Validation of 3D-CEMRA with 2D ARC Acceleration in a Porcine Study

C. J. François¹, M. L. Schiebler¹, S. B. Reeder¹, O. Wieben², R. F. Busse³, J. H. Brittain¹, and T. A. Bley⁴

¹Radiology, University of Wisconsin, Madison, WI, United States, ²Medical Physics, University of Wisconsin, Madison, WI, United States, ³MR Applied Science Laboratory, GE Healthcare, Madison, WI, United States

INTRODUCTION: Contrast enhanced MR angiography (CEMRA) has become widely accepted for the noninvasive evaluation of the intra-abdominal vasculature. Typically, data acquisition is completed within a single breath-hold limiting the total scan time to 15-30s. With traditional CEMRA techniques the volume that can be obtained within that duration is limited. As a result, examinations are typically focused on only a subset of the intra-abdominal vessels (e.g. a coronal slab for renal CEMRA and a sagittal slab for mesenteric CEMRA). With parallel imaging methods, greatly accelerated acquisitions now offer the opportunity to increase the volume of coverage (Fig. 1), while maintaining image quality. The purpose of this study was to validate a previously described CEMRA with 2D parallel imaging acceleration (auto-calibrating reconstruction for Cartesian sampling, “ARC”) for quantifying the severity of renal artery stenosis (RAS) in a porcine model using digital subtraction angiography (DSA) as a gold standard.

MATERIALS AND METHODS: Following local Animal Care and Use Committee approval, RAS were created surgically in 12 swine (weight = 36.4±1.8kg). All examinations were performed under general anesthesia. 3D rotational DSA was used as the gold standard for quantification of the degree of stenosis in 8 animals. Projectional DSA was used for comparison in the other 4 animals. Following DSA, each animal was imaged on a clinical 1.5T system (Signa HDx TwinSpeed, GE Healthcare, Waukesha, WI). CEMRA was performed during the hand injection of 0.1mmol/kg (6.8-7.9ml) of gadobenate dimeglumine (MultiHance, Bracco Diagnostics, Inc., Princeton, NJ). Parameters used for the CEMRA include: TR/TE = 3.4/1.1ms, flip angle = 25°, bandwidth = ±83.3kHz, FOV = 34x27cm², matrix = 256x224, 184 slices, slice thickness = 1.5mm, for a true acquired spatial resolution of 1.3x1.2x1.5mm³ which were zero-filled to 0.7x0.7x0.8mm³. A clinical cardiac phased array coil with 8 elements and a net acceleration factor of 3.67 was used for data acquisition. Total scan time was 16s. CEMRA images were reviewed independently in randomized order by 3 expert cardiovascular radiologists on a PACS workstation. Reviewers graded the severity of the renal artery stenosis on a six-point scale (0=normal; 1=1-24% stenosis; 2=25-49% stenosis; 3=50-74% stenosis; 4=75-99% stenosis; 5=occluded). The severity of renal artery stenosis by CEMRA was compared to quantitative DSA measurements. Reviewers also assessed (A) the number of visible segmental renal artery branch vessels; (B) the overall image quality for the renal arteries, (C) the presence of noise, and (D) the presence of artifacts.

RESULTS: CEMRA was successfully performed in all studies (Figs. 1, 2). The severity of stenosis on the CEMRA images correlated well with that determined by DSA (Pearson correlation coefficient = 0.69, 0.72, and 0.84 for readers 1, 2, and 3, respectively). The mean difference in stenosis severity between CEMRA and DSA was -0.25 (±0.75) for the three readers. 3rd and 2nd degree renal branch vessel were depicted in 51.4% and 30.6% by CEMRA, respectively. Image quality was rated excellent (4/4) in 86.1%. Artifacts (8.3% of cases) and substantial noise (19.4% of cases) were present on the CEMRA studies, but did not interfere with image interpretation in any of the cases.

CONCLUSIONS: Rapid CEMRA with large volumetric coverage using 2D ARC parallel imaging is a highly accurate means of grading renal artery stenosis, compared to DSA. The use of 2D-ARC allows for an approximately 3.7x increase in scan coverage, facilitating acquisitions that cover the entire abdomen with high spatial resolution for all abdominal 3D-CEMRA indications.


Fig. 1: With 2D ARC parallel imaging, a volumetric CEMRA dataset can be acquired within 16 seconds. Coronal (A), sagittal (B), and axial (C) MPR images.

TR/TE = 3.4/1.1ms, flip angle = 25°, bandwidth = ±83.3kHz, FOV = 34x27cm², matrix = 256x224, 184 slices, slice thickness = 1.5mm, for a true acquired spatial resolution of 1.3x1.2x1.5mm³ which were zero-filled to 0.7x0.7x0.8mm³. A clinical cardiac phased array coil with 8 elements and a net acceleration factor of 3.67 was used for data acquisition. Total scan time was 16s. CEMRA images were reviewed independently in randomized order by 3 expert cardiovascular radiologists on a PACS workstation. Reviewers graded the severity of the renal artery stenosis on a six-point scale (0=normal; 1=1-24% stenosis; 2=25-49% stenosis; 3=50-74% stenosis; 4=75-99% stenosis; 5=occluded). The severity of renal artery stenosis by CEMRA was compared to quantitative DSA measurements. Reviewers also assessed (A) the number of visible segmental renal artery branch vessels; (B) the overall image quality for the renal arteries, (C) the presence of noise, and (D) the presence of artifacts.

RESULTS: CEMRA was successfully performed in all studies (Figs. 1, 2). The severity of stenosis on the CEMRA images correlated well with that determined by DSA (Pearson correlation coefficient = 0.69, 0.72, and 0.84 for readers 1, 2, and 3, respectively). The mean difference in stenosis severity between CEMRA and DSA was -0.25 (±0.75) for the three readers. 3rd and 2nd degree renal branch vessel were depicted in 51.4% and 30.6% by CEMRA, respectively. Image quality was rated excellent (4/4) in 86.1%. Artifacts (8.3% of cases) and substantial noise (19.4% of cases) were present on the CEMRA studies, but did not interfere with image interpretation in any of the cases.

CONCLUSIONS: Rapid CEMRA with large volumetric coverage using 2D ARC parallel imaging is a highly accurate means of grading renal artery stenosis, compared to DSA. The use of 2D-ARC allows for an approximately 3.7x increase in scan coverage, facilitating acquisitions that cover the entire abdomen with high spatial resolution for all abdominal 3D-CEMRA indications.