Renovascular Hypertension
EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
1. Lewin A, Blaufox MD, Castle H, Entwisle G, Langford H. Apparent prevalence of curable hypertension in the Hypertension Detection and Follow-up Program. *Arch Intern Med* 1985; 145(3):424-427.	Review/Other-Dx	5,485 patients	To determine the apparent prevalence of renal parenchymal and reversible, secondary hypertension.	The combined occurrence of an elevated serum creatinine level plus one or more urinary abnormalities was noted in 0.95%. Initial review of case reports revealed six participants with hypertension secondary to use of birth control pills and three participants with hypertension that was proved to be secondary to renovascular disease. Specific laboratory or historical criteria were used as indications for more intensive investigation in an additional 65 participants. Among these individuals, one participant with renovascular disease and three with possible primary hyperaldosteronism were identified. A rapid-sequence IVU or radionuclide scan was performed on another subgroup of 62 participants whose hypertension was "poorly" controlled (diastolic blood pressure, ≥95 mm Hg). 59 studies were negative, one was positive, and two were equivocal. These results suggest that the frequency of clinically relevant cases of reversible, secondary hypertension, at least among individuals with mild to moderate elevation of blood pressure, is low.	4

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2. Baumgartner I, Lerman LO. Renovascular hypertension: screening and modern management. *Eur Heart J* 2011; 32(13):1590-1598.	Review/Other-Dx	N/A	To review the screening and modern management of renovascular hypertension.	The indications for revascularization of the renal arteries are the subject of continuing controversy. Based on the results of the STAR and ASTRAL trials, the practice of indiscriminately revascularizing atherosclerotic renal-artery stenosis is no longer tenable. The challenge is to identify those selected patients who would respond, and to intervene early enough to reverse kidney damage. Intervention is not recommended if renal function has remained stable over the past 6–12 months and if hypertension can be controlled with an acceptable medical regimen. Anatomically relevant RAS.70% should be verified by functional measurements as systolic pressure gradient ≥21 mmHg or Pd/Pa pressure ratio of 0.9. The best evidence supporting intervention seems to be for bilateral stenosis with 'flash' pulmonary oedema unrelated to acute coronary syndrome, but the evidence is from retrospective studies. Indeed, in patients with atherosclerotic renal-artery stenosis, control of hypertension may be facilitated by revascularization, but cure of hypertension is unusual, and preservation of renal function may be a more realistic goal. The choice of revascularization technique depends on the presence of associated aortoiliac diseases. For complicated cases, surgical revascularization and renal bypass are both acceptable. Novel approaches to attenuate kidney tissue injury and increase its viability regardless of revascularization may prove vital and are under investigation.	4

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
3. Textor SC, Lerman L. Renovascular hypertension and ischemic nephropathy. *Am J Hypertens* 2010; 23(11):1159-1169.	Review/Other-Dx	N/A	Review of epidemiological studies to address the prevalence of renovascular hypertension and ischemic nephropathy.	Advances in antihypertensive drug therapy and intensive risk factor management including smoking cessation and statin therapy can provide excellent blood pressure control for many individuals. Despite extensive observational experience with renal revascularization in patients with renovascular hypertension, recent prospective randomized trials fail to establish compelling benefits either with endovascular stents or with surgery when added to effective medical therapy. These trials are limited and exclude many patients most likely to benefit from revascularization. Meaningful recovery of kidney function after revascularization is limited once fibrosis is established. Recent experimental studies indicate that mechanisms allowing repair and regeneration of parenchymal kidney tissue may lead to improved outcomes in the future. Until additional staging tools become available, clinicians will be forced to individualize therapy carefully to optimize the potential benefits regarding both blood pressure and renal function for such patients.	4

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
4. Colyer WR, Eltahawy E, Cooper CJ. Renal artery stenosis: optimizing diagnosis and treatment. *Prog Cardiovasc Dis* 2011; 54(1):29-35.	Review/Other-Dx	N/A	To review the diagnostic methods of RAS.	Invasive angiography has been considered the "gold standard" for the diagnosis and evaluation of RAS. Currently, the most commonly used methodology is intra-arterial DSA. Carbon dioxide can be used for intra-arterial angiography, but image quality is reduced, and this may create greater uncertainty about lesion severity unless combined with judicious use of iodinated contrast. Duplex US is an excellent screening test for RAS because it is nontoxic, involves no exposure to ionizing radiation, and, in capable hands, is reliable. The major limitation to this method is its dependence on technician skill for acquisition of adequate images. In duplex US, peak systolic and end-diastolic velocities of the renal artery as well as the ratio of velocities in the renal artery to the aorta are obtained. Sensitivities of 92.5% to 98% and specificities of 96% to 98% have been reported. A number of factors may limit image quality and, thus, the diagnostic accuracy of the test including obesity, bowel gas, and recent food intake. MRA and CTA are both noninvasive imaging methods that can visualize RAS. A meta-analysis by Vasbinder suggests that duplex US is inferior to MRA and CTA; however, the safety of duplex US makes it ideal as an index strategy.	4
5. Maxwell MH, Gonick HC, Wiita R, Kaufman JJ. Use of the Rapid-Sequence Intravenous Pyelogram in the Diagnosis of Renovascular Hypertension. *N Engl J Med* 1964; 270:213-220.	Review/Other-Dx	121 patients	To evaluate the use of a rapid-sequence technique and its ability to improve the diagnostic potentiality of the IV pyelogram in the screening of patients with diastolic hypertension.	In 121 patients with and without diastolic hypertension but free of renal-artery disease it was established that the "appearance time" of injected contrast medium is equal in both kidneys and generally occurs two or three minutes after injection. Abnormalities in the rapid-sequence pyelogram were noted in 39/42 patients with renovascular hypertension. The rapid-sequence pyelogram compares favorably with the radioisotope renogram and individual kidney-function tests as a screening procedure for renovascular hypertension.	4

