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Original Article

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The Utility of Unenhanced Renal Artery Magnetic Resonance Angiography Using Inhance Sequence in Depiction of Renal Vasculature and Related Abnormalities in Patients with Suspected Renovascular Hypertension

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ABSTRACT

Objective: The objective of this study is to investigate the utility of unenhanced magnetic resonance angiography using Inhance (3-dimensional inflow inversion recovery sequence) sequence in the visualization of renal vasculature and related abnormalities in patients with suspected renovascular hypertension.

Methods: A total of 73 patients (57.5% were females) with clinical suspicion of renovascular hypertension who underwent Inhance sequence were included. Data on unenhanced magnetic resonance angiography image quality scores and findings on renal vasculature (main renal artery, segmental branches, and variations) and the presence of renal abnormalities were recorded. Agreement between the 3 readers was evaluated based on the intra-class correlation coefficient values for inter-rater reliability.

Results: Mean age of the patients was 53.42 ± 9.44 years (range 25-78 years). Image quality was considered to be significantly better for main kidney artery (excellent: 61.6%-83.6%) than for segmental (excellent 5.5%-21.9%) and interlobar (excellent 0.0%-2.7%) arteries by all readers ($P < .001$). Extrarenal variations (28.8-30.1%) and early branching variations (16.4%) were reported by each reader, while the kidney abnormality was considered in 8.2%-9.6% of cases. Intra-class correlation coefficient values indicated a good (0.75 to 0.90) inter-rater reliability for main renal artery (mean 0.853; CI 0.770-0.905), segmental (0.807; 0.716-0.873), and interlober arteries (0.861; 0.793-0.909), while variations (0.996; 0.994-0.997) and kidney abnormality (0.936; 0.905-0.958) assessments revealed an excellent agreement (intra-class correlation coefficient > 0.90) between readers.

Conclusion: Unenhanced magnetic resonance angiography is a reliable radiologic method to describe kidney vasculature in patients with suspected renovascular hypertension. Accordingly, Inhance sequence seems to be a viable alternative method to enhanced magnetic resonance angiography by providing favorable image quality and the accurate assessment of kidney vasculature without using a contrast material along with good-to-excellent inter-rater reliability.

Keywords: Inhance, image quality, magnetic resonance angiography, renal artery, unenhanced

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INTRODUCTION

Early diagnosis of renal artery stenosis (RAS) is critical to prevent the development of renovascular hypertension (RVH) and thus the provision of reliable diagnostic kidney imaging in these patients is considered likely to affect treatment and outcomes.[1-3]

Although imaging modalities such as computed tomography angiography (CTA), magnetic resonance angiography (MRA), and digital subtraction angiography (DSA) are effective in assessing renal arteries, the need for contrast material in all and the use of ionizing radiation in CTA and DSA are important drawbacks.[4-8]

The use of gadolinium-based contrast agents has been associated with nephrogenic systemic fibrosis (NSF) in patients with kidney dysfunction as well as with a more technically challenging imaging procedure causing a narrow timing window for arterial-only imaging in kidney vasculature than other vascular regions due to comparatively low vascular resistance of the kidney.[2,3,9-13] Hence, while contrast-enhanced MRA (CE-MRA) offers an effective diagnostic quality in the absence of radiation exposure for diagnosis of RAS, recently innovative technologies that do not require contrast agents have become increasingly adopted in the kidney vasculature imaging.[2,3,9-13]

Accordingly, unenhanced MRA has become a popular imaging modality given that it is a high-resolution technique not necessitating the use of contrast media or ionizing radiation.[4,8-11] Indeed, given the encouraging findings reported for sensitivity (75%-100%) and specificity (82%-99%) of inflow-based unenhanced MRA techniques with regard to DSA or CE-MRA in a limited number of studies,[2,3,14-17] several MRI system vendors have added various free-breathing, inflow-based steady-state free precession MRA implementations to their product lines.[3] Among these, Inhance is a respiratory-triggered 3D steady-state free precession sequence in which high arterial signal intensity is achieved via inflow inversion recovery and combining the advantages of the inflow influences of time-of-flight (TOF) MRA with those of the bright luminal signal of fast imaging employing steady-state acquisition (FIESTA) sequences.[2,17,18]

Our study was designed to evaluate the diagnostic performance of unenhanced MRA using a 3-dimensional inflow inversion recovery technique in the depiction of kidney vasculature and related abnormalities in patients with suspected RVH.

