4</td>
<td>192x320</td>
<td>2.5x1.5x2.0</td>
</tr>
<tr>
<td>bottom</td>
<td>34</td>
<td>1</td>
<td>5.5/2.2</td>
<td>280x512</td>
<td>1.7x0.8x1.2</td>
</tr>
</tbody>
</table>

Mask images for subtraction were automatically acquired at each station followed by contrast-enhanced acquisitions. 42ml of gadodiamide (Omniscan, Nycomed) were infused in a dual-bolus injection scheme (15ml@1.5ml/s + 27ml@0.7ml/s). Contrast arrival in the abdominal aorta was automatically detected using the Smartprep technique (GE Med. Sys.). 15 patients with vascular disease were evaluated.

Results and Discussion
In aortic aneurysms, dissections or occlusive disease, substantially delayed fill-in of aneurysmal segments, false lumens or reconstituted arteries occurs, which is only detected on the later 3D-Gd-MRA phases. At the same time, high-resolution arterial phase scans in the calves are obtained with minimal venous overlay. Multiphase-multistep 3D-Gd-MRA therefore integrates fundamentally different imaging requirements for temporal and spatial resolution in an automated exam. It overcomes the limitations of standard 3D-Gd-MRA techniques in respect to complexity of setup, anatomic coverage, spatial resolution and non-uniform arterial vessel enhancement.

Fig. 1: a) Multiphase MRA of aortic aneurysm revealing delayed fill-in of iliac arteries. b) Multiphase-multistep MRA shows complete fill-in of an aortic aneurysm in the later phase and pure arterial phase images of the calves with high spatial resolution (1.8mm³) and without venous overlay.

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References