Original Investigation

Validation of Renal Artery Dimensions Measured by Magnetic Resonance Angiography in Patients Referred for Renal Sympathetic Denervation

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Rationale and Objectives: Magnetic resonance angiography (MRA) is a well-established modality for the assessment of renal artery stenosis. Using dedicated quantitative analyses, MRA can become a useful tool for assessing renal artery dimensions in patients referred for renal sympathetic denervation (RDN) and for providing accurate measurements of vascular response after RDN. The purpose of this study was to test the reproducibility of a novel MRA quantitative imaging tool and to validate these measurements against intravascular ultrasound (IVUS).

Materials and Methods: In nine patients referred for renal denervation, renal artery dimensions were measured. Bland–Altman analysis was used to assess the intraobserver and interobserver reproducibility.

Results: Mean lumen diameter was 5.8 ± 0.7 mm, with a very good intraobserver and interobserver variability of 0.7% (reproducibility: bias, 0 mm; standard deviation [SD], 0.1 mm) and 1.2% (bias, 0 mm; SD, 0.1 mm), respectively. Mean total lumen volume was 1035.3 ± 403.6 mm^3 with good intraobserver and interobserver variability of 2.9% (bias, −9.7 mm^3; SD, 34.0 mm^3) and 2.8% (bias, −11.4 mm^3; SD, 42.4 mm^3). The correlation (Pearson *R*) between mean lumen diameter measured with MRA and IVUS was 0.750 (*P* = .002).

Conclusions: Using a novel MRA quantitative imaging tool, renal artery dimensions can be measured with good reproducibility and accuracy. MRA-derived diameters and volumes correlated well with IVUS measurements.

Key Words: Renal artery; percutaneous renal sympathetic denervation; magnetic resonance angiography; intravascular ultrasound.

Percutaneous renal sympathetic denervation (RDN) is currently being studied as a potential treatment to lower sympathetic nerve activity in a broad spectrum of diseases (1,2). At present, more than 53 devices are available to disrupt renal afferent and efferent nerves traveling along the renal arterial wall. Besides the fact that initial promising, but noncontrolled studies on clinical efficacy in patients with therapy-resistant hypertension were recently challenged by a negative randomized controlled trial, data on long-term safety are mainly limited to the use of the first-generation radiofrequency devices (3–5). The currently available data on the incidence of renal artery stenosis, mostly derived from duplex ultrasound findings, are showing a low rate of adverse events, both at short and longer term follow-up (4,6). Published data from computed tomography angiography (CTA) or magnetic resonance angiography (MRA) report only binary outcomes (7), precluding firm conclusion on the true vascular response to RDN itself. As new renal denervation systems are being introduced, there is a need for dedicated volumetric noninvasive imaging tools to accurately assess renal artery integrity at the medium to long term (8). Furthermore, balloon-based RDN devices require accurate sizing to avoid complications due to oversizing (9). The aim of the present study was to evaluate a new software tool allowing automated vessel

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segmentation for quantitative renal artery lumen dimension assessment. Intraobserver and interobserver reproducibility were studied, and MRA-derived measurements were validated with intravascular ultrasound (IVUS).

MATERIALS AND METHODS

Patient Selection

Nine consecutive patients underwent both MRA and preprocedural IVUS at the time of the renal denervation procedure. Because of an early trifurcation in the vessel in one patient, automated segmentation with MRA was not successful in one artery. For the MRA analyses, 17 vessels were used. For the correlation analyses between MRA and IVUS, MRA vessel length was determined and manually adjusted on the basis of the length of the IVUS pullback with either the ostium or bifurcation as landmark. Because of a lack of IVUS measurement in 1 vessel and a lack of visualization of either bifurcation or ostium, a total of 16 arteries in which both MRA and IVUS data were available were used for validation of MRA against IVUS measurements. The study was approved by the hospital ethics committee and conforms to the declaration of Helsinki. All patients provided written informed consent before inclusion.