METHODS

Study Population

A total of 78 patients who underwent non-contrast MRA using the Inhance sequence due to suspected RVH were included in this retrospective study. Five patients were excluded from the study because of nondiagnostic images obtained in the Inhance sequence due to motion artifacts. As a result, the study was conducted with 73 patients (mean ± standard deviation (SD) age = 53.4 ± 9.4 years, 57.5% were females) with adequate diagnostic image quality. The ethics committee of our university hospital approved this study (Date of Approval: December 16, 2019; Reference number/Protocol No: 2019/189). Informed consent was waived in our retrospectively designed study.

Study Parameters

Data on Inhance unenhanced MRA image quality scores and findings on assessment of renal arteries (main renal arteries, segmental and interlober branches, and variations) and presence of kidney abnormality as assessed by 3 readers were recorded. The agreement between confidence scale scores reported by the 3 readers was evaluated based on the intra-class correlation coefficient (ICC) values for inter-rater reliability. Also, kidney function tests (creatinine, glomerular filtration rate (GFR) values) and the presence of protein in the urine analysis of our patients were checked from laboratory records. If the creatinine value was > 1.2 mg/dL and the GFR value was below 60 mL/min, it was defined as pathological.

Unenhanced Magnetic Resonance Angiography Assessments

All magnetic resonance (MR) examinations were performed using a 3.0-T whole-body imaging MR system (General Electrics (GE) Healthcare Discovery MR750, Waukesha, Wis, USA) with a 16-channel phased array abdominal-pelvic coil. Unenhanced MRA examination was conducted using respiratory-triggered 3D fat-saturated fast imaging by employing an inflow inversion recovery steady-state free precession technique (Inhance). The scan parameters were applied as follows: Echo Time (TE) 1.0 ms, Repetition time (TR) 2.2 ms, flip angle 50°, Inversion Time (TI) =1400 ms, receiver bandwidth 125 Hz/pixel; field of view 380×270 mm for covering both kidneys, slice thickness 1.6 mm, locations per slab 192, frequency matrix 192, phase matrix 320, number of excitation 1, phase Field of view (FOV) 1.0, and an acquisition time of 12-15 seconds. Three radiologists independently evaluated the main renal artery, segmental, and interlober branches within the kidney parenchyma with the "Inhance" sequences, retrospectively. Magnetic resonance angiography image quality was rated by all 3 readers on a 4-point confidence scale (1 = very weak to 4 = excellent) based on vessel signal intensity, acuity, and precise definition of vessel boundaries. Abnormalities that may belong to the main renal arteries (stenosis or occlusion) were evaluated. In our study, a decrease in renal artery diameter of 50% or more and/or accompanying poststenotic dilatation were considered as hemodynamically significant stenosis. Consensus was reached to resolve discrepancies that occurred after independent reviews. Consensus data were used as a reference for the unenhanced MRA reading.

Statistical Analysis

Statistical analysis was made using IBM Statistical Package for Social Sciences Statistics for Windows, version 22.0 (IBM Corp., Armonk, NY, USA). The Kolmogorov–Smirnov test was used to show deviation from the normal distribution. Agreement between the readers was evaluated with ICC values and the

MAIN POINTS

- Inhance sequence is a reliable diagnostic method to depict kidney vasculature in patients with suspected renovascular hypertension.
- Inhance sequence can be used as a problem-solving method in cases where the use of contrast material is contraindicated.
- Kidney vascularization can be evaluated in detail with high image quality.