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
6. Bookstein JJ, Abrams HL, Buenger RE, et al. Radiologic aspects of renovascular hypertension. 1. Aims and methods of the radiology study group. *JAMA* 1972; 220(9):1218-1224.	Review/Other-Dx	N/A	Review report by a Radiologic Study Group. Define and evaluate major (kidney length, calyceal appearance time, and concentration of contrast medium) and minor urographic features. Contrast agent, route of administration and complications were included in arteriographic evaluation.	Significant differences were seen between local, central, and re-review interpretation of renal length, appearance time, and concentration of contrast medium and in estimating the degree of arterial stenosis from the arteriogram.	4
7. Bookstein JJ, Abrams HL, Buenger RE, et al. Radiologic aspects of renovascular hypertension. 2. The role of urography in unilateral renovascular disease. *JAMA* 1972; 220(9):1225-1230.	Review/Other-Dx	771 patients urograms evaluated for all 3 features	Correlate urograms with arteriographic findings and treatment results to determine the role of urography in unilateral renovascular disease and its usefulness in predicting surgical results.	Urogram is a satisfactory method for diagnosing severe renovascular disease. Differentiating patients for surgery or not was not possible with urography.	4
8. Thornbury JR, Stanley JC, Fryback DG. Hypertensive urogram: a nondiscriminatory test for renovascular hypertension. *AJR* 1982; 138(1):43-49.	Observational-Dx	1st group – 197 patients operated for RAS: 2nd group – 131 patients had hypertensive urography	Retrospective study to assess usefulness of hypertensive urogram in hypertension patients and compare results to a prospective cooperative study that says hypertensive urogram is a satisfactory primary screening test for evaluation of hypertensive patients.	1st group: True-positive rate for hypertensive urography for prediction of surgical cure was 60.2%. 2nd group: Incidence of positive exams in screening was 0.8%. Reexamination of the cooperative study data reveals that false-negative rate for screening is at least 21.8%, rather than 1.7%. Study does not recommend hypertensive urography.	3
9. Havey RJ, Krumlovsky F, delGreco F, Martin HG. Screening for renovascular hypertension. Is renal digital-subtraction angiography the preferred noninvasive test? *JAMA* 1985; 254(3):388-393.	Review/Other-Dx	N/A	To review the literature for screening of renovascular hypertension.	The main advantage of the DSA is that it produces arterial images similar to those obtained with conventional arteriograms but with less risk, discomfort, and expense. There are several disadvantages of DSA when compared with conventional arteriography, however.	4
10. Cameron HA, Close CF, Yeo WW, Jackson PR, Ramsay LE. Investigation of selected patients with hypertension by the rapid-sequence intravenous urogram. *Lancet* 1992; 339(8794):658-661.	Observational-Dx	241 patients	Retrospective review of case records to determine the diagnostic yield of the rapid-sequence IVU in hypertensive patients selected for features suggesting renal or renovascular disease.	The IVU was abnormal in 27% of patients. The IVU led to intervention aiming at correcting hypertension in 5% of patients. A normal rapid-sequence IVU excludes renovascular disease with 93% probability but failed to diagnose about 20% of cases.	3

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
11. van Jaarsveld BC, Pieterman H, van Dijk LC, et al. Inter-observer variability in the angiographic assessment of renal artery stenosis. DRASTIC study group. Dutch Renal Artery Stenosis Intervention Cooperative. *J Hypertens* 1999; 17(12 Pt 1):1731-1736.	Experimental - Dx	312 renal angiograms obtained in 289 consecutive patients	To assess inter-observer agreement in the interpretation of renal angiograms.	Comparison of the assessment of renal angiograms by three experienced radiologists. Agreement about the number of renal arteries was reasonable (kappa = 0.50-0.72), as was agreement about the presence of stenosis (kappa = 0.68-0.86). Agreement about stenosis location and aspect was poor (kappa = 0.26-0.47 and kappa = 0.15-0.26, respectively). There was general agreement about the severity of stenosis (weighted kappa = 0.65-0.70), but it was not possible to distinguish between 50% and 60% stenosis or between 60% and 70% stenosis (kappa < 0.40). No correlation was found between agreement on severity of stenosis and the quality of the images.	3
12. De Bruyne B, Manoharan G, Pijls NH, et al. Assessment of renal artery stenosis severity by pressure gradient measurements. *J Am Coll Cardiol* 2006; 48(9):1851-1855.	Review/Other-Dx	15 patients	To define "significant" RAS (ie, a stenosis able to induce arterial hypertension).	For a P(d)/P(a) ratio >0.90, no significant change in plasma renin concentration was observed. However, when P(d)/P(a) became <0.90, a significant increase in renin was observed in the renal vein of the stenotic kidney, finally reaching a maximal increase of 346 +/- 145% for P(d)/P(a) of 0.50 (P=0.006). These values returned to baseline when the stenosis was relieved. In addition, plasma renin concentration increased significantly in the vein from the non-stenotic kidney (P=0.02). In renal artery stenoses, a P(d)/P(a) ratio of 0.90 can be considered a threshold value below which the stenosis is likely responsible for an up-regulation of renin production and, thus, for renovascular hypertension. These findings might contribute to better patient selection for renal angioplasty.	4

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
13. Mangiacapra F, Trana C, Sarno G, et al. Translesional pressure gradients to predict blood pressure response after renal artery stenting in patients with renovascular hypertension. *Circ Cardiovasc Interv* 2010; 3(6):537-542.	Observational-Dx	53 consecutive patients	To evaluate whether translesional pressure gradients could identify the patients with RAS who might benefit from stenting.	Average reductions in systolic blood pressure and diastolic blood pressure at follow-up were -20±30 mm Hg and -2±12 mm Hg, respectively. At multivariate analysis, dopamine-induced mean gradient was the only independent predictor of the variations of both systolic blood pressure (regression coefficient = -4.03, standard error = 1.11; P<0.001) and diastolic blood pressure (regression coefficient = -3.11, standard error = 1.20; P=0.009). Patients who showed a decline in systolic blood pressure from the baseline value >20 mm Hg were considered as "responders." The optimal cutoff for identification of "responders" was a dopamine-induced mean gradient ≥20 mm Hg (area under the curve, 0.77; 95% confidence interval, 0.64 to 0.90; P=0.001). A dopamine-induced mean pressure gradient of ≥20 mm Hg is highly predictive of arterial hypertension improvement after renal stenting, and therefore this measurement is useful for appropriate selection of patients with arterial hypertension.	4

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
14. Caridi JG, Stavropoulos SW, Hawkins IF, Jr. CO2 digital subtraction angiography for renal artery angioplasty in high-risk patients. *AJR* 1999; 173(6):1551-1556.	Review/Other-Dx	21 patients	To evaluate the efficacy of CO2 DSA for performing renal artery angioplasty in high-risk patients.	21 patients (13 men and 8 women) underwent 29 angioplasties (2 were bilateral and 6 were repeated). Four kidney transplantation patients had ostial stenosis and the remaining 17 patients had nonostial stenosis. For all patients except one, angioplasty initially was a technical success, as defined by a residual stenosis of <30%. Supplemental iodinated contrast material was used in only 6 patients (average dose, 8.5 ml). A range of 80-200 ml of carbon dioxide per procedure was used (average dose, 114.6 ml). One renal artery dissection occurred, which was unrelated to the carbon dioxide. There were no allergic reactions. The level of serum creatinine remained the same after 11 procedures, decreased after 12 procedures, and increased minimally after 4 procedures (<0.5 mg/dl). On the basis of our preliminary findings in a small group of patients, using carbon dioxide as an intravascular contrast agent to perform renal artery angioplasty in patients who have an allergy to iodinated contrast material or who suffer from renal insufficiency is safe and efficacious.	4