Magnetic Resonance Angiography Acquisition

MRA was performed on a 1.5T MRI scanner (Discovery MR450; GE Medical systems, Milwaukee, WI). Patients were positioned in supine position, and an eight-channel cardiac coil was placed on the thorax and upper abdomen. A dedicated RDN-MRI protocol was used. As part of this MRI protocol, a three-dimensional (3D) Vasc Fast time of flight (TOF) spoiled gradient-echo sequence was used to acquire images of the renal vasculature, after a test bolus procedure. Images were acquired during a breath-hold. The following parameters were used: field of view, 46 cm × 41.4 cm; matrix, 320 × 192, upsampled to 512 × 512; number of excitations, 0.75; pixel size, 0.89 × 0.89 mm; flip angle, 17°; slice thickness, 1.6 mm; location per slab, 28 upsampled to 56 with ZIP2; repetition time, 3.2 milliseconds; echo time, 1.2 milliseconds; bandwidth, 83.33 Hz. Approximately, 20 seconds was the duration of the breath-hold, depending on the locations per slab. A power injector (Medrad Spectris, Warrendale, PA) was used to inject gadobutrol (Gadovist 1.0 mmol/mL; Bayer, Mijdrecht, The Netherlands). Gadovist was injected, around 18 seconds before acquisition, with a dose of 0.1 mmol/kL ml into an antecubital vein followed by 15 mL of saline at a rate of 2.5 mL/s to visualize the renal arteries.

MRA Analysis

Renal arteries were analyzed with CAAS MRA version 1.0 (Pie Medical Imaging B.V, Maastricht, The Netherlands). The segmentation was initialized by placing four delimiter points on the volumetric rendered contrast-enhanced MRA view; root delimiter point at the thoracic aorta, abdominal aorta, and finally two points distal of the bifurcation of the renal artery (Supplementary Figure 1). Ray tracing was used to extract the 3D position of the user-defined delimiter points within the rendered volume. The acquired position was centralized within the lumen by image processing techniques. The 3D segmentation used a deformable model algorithm (10) that iteratively optimized the location of the surface toward the luminal border based on image gradients while simultaneously maintaining local smoothness of the 3D segmented surface. After segmentation, the center lines of the 3D segmentation were extracted as the minimum path of maximal inscribed spheres from the root delimiter point to the distal delimiter points (11). Within this process, the diameter of the spheres resembled the minimum diameter along the center line of the 3D segmentation (Supplementary Figure 2). The ostium and bifurcation of the renal arteries were automatically detected, by generation of a polygon of confluence (POC) (12). The center line splits in the POC from the proximal main vessel splits in the renal artery and the bifurcation of the renal artery. Outside the POC, the cross-sectional area was defined perpendicular to the lumen wall along each position of the center line. Based on the cross-sectional area, the lumen diameter was defined as the equivalent diameter on the basis of the assumption of circularity. For analysis, the arteria renal was selected, which is the single vessel segment between the ostial POC and the bifurcation POC. In case of failure of this method, only the bifurcation of the renal artery was selected manually. The automatically segmented arteries were inspected, and borders were manually corrected if necessary in the stretched multiplanar rendering and perpendicular view. Vessel length of the renal arteries was defined as the distance between the automatically defined ostium and bifurcation of the renal artery (Fig 1). Minimal lumen diameter, mean lumen diameter, and total lumen volume were based on semiautomatic segmentation. To compare and validate MRA with IVUS, images were matched and MRA dimensions were measured again with use of IVUS references. IVUS-derived borders were used as a reference. To be able to validate the MRA volumetric measurements with IVUS, the segment of interest was matched by using either the ostium or bifurcation of the renal artery as a landmark. MRA borders were adjusted according to the vessel length measured with IVUS. In this way, we were able to validate the volume measurements of the renal artery segment between MRA and IVUS.

IVUS Acquisition

Renal arteries were examined with an IVUS system with automatic pullback at 0.5 mm/s (Atlantis SR Pro Imaging Catheter; Boston Scientific, Natick, MA) before renal denervation in all vessels. Spatial resolution was 100 μm. A total dose of 200 μg of nitrates was locally administered before invasive imaging to prevent catheter-induced spasm.