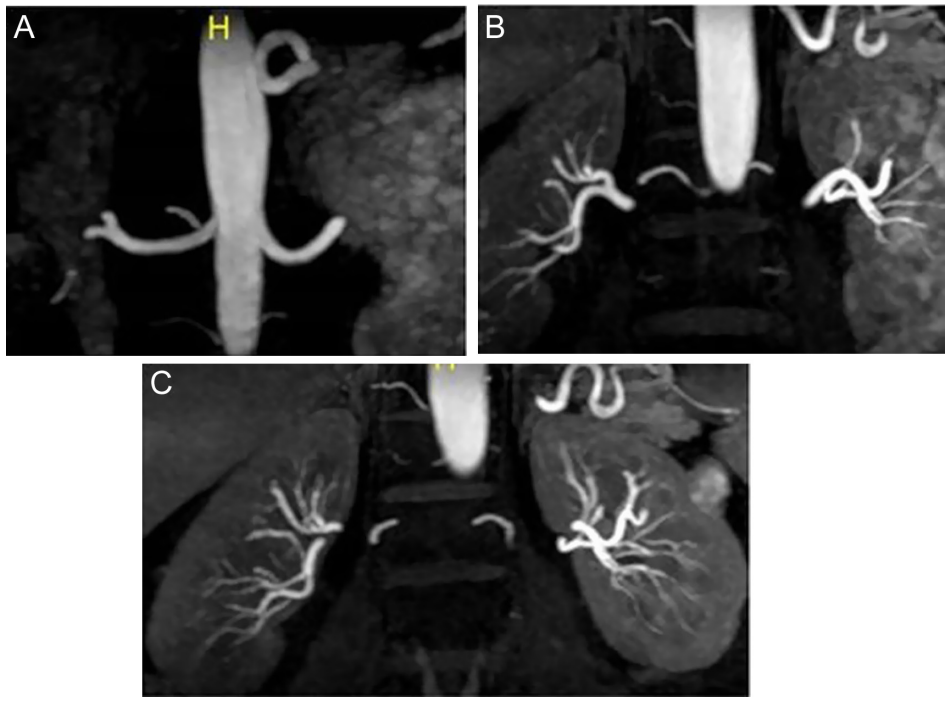

Figure 1. Inhance sequence in a 44-year-old female patient. Coronal reformatted Maximum Intensity Projection (MIP) images for (A) main renal arteries (VP 4), (B) segmental branches (VP 4), and (C) interlober branches (VP 3).

inter-rater reliability was categorized as poor (values <0.5), moderate (0.5-0.75), good (0.75-0.9), and excellent (values > 0.90).[19] Data were expressed as mean ± SD, minimum–maximum, 95% CI, and percent (%) where appropriate. $P < .05$ was considered significant.

RESULTS

Patient Demographics

Mean age of participants was 53.42 ± 9.44 and median age was 52.0 (25-78). 31 (42.5%) participants were male, and 42 (57.5%) of them were female.

The median creatinine value of our patients was found to be 0.85 mg/dL (range; 0.47-3.34 mg/dL). While blood creatinine values were normal in 61 patients (83.6%), creatinine values in 12 patients were found to be above 1.2 mg/dL. The median GFR value was determined as 90 mL/min (range 17-119 mL/min) and it was below 30 mL/min in 2 of our patients (2.7%) and in the range of 30-59 mL/min in 9 of them (12.3%). In addition, the presence of proteinuria was found in 6 (8.2%) of our patients (1+ in 2 patients, 2+ in 2 patients, and 3+ in other 2 patients).

Kidney Vasculature-Related Findings

The presence of more than 1 renal artery was detected in 24 of our patients. Early division was detected in 15 patients. Both extrarenal artery and early division variations were detected in 3 of the patients. All of the variations were correctly detected by all readers. In 5 patients, all readers suspected the presence of stenosis of the main renal arteries. In one of the patients who was thought to have RAS, the renal artery diameter was severely reduced (chronic stenosis); in other patients, at least 50% reduction in renal artery diameter and the presence of concomitant poststenotic dilatation were determined. Two patients were evaluated as having RAS by 2 readers and interpreted as normal by 1 reader. One patient was evaluated as normal by 2 readers and was diagnosed with RAS by the other reader. Left renal artery was suspected in 4 of the patients with RAS, and right renal artery was suspected in 3 of them (Figures 1-6).

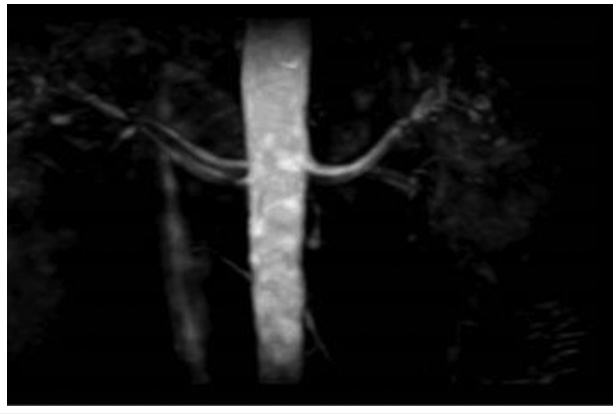

Figure 2. Inhance sequence in a 53-year-old male patient. Coronal reformatted MIP images for (A) main renal arteries (VP 2-3-3), (B) segmental branches (VP 1-1-1), and (C) interlober branches (VP 1-1-1).

