Time-resolved contrast-enhanced magnetic resonance angiography (CEMRA) of the left atrium-pulmonary veins complex with half dose of intravenous gadolinium-based contrast agent: Comparison of image quality with a conventional CEMRA protocol

Poster No.: B-867
Congress: ECR 2010
Type: Scientific Paper
Topic: Cardiac - Without Subtopic
Authors: V. Zampa, L. Faggioni, F. Odoguardi, E. Picano, C. Bartolozzi; Pisa/IT
Keywords: Atrial fibrillation, Magnetic resonance angiography, Paramagnetic contrast material
Keywords: Cardiac
DOI: 10.1594/ecr2010/B-867

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Purpose

- Atrial fibrillation (AF) is the most common heart rhythm disorder and is characterised by rapid and uncoordinated atrial electric activity, resulting in abnormal atrial contraction and irregular ventricular response.

- AF is typically initiated by arrhythmogenic foci predominantly located at the junctions between the ostia of the pulmonary veins (PV) and the left atrium (LA). Electrical insulation of these foci by local transcathester energy delivery (e.g. radiofrequency) can lead to stable restoration of sinus rhythm.

- Transcatheter radiofrequency ablation of AF is increasingly being performed with the aid of cross-sectional imaging modalities (such as multidetector computed tomography [MDCT] and magnetic resonance imaging [MRI]), allowing for an accurate pre-procedural evaluation of the LA-PV complex anatomy and real-time guidance of the ablation procedure by means of image fusion algorithms.

- Compared with MDCT, MRI has the advantages of no exposure to ionising radiation and iodinated contrast material (CM). However, conventional contrast-enhanced MR angiography (CEMRA) sequences require relatively long acquisition times and large volumes of intravenous paramagnetic CM. As a consequence, poor differentiation between the LA-PV complex and the pulmonary arteries (PA) may occur, potentially complicating image interpretation, as well as 2D and 3D image reconstructions. Moreover, the administration of high doses of paramagnetic CM can raise safety issues in patients with impaired renal function.

- Our purpose is to evaluate feasibility and image quality of a time-resolved CEMRA protocol with half dose of paramagnetic CM in comparison with a conventional CEMRA acquisition obtained with full CM dose.
Methods and Materials

- Sixty-five patients with paroxysmal AF candidate to transcatheter radiofrequency AF ablation underwent CEMRA of the LA-PV complex on a 1.5T MRI system (Signa Excite HDx; General Electric, Milwaukee, WI) equipped with an 8-channel phased array cardiac coil.

- In 31/65 patients (male:female=18:13, age 54.7±17.3 years [mean±standard deviation]: protocol A), a conventional Fast Spoiled GRadient echo (FSPGR) CEMRA sequence was performed on the coronal plane with the following parameters: TR/TE 3.9ms/1.5ms, flip angle 35°, matrix 320x190, 0.5 NEX, bandwidth 63kHz, fat suppression, thickness/spacing 3.0/-1.5mm, centric k-space filling scheme. A bolus of 0.2mL/kg of Gd-BOPTA (MultiHance®; Bracco, Milan, Italy) was administered intravenously through a power injector via a 20G needle placed in the left antecubital vein at a flow rate of 3mL/s, followed by 20mL of saline flush at the same flow rate. Acquisition time was 18-22s depending on the antero-posterior diameter of the LA.

- In the remaining 34/65 patients (male:female=20:14, age 50.2±13.6 years: protocol B), a time-resolved (TRICKS: Time Resolved Imaging of Contrast KineticS) was run on the coronal plane with the following parameters: TR/TE 3.4ms/1.3ms, flip angle 35°, matrix 320x224, 0.75 NEX, bandwidth 83kHz, 8 temporal frames (frame resolution 3.5-3.8s depending on the antero-posterior diameter of the LA), thickness/spacing 3.0/-1.5mm. A bolus of 0.1mL/kg of Gd-BOPTA was injected intravenously at a 3mL/s flow rate, followed by 20mL of saline flush at the same flow rate. Total acquisition time was 44-49s. Before CM injection, an unenhanced dataset was acquired for digital subtraction of stationary tissues on contrast-enhanced frames.

- CEMRA datasets were exported in DICOM format on a workstation (Advantage Windows 4.4; General Electric, Milwaukee, WI). For protocol B datasets, the frame with the highest differential enhancement between the LA-PV complex and the PA was selected and loaded on the workstation. Maximum Intensity Projection (MIP), Volume Rendering (VR), and Virtual Endoscopy (VR) reconstructions were created. Three radiologists in consensus assessed semiquantitatively the diagnostic quality of reconstructions using a four-point scale (0=poor, 1=fair, 2=good, 3=excellent).

- Finally, the datasets used for image reconstructions were exported on a Macintosh® computer (iMac 2.93GHz Intel Core 2 Duo; Apple Inc., Cupertino, CA) running OsiriX 3.6.1 (http://www.osirix-viewer.com).
intensity inside the LA (SI_{LA-PV}) and at the bifurcation of the common trunk of the PA (SI_{PA}) was measured by two radiologists in consensus by placing regions of interest (ROI) on orthogonal multiplanar views, so to maximize the amount of sampled voxels while avoiding measurement errors due to partial volume effect.