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
15. Spinosa DJ, Matsumoto AH, Angle JF, Hagspiel KD, McGraw JK, Ayers C. Renal insufficiency: usefulness of gadodiamide-enhanced renal angiography to supplement CO2-enhanced renal angiography for diagnosis and percutaneous treatment. *Radiology* 1999; 210(3):663-672.	Review/Other-Dx	24 patients	To determine whether gadodiamide is a safe and useful angiographic contrast agent for help in diagnosis and percutaneous treatment of RAS in patients with renal insufficiency.	In 23 (92%) of 25 procedures, there was no increase in serum creatinine level at 48 hours. One patient with acute and chronic rejection of a renal transplant and one with evidence of cholesterol embolization had a clinically important increase in serum creatinine level at 48 hours. No marked increase in creatinine level was observed in patients with relatively low baseline levels (n = 19). Gadodiamide-enhanced angiograms appeared to be better than CO2-enhanced angiograms for help in identifying renal artery occlusions, visualizing renal vessels incompletely filled with CO2, and determining the progress of intervention. Gadodiamide appears to be a safe and useful intra-arterial contrast agent in patients with renal insufficiency and can be used to supplement or confirm CO2-enhanced angiographic findings.	4
16. Clark RA, Alexander ES. Digital subtraction angiography of the renal arteries. Prospective comparison with conventional arteriography. *Invest Radiol* 1983; 18(1):6-10.	Observational-Dx	40 patients 92 renal arteries	To prospectively compare IV-DSA of the aorta and renal arteries with conventional arteriography in patients with renal arteries.	Sensitivity of IV-DSA was 87.5%, specificity 100% and accuracy 95.3%. Overall, accurate IV-DSA was obtained in 89.1% of arteries and 85% of the patients. IV-DSA is recommended for RAS.	2
17. Dunnick NR, Svetkey LP, Cohan RH, et al. Intravenous digital subtraction renal angiography: use in screening for renovascular hypertension. *Radiology* 1989; 171(1):219-222.	Observational-Dx	94 patients	Prospective study to determine the sensitivity and specificity of IV-DSA as compared to conventional angiography in hypertensive patients.	In 20 patients, a stenosis of a renal artery confirmed. Sensitivity of IV-DSA was 100%, specificity 93%, PPV 83% and NPV 100%. IV-DSA is recommended in patients at increased risk for renovascular hypertension.	2
18. Hillman BJ, Ovitt TW, Capp MP, Fisher HD, 3rd, Frost MM, Nudelman S. Renal digital subtraction angiography: 100 cases. *Radiology* 1982; 145(3):643-646.	Review/Other-Dx	100 cases	To evaluate the utility of IV-DSA in the evaluation of renal vascular disease. Prospective data was used and retrospective chart review was performed.	DSA is safe, quickly performed, and relatively inexpensive and suitable for examining patients with renal-related indications.	4

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
19. Smith CW, Winfield AC, Price RR, et al. Evaluation of digital venous angiography for the diagnosis of renovascular hypertension. *Radiology* 1982; 144(1):51-54.	Observational-Dx	32 patients	To evaluate DSA for the diagnosis of renovascular hypertension.	Two experienced angiographers evaluated the DSA studies without knowledge of the angiographic results. The accuracy of DSA for evaluation of renal arteries was 87% for Observer I and 80% for Observer II. Sensitivities were 87% and 83% and specificities 87% and 79% for the two observers. Of the 13 patients with significant lesions, Observer I identified at least one lesion in all 13, while Observer II identified a lesion in 12/13. The high false-positive rate (26% for Observer I and 37% for Observer II) was thought to be caused by subtraction artifacts, quantum noise, relatively low spatial resolution, and the Mach effect.	3
20. Illescas FF, Ford K, Braun SD, Dunnick NR. Intraarterial digital subtraction angiography in hypertensive azotemic patients. *AJR* 1984; 143(5):1065-1067.	Review/Other-Dx	10 intraarterial DSA studies in 9 azotemic patients	Review intra-arterial DSA studies in azotemic patients to assess the technical adequacy and the effect of contrast load on renal function.	All studies were of diagnostic quality. 2/10 had transient deterioration in the degree of renal insufficiency. Intra-arterial DSA is recommended for evaluating azotemic patients.	4
21. Norman D, Ulloa N, Brant-Zawadzki M, Gould RG. Intraarterial digital subtraction imaging cost considerations. *Radiology* 1985; 156(1):33-35.	Review/Other-Dx	400 angiograms	Retrospective study to estimate cost savings in intra-arterial DSA studies as compared to conventional film screen angiography.	Digital angiographic unit resulted in 82% reduction in film costs, 25% reduction in staffing costs, 19% reduction in time of exam, and 30% reduction in the time required per run.	4
22. Wilms GE, Baert AL, Staessen JA, Amery AK. Renal artery stenosis: evaluation with intravenous digital subtraction angiography. *Radiology* 1986; 160(3):713-715.	Observational-Dx	45 patients 92 arteries	To compare IV-DSA with intra-arterial DSA and define the ability of IV-DSA to quantify RAS.	90% of cases had agreement about the degree of stenosis. IV-DSA grading was correct in 94% of atheromatous lesions and in 56% of the fibromuscular dysplastic lesions. In high-grade atheromatous lesions, degree of stenosis was slightly overestimated on IV-DSA studies in 22.5%. In fibromuscular dysplasia, stenosis was underestimated in 33% of the cases.	3

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23. Sellars L, Shore AC, Wilkinson R. Renal vein renin studies in renovascular hypertension--do they really help? *J Hypertens* 1985; 3(2):177-181.	Review/Other-Dx	37 patients	To evaluate the measurement of the renal vein renin ratio to predict the response of blood pressure to surgery in hypertensive patients with unilateral renovascular disease.	24 patients were cured or improved. When a basal ratio of ≥1.5 (diseased: normal kidney) was taken as a positive test the false positive rate was 39% and the false negative rate 71%, there being little difference in outcome between those with ratios above or below 1.5. No other threshold value of renal vein renin ratio identified those responding to surgery, and acute stimulation of renin secretion did not increase the value of the test. It is concluded that the renal vein renin ratio is of no prognostic value in the surgical treatment of hypertension due to unilateral renovascular disease.	4
24. Luscher TF, Greminger P, Kuhlmann U, Siegenthaler W, Largiader F, Vetter W. Renal venous renin determinations in renovascular hypertension. Diagnostic and prognostic value in unilateral renal artery stenosis treated by surgery or percutaneous transluminal angioplasty. *Nephron* 1986; 44 Suppl 1:17-24.	Observational-Dx	95 patients	To evaluate the diagnostic value in unilateral RAS treated by surgery or PTA.	Patients with fibromuscular hyperplasia had more frequently PRA ratios <1.5 than those with arteriosclerotic stenosis (P<0.05). The renin secretion index proved to have a higher sensitivity (92%) and predictive value (92%) for a successful outcome of both surgery and PTA than the PRA ratio (69% and 89%, respectively), while the specificity was the same with both parameters (42% and 43%, respectively). The contralateral suppression index was most specific in predicting an unfavorable outcome. However, with all ratios used, a considerable number of false-negative and false-positive tests were observed both with surgery and PTA, a finding limiting the value of the method in selecting patients for these interventions. Other factors, such as age of the patient, kidney function and the underlying arterial disease turned out to be equally important prognostic factors. Thus, although cure after both surgery and PTA is more likely in the presence of lateralized renin secretion and contralateral suppression, the method does not allow to exclude patients with severe RAS, hypertension and negative renal venous renin tests from these interventions.	3