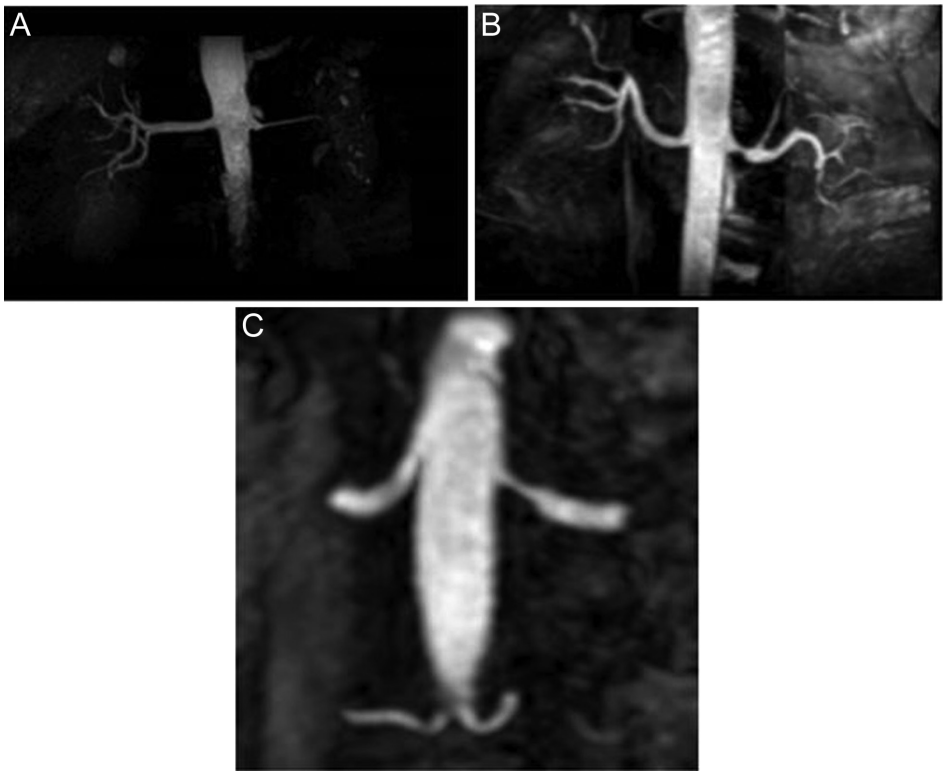

Figure 3. Coronal reformatted MIP images of Inhance sequence for (A) a 58-year-old male patient, left renal artery (long segment) chronic stenosis (arrow), ischemic nephropathy, and atrophic left kidney, (B) a 60-year-old female patient, left renal artery proximal stenosis (arrow), post-stenotic dilatation (curved arrow), (C) a 45-year-old female patient, left renal artery proximal stenosis (arrow), and post-stenotic dilatation (curved arrow).

Magnetic Resonance Angiography Image Quality Scores on Assessment of Kidney Vasculature by 3 Readers

Image quality was considered to be significantly better for main renal artery (excellent: 61.6%-83.6%) than for segmental branches (excellent 5.5%-21.9%) and interlober branches (excellent 0.0%-2.7%) by all readers ($P < .001$) (Table 1).

Extra-renal variations (28.8%-30.1%) and early branching variations (16.4%) were reported by each reader, while the RAS was considered to be evident in 8.2%-9.6% of cases (Table 1).

Inter-rater Reliability and Agreement between Readers

Intraclass correlation coefficient values indicated a good (0.75-0.90) inter-rater reliability for main renal artery (mean; CI 0.853; 0.770-0.905), segmental branches (0.807; 0.716-0.873), and interlober branches (0.861; 0.793-0.909), while variations (0.996; 0.994-0.997) and RAS (0.936; 0.905-0.958) assessments revealed an excellent agreement (ICC > 0.90) between 3 readers (Table 2).

