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Original Article

Visualization of the radiofrequency lesion after pulmonary vein isolation using delayed enhancement magnetic resonance imaging fused with magnetic resonance angiography

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ABSTRACT

Background: The radiofrequency (RF) lesions for atrial fibrillation (AF) ablation can be visualized by delayed enhancement magnetic resonance imaging (DE-MRI). However, the quality of anatomical information provided by DE-MRI is not adequate due to its spatial resolution. In contrast, magnetic resonance angiography (MRA) provides similar information regarding the left atrium (LA) and pulmonary veins (PVs) as computed tomography angiography. We hypothesized that DE-MRI fused with MRA will compensate for the inadequate image quality provided by DE-MRI.
Methods: DE-MRI and MRA were performed in 18 patients who underwent AF ablation (age, 60 ± 9 years; LA diameter, 42 ± 6 mm). Two observers independently assessed the DE-MRI and DE-MRI fused with MRA for visualization of the RF lesion (score 0–2; where 0: not visualized and 2: excellent in all 14 segments of the circular RF lesion).
Results: DE-MRI fused with MRA was successfully performed in all patients. The image quality score was significantly higher in DE-MRI fused with MRA compared to DE-MRI alone (observer 1: 22 (18, 25) vs 28 (28, 28), $p < 0.001$; observer 2: 24 (23, 25) vs 28 (28, 28), $p < 0.001$).
Conclusions: DE-MRI fused with MRA was superior to DE-MRI for visualization of the RF lesion owing to the precise information on LA and PV anatomy provided by DE-MRI.

1. Introduction

Pulmonary vein isolation (PVI) is the cornerstone of ablation for atrial fibrillation (AF) [1,2]. We have previously reported that the radiofrequency (RF) lesion can be visualized with delayed enhancement magnetic resonance imaging (DE-MRI) [3]. However, visualization of the RF lesion gap, especially that located at the anterior ridge or carina, was difficult in some patients for the following reasons: (1) The anatomy of the anterior ridge between the left pulmonary vein (LPV) and left atrial appendage (LAA) and the carina between the superior PV and inferior PV is complex and varied among patients. (2) The spatial resolution of DE-MRI is not adequate for visualization of complex anatomy. Recently, magnetic resonance angiography (MRA) was reported to provide similar information on the left atrium (LA) and PV anatomy as contrast-enhanced computed tomography angiography (CTA) [4]. Thus, we hypothesized that DE-MRI fused with MRA compensates for the inadequate quality of the anatomical information provided by DE-MRI alone.

Abbreviations: RF, radiofrequency; AF, atrial fibrillation; DE-MRI, delayed enhancement magnetic resonance imaging; MRA, magnetic resonance angiography; LA, left atrium; PV, pulmonary vein

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2. Material and methods

2.1. Patient selection

Eighteen consecutive patients who underwent AF ablation were included in the study. All patients underwent contrast-enhanced MRI using a 1.5-T MR system (Intera Achiva; Philips Medical Systems, Best, the Netherlands) equipped with a 32-channel cardiac coil. In this study, MRI consisted of contrast-enhanced MRA (CE-MRA) and DE-MRI. DE-MRI and MRA scans were interpretable in all patients. MRI was performed at least 1 month after AF ablation. The patients with an inadequate image quality of the RF lesion on DE-MRI were excluded from this study. The study was approved by the local institutional review board (date: 19.11.2013; approval number: 20), and written informed consent was obtained from all patients.