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25. Roubidoux MA, Dunnick NR, Klotman PE, et al. Renal vein renins: inability to predict response to revascularization in patients with hypertension. *Radiology* 1991; 178(3):819-822.	Observational-Dx	133 patients	Prospectively examine patients with hypertension to determine the usefulness of captopril-stimulated renal vein renin ratio to aid detection of patients with menovasculam hypertension due to RAS.	Captopril-stimulated renal vein renin ratio >1.5 in 13/20 hypertension patients (sensitivity 65%), but also >1.5 in 54/113 patients without hypertension (false-positive rate 47.8%). PPV of captopril-stimulated renal vein renin ratio was 18.6%; NPV 89.3%. Captopril-stimulated renal vein renin ratio has low sensitivity and specificity.	3
26. Postma CT, van Oijen AH, Barentsz JO, et al. The value of tests predicting renovascular hypertension in patients with renal artery stenosis treated by angioplasty. *Arch Intern Med* 1991; 151(8):1531-1535.	Observational-Dx	31 patients	To evaluate and compare renal vein renins, captopril test and renal scintigraphic tests to the blood pressure outcome 12 months after relief of RAS by PTA.	Captopril test showed a sensitivity of 36% and accuracy of 43%. Renal captopril technetium Tc-99m-labeled pentetic acid scintigraphy had 60% sensitivity.	3
27. Postma CT, van Aalen J, de Boo T, Rosenbusch G, Thien T. Doppler ultrasound scanning in the detection of renal artery stenosis in hypertensive patients. *Br J Radiol* 1992; 65(778):857-860.	Observational-Dx	61 patients	Prospective study to determine the accuracy of Doppler US compared with renal angiography in the diagnosis of RAS in hypertensive patients.	The sensitivity of Doppler ultrasound was 62.5%, the specificity 86.4% and the overall diagnostic accuracy was 73.9%. By comparing the 15 patients in whom Doppler ultrasound failed with the 46 in whom it was successful, age appeared to be higher and creatinine clearance lower in the failure group. By comparing the 34 patients with true positive and true negative results with the 12 patients with false results, no significant differences were found. In a multivariate analysis, higher age showed a significant relation to failure of Doppler ultrasound. Doppler ultrasound has limited value in the screening of hypertensive patients for renal artery stenosis.	2
28. Berland LL, Koslin DB, Routh WD, Keller FS. Renal artery stenosis: prospective evaluation of diagnosis with color duplex US compared with angiography. Work in progress. *Radiology* 1990; 174(2):421-423.	Observational-Dx	50 kidnesy in 26 patients	Prospective, double-blinded study comparing color duplex US to angiography in the detection of RAS.	Color duplex helped identify 58% of the main arteries. 9/29 vessels identified with duplex were incorrectly diagnosed as stenotic, findings yielding a specificity of 37%. Published velocity threshold of 100 cm/sec is too low. It is unlikely for duplex scanning to prove satisfactory in RAS.	3

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29. Stavros AT, Parker SH, Yakes WF, et al. Segmental stenosis of the renal artery: pattern recognition of tardus and parvus abnormalities with duplex sonography. *Radiology* 1992; 184(2):487-492.	Observational-Dx	56 patients	To prospectively evaluate segmental renal artery branches within the renal sinus with color Doppler imaging and pulsed-Doppler spectral analysis in patients before angiography. Findings were compared with subsequent findings on angiograms to determine their value in detection of hemodynamically significant renal arterial stenosis in 32 kidneys in 26 patients.	Loss of early systolic compliance peak/reflective-wave complex helped identify RAS with 95% sensitivity, 97% specificity, 92% PPV, 98% NPV, 96% accuracy.	3
30. Taylor DC, Kettler MD, Moneta GL, et al. Duplex ultrasound scanning in the diagnosis of renal artery stenosis: a prospective evaluation. *J Vasc Surg* 1988; 7(2):363-369.	Observational-Dx	29 patients 58 renal arteries	Prospective study to compare duplex Doppler (renal/aortic ratio) to angiography in the detection of RAS.	Renal duplex scanning had a sensitivity of 84%, specificity of 97%, PPV of 94% for the detection of >60% diameter-reducing stenosis. Overall agreement with angiography was 93%. Renal duplex scanning is recommended in the diagnoses of RAS in patients with hypertension or renal dysfunction.	2
31. De Cobelli F, Venturini M, Vanzulli A, et al. Renal arterial stenosis: prospective comparison of color Doppler US and breath-hold, three-dimensional, dynamic, gadolinium-enhanced MR angiography. *Radiology* 2000; 214(2):373-380.	Observational-Dx	45 patients	Prospective comparison of color Doppler US with fast, breath-hold, 3D gadolinium-enhanced MRA in detecting renal arterial stenosis. DSA was used as standard of reference.	For all stenoses, MRA had a sensitivity of 94% and accuracy of 91%. US had sensitivity of 71% and specificity of 76%. For stenoses with at least 50% narrowing, sensitivity for MRA was 100%, specificity 93%, accuracy 95% and NPV 100%. US had sensitivity of 79%, specificity of 93%, and accuracy of 95% and NPV of 90%. MRA is superior to color Doppler US in accessory renal artery detection.	2
32. Ciccone MM, Cortese F, Fiorella A, et al. The clinical role of contrast-enhanced ultrasound in the evaluation of renal artery stenosis and diagnostic superiority as compared to traditional echo-color-Doppler flow imaging. *Int Angiol* 2011; 30(2):135-139.	Observational-Dx	120 patients	To investigate the feasibility of contrast-enhanced US in the evaluation of RAS as compared with traditional techniques: echo color Doppler investigation and selective angiography. Contrast-enhanced US is a technique based on the injection of an intravascular biocompatible tracer, namely an IV contrast galactose microparticle suspension containing microbubbles (Levovist), that has a similar rheology to that of red blood cells, allowing quantification of renal tissue perfusion.	Echo color Doppler identified RAS in 33 cases and contrast-enhanced US in 38. Instead, selective angiography had detected RAS in 38 patients, the same with RAS diagnosed by contrast-enhanced US. Thus, contrast-enhanced US sensitivity, specificity and accuracy were similar to those of angiography while six false negatives and two false positives were obtained with echo color Doppler. The results suggest that this renal contrast-enhanced US is a promising, new, non-invasive method for screening patients with suspected RAS. This technique appears to be superior to traditional echo color Doppler flow imaging for diagnosing RAS and so may be an important aid in cardiovascular diagnostics.	3