DISCUSSION

Our findings revealed the favorable image quality (particularly for the main renal artery) and diagnostic performance of

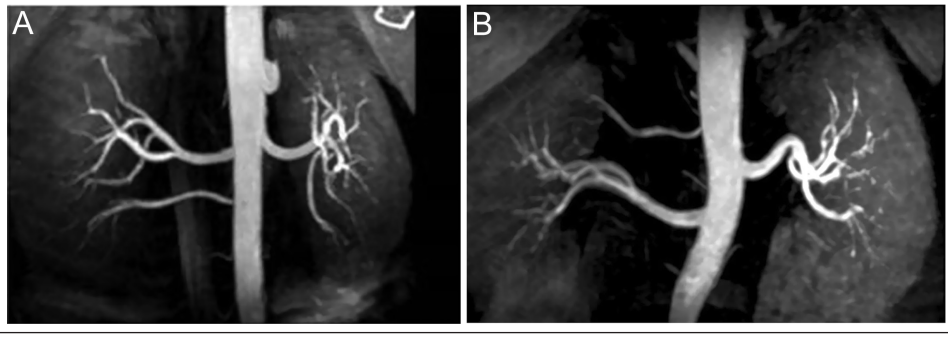

Figure 4. Coronal reformatted MIP images of Inhance sequence for (A) a 39-year-old female patient, right aberrant renal artery (supplying the inferior pole) variation. (B) a 46-year-old female patient, right aberrant renal artery (supplying the superior pole) variation.

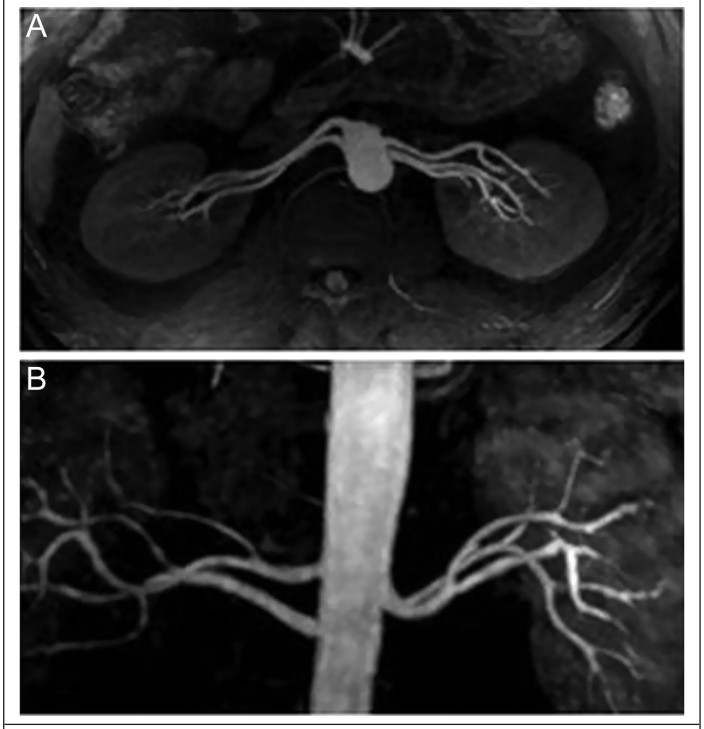

Figure 5. Axial and coronal reformatted MIP images of Inhance sequence for a 49-year-old male patient. Accessory renal artery (bilateral double renal artery) variation.

Inhance sequence in the detection of renovascular pathology including extra-renal artery and early division variations and RAS in patients suspected to have RVH. There was good-to-excellent inter-rater reliability for findings on main renal artery, segmental and interlober branches, as well as variations and RAS.

Likewise, in a past study by Glockner et al[17] among 64 patients with suspected RVH, unenhanced MRA was reported to have good agreement with enhanced MRA for the detection of significant RAS (in 34 arteries on both methods). The authors also noted the achievement of high sensitivity (94%/82%) and specificity (82%/87%) for detection of significant stenosis per renal artery by the 2 unenhanced MRA readers.[17]

Similarly, in a study by Lal et al[20] in 201 patients (400 renal arteries) suspected to have RAS, comparison of unenhanced MRA with conventional CE-MRA revealed that unenhanced MRA correctly diagnosed 72 patients (95 arteries) along with the excellent agreement between unenhanced and enhanced MRA for detection of RAS.[20]

Also, in a study by Aydın et al[2] in 66 patients (126 main renal and 12 accessory renal arteries) with hypertension, the authors reported that overall image quality with unenhanced MRA was good to excellent in 89.5% of cases and the inter-reader agreement was excellent regarding all segments along with no significant differences between unenhanced and enhanced MRA in terms of identifying stenosis, image, or diagnostic quality.