- SI_{LA-PV} and SI_{PA} values (expressed in arbitrary units), SI_{LA-PV}/SI_{PA} ratios, and quality scores of MIP, VR, and VE image reconstructions with protocols A and B were compared by means of two-tailed Mann-Whitney test. A p-value less than 0.05 was considered statistically significant.
Fig. 0: Scheme of the two CEMRA protocols under evaluation.

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Fig. 1: Demonstration of the ‘fluoroscopic’ approach of time-resolved CEMRA. A set of 8 temporal frames (each with 3.5-3.8s time resolution, varying upon LA anteroposterior diameter) is generated, making calculation of CM bolus arrival time or bolus tracking unnecessary.

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**Fig. 0:** LA-PV complex ROI taken at the center of the LA on coronal view for signal intensity measurement.

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**Fig. 0:** PA ROI taken at the bifurcation of the common PA trunk on axial view for signal intensity measurement.
Results

- Image quality of MIP, VR, and VE reconstructions was significantly higher with protocol B than with protocol A (2.67±0.62 vs 1.15±0.90, p=0.005; 2.60±0.63 vs 1.46±0.78, p=0.0001; and 2.47±0.74 vs 1.69±0.95, p=0.005, respectively).

- SI_{LA-PV} was lower with protocol B than with protocol A (673.6±137.9 vs 721.9±239.1, respectively), but such difference was not statistically significant (p=0.4231).

- SI_{PA} was significantly lower with protocol B than with protocol A (332.3±163.2 vs 543.3±184.7, respectively; p=0.0013).

- The SI_{LA-PV}/SI_{PA} ratio was significantly higher with protocol B than with protocol A (2.08±0.67 vs 1.47±0.53; p=0.0154).
**Fig. 0:** Image quality scores of MIP, VR, and VE reconstructions with protocols A and B.

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**Fig. 0:** Signal intensity (expressed in arbitrary units) in the LA-PV complex, in the PA and their ratio with protocols A and B.

<table>
<thead>
<tr>
<th>Signal intensity</th>
<th>Protocol A</th>
<th>Protocol B</th>
</tr>
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<tbody>
<tr>
<td>$S_{LA-PV}$</td>
<td>$721.9 \pm 239.1$</td>
<td>$673.6 \pm 137.9$</td>
</tr>
<tr>
<td>$S_{PA}$*</td>
<td>$543.3 \pm 184.7$</td>
<td>$332.3 \pm 163.2$</td>
</tr>
<tr>
<td>$S_{LA-PV}/S_{PA}$**</td>
<td>$1.47 \pm 0.53$</td>
<td>$2.08 \pm 0.67$</td>
</tr>
</tbody>
</table>

* $p=0.0013$, ** $p=0.0154$
**Fig. 0:** MIP reconstruction of CEMRA of the LA-PV complex performed with protocol A. Patient has normal PV anatomy with adjacent ostia of the right PV; although diagnostic, the MIP image has blurred vessel contours. The scores assigned to this MIP image was 1 (fair).

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**Fig. 0:** VR reconstruction of CEMRA of the LA-PV complex performed with protocol A. Patient has normal PV anatomy with adjacent ostia of the right PV; this latter finding is adequately depicted on VR reconstruction, although the walls of the PV and the LA have a coarse appearance. The score assigned to this VR reconstruction was 1 (fair).

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**Fig. 0:** VE reconstruction of CEMRA of the LA-PV complex performed with protocol A. Patient has normal PV anatomy with adjacent ostia of the right PV; the VE view of the PV ostia is good, despite with some parietal roughness. The score assigned to this VE reconstruction was 2 (good).

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**Fig. 0:** MIP reconstruction of CEMRA of the LA-PV complex performed with protocol B. Patient has a common left venous trunk. On MIP image vessel contours are sharply delineated, and the score assigned to it was 3 (excellent).

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**Fig. 0:** VR reconstruction of CEMRA of the LA-PV complex performed with protocol B. Patient has a common left venous trunk, and the VR reconstruction offers a neat and detailed depiction of the LA-PV complex walls. The score assigned to it was 3 (excellent).

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**Fig. 0:** VE reconstruction of CEMRA of the LA-PV complex performed with protocol B. Patient has a common left venous trunk. The VE reconstruction yields a sharp endoluminal depiction of the common left venous ostium, and was assigned a score of 3 (excellent).

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Conclusion

- Time-resolved CEMRA of the LA-PV complex with half dose of intravenous paramagnetic CM is feasible for pre-procedural evaluation of patients candidate to percutaneous ablation of AF.

- Compared with a conventional CEMRA protocol with full CM dose, our protocol ensures better separation between the LA-PV complex and the PA and yields better quality MIP, VR, and VE reconstructions.

- Usage of half dose of paramagnetic CM is likely to be beneficial in terms of patient safety (especially in case of poor renal function) and imaging costs.
combination of parallel imaging, keyhole acquisition, and k-space sampling techniques at 1.5 T. Radiology 2008;246:871-9;


Personal Information

Lorenzo Faggioni, MD

Diagnostic and Interventional Radiology
University of Pisa
Via Paradisa, 2 - 56125 Pisa (Italy)
Email lorenzofaggioni@inwind.it