Feasibility of Three-Dimensional MR Angiography Image Fusion Guidance for Endovascular Abdominal Aortic Aneurysm Repair

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ABSTRACT

Magnetic resonance (MR) angiography image fusion (IF) with live fluoroscopy guidance was used while performing endovascular repair of abdominal aortic aneurysm (EVAR) in five patients with a history of chronic renal disease or severe contrast allergy. Intraprocedural technical success was 100%. Median procedure time was 120 minutes (range, 60–180 min), fluoroscopy time was 40 minutes (range, 17–65 min), dose-area product was 245,867 mGy × cm^2 (range, 68,435–690,053 mGy × cm^2), and iodinated contrast volume injected was 15 mL (range, 0–40 mL). Technical success was achieved in four of five patients (80%); one case was complicated by a type 1 endoleak on follow-up MR angiography, which was successfully treated. EVAR with MR angiography IF guidance was technically feasible and safe in five patients and reduced or eliminated the use of iodinated contrast media.

ABBREVIATIONS

AAA = abdominal aortic aneurysm, CKD = chronic kidney disease, EVAR = endovascular aneurysm repair, IF = image fusion, 3D = three-dimensional, 2D = two-dimensional

Impaired renal function limits the interventional radiologist in using iodinated contrast material for endovascular treatments. Despite the advent of low-osmolar and iso-osmolar iodinated contrast agents and hydration protocols, patients with chronic kidney disease (CKD), particularly when associated with diabetes, remain at risk for contrast-induced nephropathy (1). Reports show that 11% of patients with abdominal aortic aneurysm (AAA) who are treated with endovascular aneurysm repair (EVAR) have preexisting CKD (2). Additionally, 20% of acute kidney failure after EVAR is due to contrast-induced nephropathy (2). Severe allergy is another potential obstacle to the use of iodinated contrast material for endovascular interventions (3).

Based on the two above-mentioned obstacles with iodinated contrast material, reducing or eliminating the need for iodinated contrast material is crucial at every step of performing EVAR, including imaging before the procedure, intraprocedural image guidance, and imaging after the procedure. Gadolinium-based contrast agents, which are used in magnetic resonance (MR) imaging, represent one alternative to iodinated contrast material. MR angiography provides reliable diagnostic and follow-up data in patients with AAA treated with EVAR (4). However, MR angiography should be considered with caution according to European guidelines because of the risk of nephrogenic systemic fibrosis in patients with end-stage renal disease (5). To reduce the use of intraprocedural iodinated contrast media, previous reports demonstrated that image fusion (IF) technology using computed tomography (CT) angiography overlaid on live two-dimensional (2D) fluoroscopy facilitates the EVAR procedure with accurate positioning and deployment of the endograft and decreases the amount of contrast material used (6–8). However, reports on using IF technology and MR angiography are limited. The aim of this report is to describe the feasibility and safety of implementing MR angiography IF with live 2D fluoroscopy for EVAR in patients with high risk of acute renal failure or severe contrast allergy.

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TECHNIQUES

Institutional review board approval was obtained for this report. In this single-center retrospective report, all patients treated with standard or complex EVAR between March 2009 and January 2011 were evaluated. The inclusion criteria for standard or complex EVAR were as follows: (*a*) infrarenal AAA or complex aortic aneurysm, including aortic aneurysms involving the mesenteric or renal arteries, pararenal aneurysm, and juxtarenal aortic aneurysm; (*b*) high risk for open surgical repair as described by the *Haute Autorité de Santé* (French counterpart of the US Food and Drug Administration) and reported by Haulon et al (9); and (*c*) MR angiography performed within 1 month before procedure. The exclusion criteria were (*a*) contraindications to iliac or brachial approach because of occlusive disease, (*b*) unstable atheromatous arterial lesions with risk of embolization, (*c*) proximal aortic neck angulations $> 60^{\circ}$, and (*d*) external iliac diameter < 9 mm or > 16 mm.

MR angiography was performed before the procedure to measure the extent of the aneurysm and to determine the strategy of endovascular repair (type and sizing of the stent graft, and the need for stent placement into target vessel such as renal or mesenteric artery). MR angiography performed before the procedure was also used for intraprocedural roadmapping guidance. MR angiography and Doppler ultrasound were performed at 1 week after the procedure, 1 month after the procedure, and every 6 months during the clinical follow-up.