Our findings indicate that kidney Inhance sequence is a favorable and reliable alternative MRA technique in patients with suspected RVH, which allows imaging of the kidney vasculature without the need for contrast material and easy detection of the normality, diseases, and variations in the main renal arteries. This seems notable given the risk of NSF with the use of gadolinium-based contrast agents and thus the inability of making contrast-based examinations in patients with kidney impairment.[2,11,17]

Hence, our findings support that Inhance technique can be used safely in patients with suspected RVH who are not eligible for enhanced MRA as a viable alternative for the detection of RAS with additional advantage of no contrast agent toxicity.[2,17,20]

Notably, in a systematic review of 11 studies in 527 patients regarding the application of inflow-dependent inversion recovery in evaluation of the renal arteries for the detection of ≥50% RAS, the authors concluded a median sensitivity of 88% and a median specificity of ≈95% with respect to CE-MRA, DSA, or CTA as the reference standard examination.[21]

The better image quality reported for main renal artery in the current study seems in line with acceptable overall image quality (fair or better image quality in 88% of right and 96% of left renal artery images) reported via unenhanced MRA at 3 T with

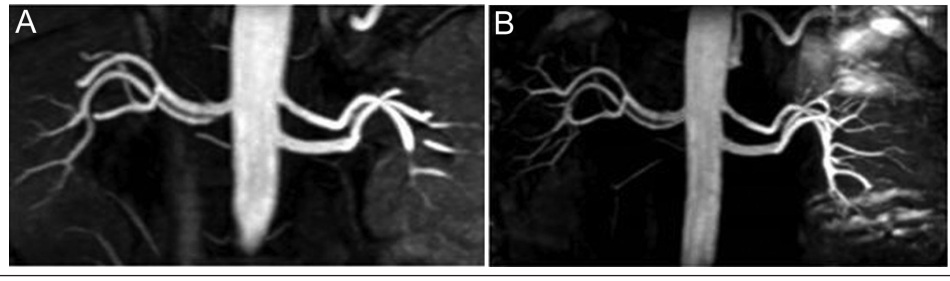

Figure 6. Coronal reformatted MIP images of Inhance sequence for a 45-year-old male patient. (A) Right early branching and (B) left accessory renal artery variations.

Table 1. Image Quality Scores of Renal Artery and Its Branches, Renal Artery Pathology, and Variations by 3 Radiologists in the Inhance Sequence

	Reader 1 n (%)	Reader 2 n (%)	Reader 3 n (%)
Main renal artery findings			
1—Not assessable	1 (1.4)	1 (1.4)	1 (1.4)
2—Poor	4 (5.5)	1 (1.4)	1 (1.4)
3—Good	23 (31.5)	10 (13.7)	22 (30.1)
4—Excellent	45 (61.6)	61 (83.6)	49 (67.1)
Segmental branches			
1—Not assessable	5 (6.8)	7 (9.6)	5 (6.8)
2—Poor	20 (27.4)	19 (26.0)	17 (23.3)
3—Good	44 (60.3)	31 (42.5)	35 (47.9)
4—Excellent	4 (5.5)	16 (21.9)	16 (21.9)
Interlober artery branches			
1—Not assessable	17 (23.3)	25 (34.2)	32 (43.8)
2—Poor	34 (46.6)	28 (38.4)	21 (28.8)
3—Good	22 (30.1)	18 (24.7)	20 (27.4)
4—Excellent	0 (0)	2 (2.7)	0 (0)
Variations			
0—None	37 (50.7)	36 (49.3)	36 (49.3)
1-—Extra renal	21 (28.8)	22 (30.1)	22 (30.1)
2—Early branching	12 (16.4)	12 (16.4)	12 (16.4)
3—Both variations	3 (4.1)	3 (4.1)	3 (4.1)
Kidney pathology			
0—Absent	66 (90.4)	67 (91.8)	67 (91.8)
1—Present	7 (9.6)	6 (8.2)	6 (8.2)

the RAVEL technique by Park et al.[15] In addition, similar to our findings, Park et al[15] also reported the diagnostic performance of unenhanced MRA to be excellent in determining the number of renal arteries along with moderate-to-high sensitivity and specificity of the method in detecting the presence or absence of early branching vessels.