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33. Lacourciere Y, Levesque J, Onrot JM, et al. Impact of Levovist ultrasonographic contrast agent on the diagnosis and management of hypertensive patients with suspected renal artery stenosis: a Canadian multicentre pilot study. *Can Assoc Radiol J* 2002; 53(4):219-227.	Experimental-Dx	78 patients	Multicenter, controlled trial to compare unenhanced US, contrast-enhanced US and captopril-enhanced renal scintigraphy and determine if contrast agent improves ability to assess the renal arteries with duplex Doppler US.	Enhanced US yielded diagnosis in 99% vs 82% for unenhanced US. Diagnosis was possible with both enhanced and unenhanced duplex Doppler US in 64 (82%), and the diagnosis was the same with both methods for 63 (98%) of 64 patients. Enhanced US is preferred over unenhanced US and captopril-enhanced renal scintigraphy.	2
34. Lee HY, Grant EG. Sonography in renovascular hypertension. *J Ultrasound Med* 2002; 21(4):431-441.	Review/Other-Dx	1,500 exams	To familiarize practitioners with different sonographic manifestations of renal artery compromise and the sonographic techniques for renal artery imaging.	The authors achieved approximately 75% to 80% success rate in obtaining technically adequate studies. The authord did not find the tardus-parvus waveform evaluation to be as valuable as direct interrogation of the renal artery.	4
35. Nchimi A, Biquet JF, Brisbois D, et al. Duplex ultrasound as first-line screening test for patients suspected of renal artery stenosis: prospective evaluation in high-risk group. *Eur Radiol* 2003; 13(6):1413-1419.	Observational-Dx	91 patients 177 arteries assessed; 2 readers	To assess how far the progress in ultrasound devices has increased feasibility and accuracy of Duplex ultrasound (DUS) for the diagnosis of renal artery stenosis (RAS), in a population with high prevalence of atherosclerotic renovascular lesions.	Accuracy, sensitivity and specificity for duplex US were 96%, 91% and 97%, respectively. Kappa for interobserver agreement was 0.95 for duplex US and 0.92 for DSA. Authors believe duplex US is accurate for RAS, although it is still unreliable for the detection of accessory arteries.	2
36. Oliva VL, Soulez G, Lesage D, et al. Detection of renal artery stenosis with Doppler sonography before and after administration of captopril: value of early systolic rise. *AJR* 1998; 170(1):169-175.	Observational-Dx	71 patients 135 kidneys 2 observers	To assess the value of quantitative and qualitative analysis of early systolic rise on Doppler waveform before and after administration of captopril. All cases were compared with conventional or DSA.	Before captopril the Doppler US had a sensitivity of 81% and specificity of 98% for detection of RAS ≥50%; sensitivity and specificity of Doppler US after captopril was 100%. For RAS ≥70%, sensitivity was 94% and specificity was 89% before administration of captopril. After captopril administration, an acceleration threshold value of 440 cm/sec2 for early systolic rise was associated with a sensitivity of 100% and a specificity of 94% for the detection of RAS ≥50%. Doppler US of the renal arteries performed before administration of captopril is recommended in the detection of severe stenosis (≥70%).	1
37. Radermacher J, Chavan A, Bleck J, et al. Use of Doppler ultrasonography to predict the outcome of therapy for renal-artery stenosis. *N Engl J Med* 2001; 344(6):410-417.	Review/Other-Dx	5950 patients	Prospectively identify patients whose renal function and blood pressure will improve after the correction of RAS to determine whether a high level of resistance to flow in segmental arteries can be used to select patients.	Of 5,950 patients, 138 had RAS. They were grouped into those with resistive index >80 and those with resistive index value <80. A resistive index >80 will not improve in renal function, blood pressure or kidney survival following treatment.	4

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
38. Stewart BH, Haynie TP. Critical appraisal of the renogram in renal vascular disease. *JAMA* 1962; 180:454-459.	Observational-Dx	64 patients	To describe the advantages as well as the shortcomings of the radioisotope renogram.	Quantitative radioactive o-iodohippurate renography was performed on 64 hypertensive patients with suspected renal vascular disease. Of these patients, 44 were found to have normal IV pyelograms, normal renal arteriograms, and equal renal function by simultaneous ureteral catheterization studies. These patients were therefore felt to have normal renal vessels bilaterally. The radioactive o-iodohippurate renogram was abnormal in 11 of these patients, however, giving a false positive rate of 27%. 20 patients were found to have occlusive renal vascular disease, proved at operation in each case. The o-iodohippurate renogram was highly reliable in cases of unilateral main artery occlusion, being positive in all of the 9 patients so studied. The renogram was somewhat less reliable in patients with bilateral occlusive disease, being positive in 67% of 6 patients studied. One of the false negative renograms in this group was particularly disturbing in that a normal renographic tracing was obtained over a kidney whose main artery was almost totally occluded. The radioactive o-iodohippurate renogram was highly unreliable in segmental renal vascular disease, with 60% of the 5 patients studied showing a normal tracing over the affected kidney.	4

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
39. Soulez G, Oliva VL, Turpin S, Lambert R, Nicolet V, Therasse E. Imaging of renovascular hypertension: respective values of renal scintigraphy, renal Doppler US, and MR angiography. *Radiographics* 2000; 20(5):1355-1368; discussion 1368-1372.	Review/Other-Dx	N/A	To review and assess the roles of renal scintigraphy, renal Doppler US, and MRA in diagnosis of renovascular hypertension.	Doppler US or scintigraphy should be the primary screening methods for renovascular hypertension. In a center with good expertise with Doppler US, the cost-effectiveness of this technique is probably superior to that of scintigraphy. MRA has a higher cost and lesser availability, so this should be reserved for patients with indeterminate functional imaging results, patients with normal functional imaging results but high clinical suspicion of renovascular hypertension, and patients with abnormal functional imaging results who have a contraindication to conventional angiography, such as renal failure or a history of allergy to iodinated contrast material.	4
40. Vasbinder GB, Nelemans PJ, Kessels AG, Kroon AA, de Leeuw PW, van Engelshoven JM. Diagnostic tests for renal artery stenosis in patients suspected of having renovascular hypertension: a meta-analysis. *Ann Intern Med* 2001; 135(6):401-411.	Review/Other-Dx	N/A	To summarize and compare the validity of CTA, MRA, US, captopril renal scintigraphy, and the captopril test for diagnosis of RAS in patients suspected of having renovascular hypertension.	Although accuracy varied greatly for all diagnostic modalities, summary ROC curves found that CTA and gadolinium-enhanced, three-dimensional MRA performed significantly better than the other diagnostic tests. CTA and gadolinium-enhanced three-dimensional MRA seem to be preferred in patients referred for evaluation of renovascular hypertension. However, because few studies of these tests have been published, further research is recommended.	4
41. Geyskes GG, de Bruyn AJ. Captopril renography and the effect of percutaneous transluminal angioplasty on blood pressure in 94 patients with renal artery stenosis. *Am J Hypertens* 1991; 4(12 Pt 2):685S-689S.	Observational-Dx	94 patients	To evaluate captopril renography and the effect of PTA on blood pressure.	Of the remaining 77 patients, a positive captopril renogram was seen in all 31 cured patients, in 22/27 patients with improvement, and in 6/19 patients with no change of their blood pressure. The sensitivity of the tests for cure and improvement of the blood pressure was 91% (53/58 patients) for all patients, 95% in patients with unilateral RAS (35/37), and 86% (18/21 patients) in patients with bilateral RAS, bilaterally treated. In 18 patients with a negative captopril renogram the blood pressure improved in five, and did not change in 13 patients.	4