2.2. Mapping and ablation procedure

Prior to the procedure, transesophageal echocardiography was performed to exclude thrombus formation. The study was performed in spontaneously breathing patients under deep propofol sedation. Standard electrode catheters were placed in the right ventricular apex and the coronary sinus after which a single transseptal puncture was performed. Unfractionated heparin was administered in bolus form before the transseptal puncture to maintain an activated clotting time of >300 s. If AF was sustained, an internal electrical cardioversion was performed to restore sinus rhythm (SR). Mapping and ablation were performed using the CARTO3 system (Biosense Webstar, Diamond Bar, CA, USA) or the NavX system (St. Jude Medical, Inc., St. Paul, MI) as a guide after integration of a three-dimensional (3D) model of the LA and PV anatomy obtained from pre-interventional computed tomography (CT). Prior to the ablation, circular mapping catheter- (Lasso, Biosense Webster; Optima, St. Jude Medical Inc.) and ablation catheter-reconstructed posterior LA anatomies were aligned with the CT image. Fine adjustment of image integration was achieved through three additional landmarks (at the top of left superior PV, right superior PV, and at the bottom of left inferior PV); these landmarks were visited with the tip of the ablation catheter (Thermocool, Biosense Webster; IBI Therapy Cool Flex, St Jude Medical, Inc.) according to fluoroscopy and electrogram information. The RF alternating current was delivered in a unipolar mode between the irrigated tip electrode of the ablation catheter and an external back-plate electrode. The initial RF generator setting consisted of an upper catheter tip temperature of 43 °C, a maximal RF power of 30 W, and an irrigation flow rate of 13 ml/min. When RF application was performed on the posterior wall, the initial RF generator setting consisted of a maximal RF power of 20 W. All patients underwent PVI. RF application could be performed in a "point by point" fashion. The level of ablation was chosen on the atrial side of the PV antrum, mainly depending on the operator's decision. The maximum time at the anterior wall and posterior wall was 40 and 20 s, respectively. RF energy was routinely reduced by 10 W when ablating the posterior wall according to the esophageal temperature measured with an esophageal temperature probe (SensiTherm, St. Jude Medical Inc.). If the esophageal temperature rose to >39 °C, the ablation was immediately stopped and energy further reduced. After the esophageal temperature decreased to within the normal range (37 °C), RF application was resumed. If the ablation could not be performed with 20 W, the line placement was performed either more antral or closer to the PV, depending on the individual anatomical findings. Catheter navigation was performed with a non-steerable sheath (Preface, Multipurpose, Biosense Webster) or steerable sheath (Agilis, St. Jude Medical Inc.). The procedural end point was considered to be the electro-physiologically proven bidirectional block for the PV-encircling ablation lines confirmed with a circular mapping catheter. After confirming bidirectional block of the PV, we performed a stimulation protocol (burst pacing from coronary sinus (CS) with 300 ms, 250 ms, and 200 ms for 10 s each) for testing the inducibility. In those cases in which atrial fibrillation was induced, patients underwent cardioversion, and the procedure ended with patients in paroxysmal atrial fibrillation; a linear ablation including roof and mitral isthmus lines was added in the patients with persistent atrial fibrillation. A pharmacological test (high dose isoproterenol infusion: 20 μg/min) was performed in order to identify non-PV triggers. Ablation of the cavotricuspid isthmus was performed only if typical right atrial flutter was either documented previously or induced by burst pacing at the end of the procedure.

2.3. CE-MRA acquisition

CE-MRA of PV–LA anatomy was acquired with a breath-hold 3D T1 fast field echo (T1-FFE) sequence in the coronal plane during the first pass of a gadopentetate dimeglumine injection (Magnevist; Bayer Yakuhin, Osaka, Japan), at a dose of 0.1 mmol/kg of body weight. The acquisition time was approximately 15 s. This scan technique has been previously established, and the acquired image has been used for the AF ablation procedure [5–7].

2.4. DE-MRI acquisition

The scan technique and parameters for DE-MRI have been previously reported [8–11]. The DE-MRI of the LA with the PVs was acquired using a 3D inversion recovery, respiration navigated, electrocardiogram-gated, T1-FFE sequence in the transverse plane 15 min after the injection of 0.1 mmol/kg gadolinium as the contrast agent. The typical scan parameters were: repetition time (TR)/echo time (TE)=4.7/1.5, voxel size=$1.25 \times 1.26 \times 2.60$ mm^3 (reconstructed to $0.63 \times 0.63 \times 1.30$ mm^3), flip angle=15, inversion time (TI)=280–330 ms, SENSE with a reduction factor of 2, and 70 reference lines. The TI value was identified from the myocardial TI_{null} using a Look-Locker. The T1 of the LA wall was similar to the myocardial T1 [8]. The data acquisition was limited to 15% of the cardiac cycle. In cases of SR, during MRI, the data acquisition was performed during the mid-diastolic phase of the left ventricle. In case of AF, during MRI, the trigger delay of the cardiac synchronization was set to the shortest value. Saturation bands were placed in the phase-encoding (right–left) line to minimize back-folding from the arms. Fat saturation was used to suppress any fat signals. The typical scan time for the DE-MRI study was 7–12 min depending on the patient's heart rate and respiration pattern. An attempt to control the heart rate at <70 bpm was made using metoprolol 20 mg or 40 mg.

2.5. A 3D visualization of RF lesions

A 3D visualization and segmentation of the MRI were performed with AZE Virtual Place (AZE Virtual Place; AZE, Tokyo, Japan). The method for the 3D visualization has been reported previously [3,12,13]. Briefly, we segmented the LA wall and calculated the mean value and standard deviation (SD) of the pixel intensity histogram. The detailed method is as follows: (1) In CE-MRA data, a 3D image was segmented from the surrounding structures. The anatomical information obtained from the 3D CE-MRA indicated the endocardial border of the LA wall (end CE-MRA). (2) We prepared the modified CE-MRA data with 3 pixel enlarged volume automatically using the AZE software. The enlarged CE-MRA data indicated the epicardial border of the LA wall (epi CE-MRA). (3) In the DE-MRI data, the LA wall segmentation was performed automatically with the 2-segmented 3D-MRA