Aydın et al[2] reported the association of Inhance technique with high diagnostic quality in the assessment of the arterial structures despite a contrast material is not used, while the authors also noted that 3D-enhanced MRA was superior to unenhanced MRA in assessing accessory renal arteries (detection ratio by unenhanced MRA: 7/12, 58%).[2]

Indeed, while unenhanced MRA revealed lower image quality in the first-order branch and parenchymal branches than in main renal artery in the current study, it should be noted that unenhanced MRA was also reported to perform better than 3D CEMRA in the imaging of intrarenal segmental arterial branches in some studies.[11,17]

Visualizing the entire of renal artery is important in diagnostic imaging, given that the main renal artery, a major branch of the aorta, reveals information on various vascular lesions besides the RVH, while visualization of small intra-parenchymal branches is important to detect polyarteritis nodosa.[11,22-24] Accordingly, by combining the advantages of the inflow influences of TOF MRA and bright luminal signal of FIESTA sequences, Inhance seems to be an advantageous angiographic sequence technique in diagnostic kidney imaging, providing consistent, reproducible images of the renal arteries while completely repressing signals from static background tissue and venous blood.[2,17,18]

Our study has some limitations. First, relatively small sample size precluded the possibility of projecting our results to the

Table 2. Inter-rater Reliability of Several KidneyImaging Scores Between Readers

Parameters (n = 73)		Confidence Scale Scores			Inter-rater Reliability[a] ICC (95% CI LB-UB)	*P*
		Reader 1	Reader 2	Reader 3		
Main renal artery	Mean ± SD	3.53 ± 0.66	3.79 ± 0.52	3.63 ± 0.58	0.853 (0.770-0.905)	**<.001**
	Median (min-max)	4 (1-4)	4 (1-4)	4 (1-4)		
Segmental branches	Mean ± SD	2.64 ± 0.69	2.77 ± 0.90	2.85 ± 0.84	0.807 (0.716-0.873)	**<.001**
	Median (min-max)	3 (1-4)	3 (1-4)	3 (1-4)		
Interlober artery branches	Mean ± SD	2.07 ± 0.73	1.96 ± 0.84	1.84 ± 0.83	0.861 (0.793-0.909)	**<.001**
	Median (min-max)	2 (1-3)	2 (1-4)	2 (1-3)		
Variations	Mean ± SD	0.74 ± 0.88	0.75 ± 0.87	0.75 ± 0.87	0.996 (0.994-0.997)	**<.001**
	Median (min-max)	0 (0-3)	1 (0-3)	1 (0-3)		
Kidney pathology	Mean ± SD	0.10 ± 0.29	0.08 ± 0.27	0.08 ± 0.27	0.936 (0.905-0.958)	**<.001**
	Median (min-max)	0 (0-1)	0 (0-1)	0 (0-1)		

ICC, intra-class correlation coefficient; LB, lower bound; SD, standard deviation; UB, upper bound.
[a]Based on average measures.

entire population. Second, lack of data on comparison with other imaging modalities is another limitation which otherwise would extend the knowledge achieved in the current study.

In conclusion, unenhanced MRA can be used as a reliable diagnostic method in demonstrating kidney vasculature and abnormalities in patients with suspected RVH. Accordingly, Inhance sequence seems to be a viable alternative to enhanced MRA sequences which provides favorable image quality and the accurate assessment of renal arteries without using a contrast material along with good-to-excellent inter-rater reliability.

Ethics Committee Approval: Ethical committee approval was received from the Ethics Committee of Recep Tayyip Erdoğan University, Faculty of Medicine (Date: December 16, 2019, Decision No: 2019/189).

Informed Consent: Informed consent was waived in our retrospectively designed study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – F.T.; Design – F.T.; Supervision – Y.M.; Resources – N.O.M., M.E.K., E.B.Ç.; Materials – N.O.M., M.E.K., E.B.Ç.; Data Collection and/or Processing – N.O.M., M.E.K., E.B.Ç.; Analysis and/or Interpretation – M.G.G.; Literature Search – F.T., M.G.G.; Writing Manuscript – F.T.

Declaration of Interests: The authors have no conflicts of interest to declare.

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