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
42. Bolduc JP, Oliva VL, Therasse E, et al. Diagnosis and treatment of renovascular hypertension: a cost-benefit analysis. *AJR* 2005; 184(3):931-937.	Observational-Dx	74 patients	To evaluate and compare the relative cost-benefit of Doppler US, MRA, and captopril-enhanced renal scintigraphy as techniques for predicting a patient's clinical response to renal angioplasty.	The costs for each improved patient were $12,579 for patients selected on the basis of a positive finding on Doppler US (false-negative results = 12/1,000) and $10,149 for patients selected with criteria combining a positive finding on Doppler US with a bilateral resistive index of <0.75 (false-negative results = 32/1,000). Patient selection based on a positive finding on MRA cost $18,119 (false-negative results = 0), whereas the cost of patient selection based on a positive finding on renal scintigraphy was $12,939 (false-negative results = 29/1,000). Doppler US is more cost-efficient but less sensitive than MRA for identifying patients with renovascular hypertension. MRA should be favored in hypertensive patients who are resistant to medical therapy to avoid false-negative examinations.	3
43. Huot SJ, Hansson JH, Dey H, Concato J. Utility of captopril renal scans for detecting renal artery stenosis. *Arch Intern Med* 2002; 162(17):1981-1984.	Observational-Dx	86 patients 169 kidneys	Retrospective review to determine value of captopril renal scans in detecting RAS. Patients also had renal arteriography.	The prevalence of RAS was 43%. Captopril renal scanning had sensitivity of 74%, specificity of 59%, PPV of 58% and NPV of 75%. Captopril renal scanning is not recommended as the initial screening test for the diagnosing RAS.	2
44. Qanadli SD, Soulez G, Therasse E, et al. Detection of renal artery stenosis: prospective comparison of captopril-enhanced Doppler sonography, captopril-enhanced scintigraphy, and MR angiography. *AJR* 2001; 177(5):1123-1129.	Observational-Dx	41 patients	Prospective study to compare the value of captopril-enhanced Doppler US, captopril-enhanced renal scintigraphy, and gadolinium-enhanced MRA for detecting RAS.	For >50% stenosis MRA had 96.6% sensitivity, captopril enhanced Doppler 69%, and Captopril enhanced scintigraphy 41.4%. Captopril enhanced Doppler US in combination with gadolinium–enhanced MRA needs to be evaluated for cost effective analysis.	2

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
45. Soulez G, Therasse E, Qanadli SD, et al. Prediction of clinical response after renal angioplasty: respective value of renal Doppler sonography and scintigraphy. AJR 2003; 181(4):1029-1035.	Observational-Dx	74 patients	To compare Doppler US and renal scintigraphy as tools for predicting the therapeutic response in patients after undergoing renal angioplasty.	For prediction of a favorable therapeutic outcome, abnormal results from renal scintigraphy before and after captopril administration had a sensitivity of 58% and specificity of 57%. Findings of Doppler US had a sensitivity of 68% and specificity of 50% before captopril administration and a sensitivity of 81% and specificity of 32% after captopril administration. Significant predictors of a cure or reduction of hypertension after revascularization were low unilateral (P=0.014) and bilateral resistive (P=0.016) indexes on Doppler US before (P=0.009) and after (P=0.028) captopril administration. On multivariate analysis, the best predictors were a unilateral resistive index of <0.65 (OR = 3.7) after captopril administration and a kidney longer than 93 mm (OR = 7.8). The two best combined criteria to predict the favorable therapeutic outcome were a bilateral resistive index of <0.75 before captopril administration combined with a unilateral resistive index of <0.70 after captopril administration (sensitivity, 76%; specificity, 58%) or a bilateral resistive index of <0.75 before captopril administration and a kidney measuring longer than 90 mm (sensitivity, 81%; specificity, 50%). Measurements of kidney length and unilateral and bilateral resistive indexes before and after captopril administration were useful in predicting the outcome after renal angioplasty. Renal scintigraphy had no significant predictive value.	3
46. Bongers V, Bakker J, Beutler JJ, Beek FJ, De Klerk JM. Assessment of renal artery stenosis: comparison of captopril renography and gadolinium-enhanced breath-hold MR angiography. *Clin Radiol* 2000; 55(5):346-353.	Observational-Dx	43 patients	Prospective study comparing captopril renography with gadolinium-enhanced breath-hold MRA in the diagnosis of 50%-99% RAS.	Captopril renography accurately categorized 22/26 patients who had RAS. The sensitivity and specificity were 85% and 71%, respectively. For MRA sensitivity and specificity were 100% and 94%, respectively. The accuracy of captopril renography was lower in patients with renal impairment than in those with normal renal function.	2

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
47. Dondi M, Monetti N, Fanti S, et al. Use of technetium-99m-MAG3 for renal scintigraphy after angiotensin-converting enzyme inhibition. *J Nucl Med* 1991; 32(3):424-428.	Experimental-Dx	82 patients	To evaluate role of Tc-99m-MAG3 for renal scintigraphy after ACEI.	Sensitivity and specificity for the detection of RAS >50% were 89% and 91%, respectively. Tc-99m-MAG3 is an effective compound for detecting RAS ≥50% with captopril renal scintigraphy.	3
48. Mann SJ, Pickering TG, Sos TA, et al. Captopril renography in the diagnosis of renal artery stenosis: accuracy and limitations. *Am J Med* 1991; 90(1):30-40.	Observational-Dx	55 patients	To determine the accuracy of renography with captopril administration ("captopril renography") in diagnosing RAS.	RAS was seen in 35/55 patients. Three criteria for diagnosing RAS: 1) a percent uptake of DTPA by the affected kidney of <40% of the combined bilateral uptake, 2) a delayed time to peak uptake of DTPA >5 minutes longer in the affected kidney than in the contralateral kidney, 3) a delayed excretion of DTPA, with retention at 15 minutes, as a fraction of peak activity, more than 20% greater than in the contralateral kidney. Presence of one or more of these criteria was diagnostic of RAS, with a sensitivity and specificity of 71% and 75%, respectively before captopril administration, and 94% and 95% after captopril administration. Lesser degrees of asymmetry (ie, uptake of 40%-50%) had very poor diagnostic specificity.	3
49. Setaro JF, Chen CC, Hoffer PB, Black HR. Captopril renography in the diagnosis of renal artery stenosis and the prediction of improvement with revascularization. The Yale Vascular Center experience. *Am J Hypertens* 1991; 4(12 Pt 2):698S-705S.	Observational-Dx	113 patients	To determine the ability of captopril renography to diagnose RAS and the prediction of improvement with revascularization.	Captopril renography was 91% sensitive and 87% specific in identifying or excluding RAS. Diagnostic utility was preserved in those patients with renal insufficiency (serum creatinine equal to or greater than 1.5 mg/dL) (n = 46). Scintigraphic abnormalities induced by captopril were strongly associated with cure or improvement in blood pressure control following revascularization or nephrectomy (16 of 19), while the lack of captopril-induced change was associated with failure of such intervention (17 of 21) (P = .0001).	3
50. Taylor A. Renovascular hypertension: nuclear medicine techniques. *Q J Nucl Med* 2002; 46(4):268-282.	Review/Other-Dx	291 patients 10 studies	Review general components of renal scintigraphy and components specific to ACEI renography.	Mean PPV of ACEI renography is 92%. ACEI renography is highly accurate in patients with suspected renovascular hypertension who have normal or near normal renal function.	4