MR Angiography Acquisition

The abdominal imaging protocol was performed using a 1.5-tesla MR system (MAGNETOM Symphony; Siemens AG, Erlangen, Germany) and two 16-channel phased-array body multicoils. Acquisitions included a three-dimensional (3D) spoiled gradient recalled echo sequence with the following parameters: repetition time/echo time, 2.41/0.86 ms; flip angle, 25°; section thickness, 1.45 mm; matrix size, 268 mm × 384 mm. The acquisition was performed using a breath-hold technique, with and without injection of contrast agent. Contrast dose was 0.1 mmol/kg gadoterate meglumine (Dotarem; Guerbet, Aulnay-sous-Bois, France) and was injected using automatic power injection at 5 mL/s and followed by a 20-mL sodium chloride chaser. Post processing of the MR angiography data sets was performed and included image subtraction of the arterial phase from the 3D MR imaging performed before contrast administration.

MR Angiography IF Guidance

Immediately before the intervention, MR angiography images were loaded onto the workstation. For registration of the live fluoroscopy with the MR angiography volume, an unenhanced low-dose cone-beam CT acquisition (Allura Xper FD20; Philips Healthcare, Best, The Netherlands) was performed after induction of general anesthesia and before draping the patient. The patient's arms remained alongside the body for the cone-beam CT acquisition. The area of interest was positioned in the system isocenter, and 120 projections (15 frames/s) were acquired over a 180° arch. The images were reconstructed into 3D volume on the dedicated 3D workstation (XtraVision Release 8; Philips Healthcare). Intraoperative cone-beam CT images were coregistered with the loaded 3D data set in the same spatial coordinates in < 5 minutes. Landmarks such as aortic wall or target vessel calcifications on cone-beam CT images (**Fig 1**) and the enhanced vessels on MR angiography images (**Fig 2**) were used for registration references. Coregistration was performed by aligning vascular calcifications of cone-beam CT images just on the border of the vascular lumen of the target vessels on MR angiography images (**Fig 3**). The volume rendering technique of the entire arterial tree from MR angiography images was used to create the 3D roadmap (**Fig 4**). The generated 3D roadmap was synchronized with the C-arm/table position to provide a live update on 2D fluoroscopy at any C-arm/table angle, position, or magnification (**Video** [available online at *www.jvir.org*]).

EVAR Procedure

Under MR angiography IF guidance, the aortic stent graft and the iliac components were inserted and

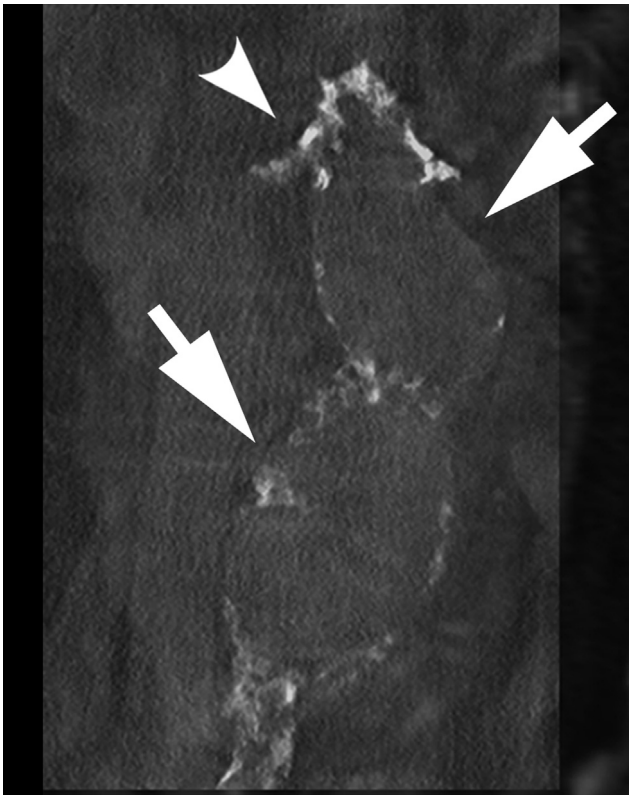

Figure 1. Coronal view of cone-beam CT image in patient 1. Landmarks such as aortic wall (arrows) or target vessels calcifications such as the right renal artery (arrowhead) were used for coregistration.