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
51. Kramer U, Wiskirchen J, Fenchel MC, et al. Isotropic high-spatial-resolution contrast-enhanced 3.0-T MR angiography in patients suspected of having renal artery stenosis. *Radiology* 2008; 247(1):228-240.	Observational-Dx	29 patients	To prospectively evaluate the accuracy of contrast material–enhanced MRA performed at 3-T for assessment of RAS by using parallel acquisition techniques with high acceleration factors compared with DSA.	The sensitivity and specificity of MRA in grading significant (>75%) stenosis were 94% and 96%, respectively. Contrast-enhanced 3-T MRA can be used to exclude RAS and can serve as a useful screening method in the diagnostic workup of patients with arterial hypertension.	1
52. McGregor R, Vymazal J, Martinez-Lopez M, et al. A multi-center, comparative, phase 3 study to determine the efficacy of gadofosveset-enhanced magnetic resonance angiography for evaluation of renal artery disease. *Eur J Radiol* 2008; 65(2):316-325.	Experimental-Dx	145 patients: 3 blinded readers; 18 centers	Multicenter, blinded, prospective study to determine the safety and efficacy of the blood-pool contrast agent gadofosveset trisodium in renal artery MRA. Images were compared to non-contrast MRA, using catheter X-ray angiography as the standard of reference.	127 with complete efficacy data entered the primary efficacy analysis. Gadofosveset-enhanced MRA led to significant improvement (P<0.01) in sensitivity (+25%, +26%, +42%), specificity (+23%, +25%, +29%), and accuracy (+23%, +28%, +29%) over non-enhanced MRA for all the readers.	1
53. Soulez G, Pasowicz M, Benea G, et al. Renal artery stenosis evaluation: diagnostic performance of gadobenate dimeglumine-enhanced MR angiography--comparison with DSA. *Radiology* 2008; 247(1):273-285.	Observational-Dx	268 patients patients successfully had DSA; 3 reviewers	Multicenter, blinded, prospective study to determine the accuracy of contrast material–enhanced MRA with 0.1 mmol/kg of body weight gadobenate dimeglumine for depiction of significant steno-occlusive disease using DSA as standard of reference.	Sensitivity, specificity, and accuracy of contrast-enhanced MRA for detection of 51% or greater stenosis or occlusion were 60.1%-84.1%, 89.4%-94.7%, and 80.4%-86.9%, respectively, at segment level. Similar values were obtained for predictive values and for patient level analyses. Few contrast-enhanced MR angiographic examinations (1.9%-2.8%) were technically inadequate. Interobserver agreement for detection of significant steno-occlusive disease was good (79.9% agreement).	1
54. Tan KT, van Beek EJ, Brown PW, van Delden OM, Tijssen J, Ramsay LE. Magnetic resonance angiography for the diagnosis of renal artery stenosis: a meta-analysis. *Clin Radiol* 2002; 57(7):617-624.	Review/Other-Dx	998 patients; 25 studies	Meta-analysis to compare the accuracy of MRA with and without gadolinium in diagnosing RAS, using catheter angiography as reference.	The number of patients included in the meta-analysis was 998: 499 with non-enhanced MRA and 499 with gadolinium-enhanced MRA. The sensitivity and specificity of non-enhanced MRA were 94% (95% CI: 90-97%) and 85% (95% CI: 82-87%), respectively. For gadolinium-enhanced MRA sensitivity was 97% (95% CI: 93-98%) and specificity was 93% (95% CI: 91-95%). Thus, specificity and positive predictive value were significantly better for gadolinium-enhanced MRA (P < 0.001). Accessory renal arteries were depicted better by gadolinium-enhanced MRA (82%; 95% CI: 75-87%) than non-gadolinium MRA (49%; 95% CI: 42-60%) (P < 0.001).	4

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
55. Utsunomiya D, Miyazaki M, Nomitsu Y, et al. Clinical role of non-contrast magnetic resonance angiography for evaluation of renal artery stenosis. *Circ J* 2008; 72(10):1627-1630.	Observational-Dx	26 patients	To retrospectively evaluate whether non-contrast enhanced MRA might provide sufficient information of RAS.	The significant RAS was visually evaluated by comparing non-contrast MRA with CT or conventional angiographic finding. Difference of the intensities between the proximal and distal aorta was quantitatively evaluated. The sensitivity, specificity, PPV and NPV of non-contrast MRA in the evaluation of the RAS was 78%, 91%, 64% and 96%, respectively. The distal abdominal aorta showed less signal intensity than the proximal aorta by 16.9+/-12.2%. Non-contrast MRA is a non-invasive and effective method that allows evaluation of the RAS.	3
56. Mohrs OK, Petersen SE, Schulze T, et al. High-resolution 3D unenhanced ECG-gated respiratory-navigated MR angiography of the renal arteries: comparison with contrast-enhanced MR angiography. *AJR* 2010; 195(6):1423-1428.	Observational-Dx	45 consecutive patients	To determine the diagnostic value of high-resolution 3D unenhanced ECG-gated respiratory-navigated MRA of the renal arteries using a steady-state free precession technique in comparison with 1.0-molar contrast-enhanced MRA in patients with suspected RAS.	Examination time was shorter for contrast-enhanced MRA (mean ± SD, 12 ± 3 minutes) than for unenhanced MRA (19 ± 3 minutes; P<0.001). On a 5-point scale, the image quality was similar for contrast-enhanced MRA (3.8 ± 1.0) and unenhanced MRA (4.0 ± 1.3; p = 0.24). Contrast-enhanced MRA offered more assessable data sets than did unenhanced MRA (95% vs 90%); however, unenhanced MRA had more data sets with maximum image quality (49% vs 30%). There was moderate agreement in stenosis grading between both MRA techniques ($\kappa = 0.51$; P<0.001), but in only one case (1.3%) we found mismatch of more than one severity stenosis grade (stenoses >75%). Sensitivity, specificity, and PPV and NPV of unenhanced MRA to detect renal artery stenoses greater than 50% were 75%, 99%, 75%, and 99%, respectively. We show that steady-state free precession 3D unenhanced MRA is a very promising technique for patients with suspected renovascular disease and could be used as an alternative if gadolinium-based contrast agents cannot be administered.	2

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
57. Volk M, Strotzer M, Lenhart M, et al. Time-resolved contrast-enhanced MR angiography of renal artery stenosis: diagnostic accuracy and interobserver variability. *AJR* 2000; 174(6):1583-1588.	Observational-Dx	40 patients; 4 observers evaluated 80 renal arteries, 19 vessels	Prospective study to compare contrast-enhanced MRA with DSA in the detection of RAS.	Overall sensitivity for significant stenoses was 92.9%, overall specificity 83.4%, and overall accuracy 85.9%. Interobserver variability of gadolinium-enhanced MRA exceeded that of DSA. Gadolinium-enhanced MRA is recommended for screening suspected RAS.	1
58. Debatin JF, Spritzer CE, Grist TM, et al. Imaging of the renal arteries: value of MR angiography. *AJR* 1991; 157(5):981-990.	Observational-Dx	32 patients: 33 MRA studies; 3 observers	Prospective study to compare the value of MRA with conventional angiography for visualizing the renal arteries and detecting renovascular disease.	Renal artery visualization and detection of renovascular disease were more complete with coronal phase-contrast (80% sensitivity, 91% specificity) than with time-of-flight (53% sensitivity, 97% specificity) images. Combined axial and coronal phase-contrast images permitted visualization of the proximal 35 mm of all dominant renal arteries and detection of 13/15 stenoses (87% sensitivity, 97% specificity). MRA is useful for the evaluation of renovascular disease.	1
59. Fain SB, King BF, Breen JF, Kruger DG, Riederer SJ. High-spatial-resolution contrast-enhanced MR angiography of the renal arteries: a prospective comparison with digital subtraction angiography. *Radiology* 2001; 218(2):481-490.	Observational-Dx	38 patients: 2 readers	Prospective study to evaluate a high-spatial-resolution 3D contrast material-enhanced MRA for detecting proximal and distal renal arterial. MR results were compared with DSA.	High-spatial-resolution small-field-of-view technique provided high sensitivity (97%) and specificity (92%) for the detection of renal arterial stenosis. The portrayal of the segmental renal arteries was adequate for diagnosis in 19 (76%) of 25 patients. In 12% of the patients, impaired depiction of the segmental arteries was linked to motion. The combined high-spatial-resolution small-field-of-view and large-field-of-view MR angiographic examination provides improved spatial resolution in the region of the renal arteries while maintaining coverage of the abdominal aorta and iliac arteries.	2
60. Korst MB, Joosten FB, Postma CT, Jager GJ, Krabbe JK, Barentsz JO. Accuracy of normal-dose contrast-enhanced MR angiography in assessing renal artery stenosis and accessory renal arteries. *AJR* 2000; 174(3):629-634.	Observational-Dx	38 patients	To examine the accuracy of normal-dose contrast-enhanced MRA in the assessment of RAS and accessory renal arteries by comparing with DSA.	DSA showed 75 main and 17 accessory renal arteries (n=92). All main renal arteries and 13 accessory renal arteries were identified on MRA. One false-positive finding on MRA identified retrospectively on DSA. Sensitivity and specificity for grading significant stenosis were 100% and 85%, respectively. Contrast-enhanced MRA using +/-0.1 mmol/kg of gadolinium is recommended in the diagnosis of RAS and accessory renal arteries.	2

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
61. Mallouhi A, Schocke M, Judmaier W, et al. 3D MR angiography of renal arteries: comparison of volume rendering and maximum intensity projection algorithms. *Radiology* 2002; 223(2):509-516.	Observational-Dx	27 patients	To compare volume rendering (VR) and maximum intensity projection (MIP) as postprocessing techniques of magnetic resonance (MR) angiography for detection and quantification of renal artery stenosis.	All main and accessory renal arteries depicted at DSA were also demonstrated on MIP and VR images. VR performed slightly better than MIP for quantification of stenoses greater than 50% (VR: r(2) = 0.84, P <.001; MIP: r(2) = 0.38, P =.001) and significantly better for severe stenoses (VR: r(2) = 0.83, P <.001; MIP: r(2) = 0.21, P =.1). For detection of stenosis, VR yielded a substantial improvement in positive predictive value (VR: 95% and 90%; MIP: 86% and 68% for stenoses greater than 50% and 70%, respectively). Image quality obtained with VR was not significantly better than that with MIP; however, vascular delineation on VR images was significantly better.	2
62. Kanal E, Barkovich AJ, Bell C, et al. ACR guidance document for safe MR practices: 2007. *AJR* 2007; 188(6):1447-1474.	Review/Other-Dx	N/A	ACR practice guideline for safe MR practices. Purpose of document is to guide MR facilities in the development of safe MR programs.	N/A	4
63. Broome DR, Girguis MS, Baron PW, Cottrell AC, Kjellin I, Kirk GA. Gadodiamide-associated nephrogenic systemic fibrosis: why radiologists should be concerned. *AJR* 2007; 188(2):586-592.	Review/Other-Dx	12 patients	Retrospective chart review to identify any common risk factors and determine whether IV gadodiamide is associated with the development of NSF.	All patients had renal insufficiency and all developed skin fibrosis within 2-11 weeks after gadodiamide administration. The OR for development of NSF after gadodiamide exposure was 22.3. Development of NSF was strongly associated with gadodiamide administration in the setting of either acute hepatorenal syndrome or dialysis-dependent chronic renal insufficiency.	4
64. Sadowski EA, Bennett LK, Chan MR, et al. Nephrogenic systemic fibrosis: risk factors and incidence estimation. *Radiology* 2007; 243(1):148-157.	Review/Other-Dx	13 patients	To retrospectively review data in patients with biopsy-confirmed NSF, assess the associated risk factors, and report the incidence of NSF at the authors' institution.	A combination of factors, including altered kidney function, inflammatory burden, and exposure to gadolinium-based contrast agents may all play a role in development of NSF. Alternative imaging should be considered in patients with these factors. If use of a gadolinium-based agent is clinically indicated, the referring physician and patient should be informed of the potential risk of developing NSF.	4

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
65. Willmann JK, Wildermuth S, Pfammatter T, et al. Aortoiliac and renal arteries: prospective intraindividual comparison of contrast-enhanced three-dimensional MR angiography and multi-detector row CT angiography. *Radiology* 2003; 226(3):798-811.	Observational-Dx	46 patients; 2 readers	Prospective study to compare contrast material-enhanced 3D MRA with MDCT in the same patients for assessment of the aortoiliac and renal arteries. DSA is the standard of reference.	Sensitivity of MR angiography for detection of hemodynamically significant arterial stenosis was 92% for reader 1 and 93% for reader 2, and specificity was 100% and 99%, respectively. Sensitivity of CT angiography was 91% for reader 1 and 92% for reader 2, and specificity was 99% and 99%, respectively. Differences between the two modalities were not significant. Interobserver and intermodality agreement was excellent (kappa = 0.88-0.90). The time for performance of 3D reconstruction and image analysis of CT data sets was significantly longer than that for MR data sets (P <.001). Patient acceptance was best for CT angiography (P =.016).	1
66. Beregi JP, Elkohen M, Deklunder G, Artaud D, Coullet JM, Wattinne L. Helical CT angiography compared with arteriography in the detection of renal artery stenosis. *AJR* 1996; 167(2):495-501.	Observational-Dx	50 patients	Prospective comparison of digital renal arteriography and helical CTA in hypertensive patients suspected to have RAS.	Arteriography visualized 131 renal arteries (including 32 accessory arteries). Sixteen had significant (greater than 50% in diameter) stenosis. On helical CT angiography, 14 of these 16 stenoses were detected; two were missed (false-negatives), and two additional stenoses (false-positives) were reported. Sensitivity and specificity were 88% and 98%, respectively. Considering only main renal arteries, the sensitivity and the specificity of helical CT angiography were 100% and 98%, respectively. Helical CT angiography detected Conn's syndrome, which was responsible for hypertension, in two other patients.	2

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
67. Farres MT, Lammer J, Schima W, et al. Spiral computed tomographic angiography of the renal arteries: a prospective comparison with intravenous and intraarterial digital subtraction angiography. *Cardiovasc Intervent Radiol* 1996; 19(2):101-106.	Observational-Dx	18 patients	Prospective comparison of CTA with IV-DSA and intra-arterial DSA in assessing RAS.	CTA had 96% sensitivity, 77% specificity, and 89% accuracy in the detection of stenoses > 50%. Due to technical errors two stenoses were erroneously diagnosed as positive but there were no false negative diagnoses. The quality of CTA was good in 56% and moderate in 34% of cases. Visualization of the ostium and main artery was graded as 1.74 (out of 2) points and of the renal branches as 1.02 (out of 2) points and of the renal branches as 1.02 (out of 2) points. The quality of CTA images was worse than that of IADSA in 52%, equal in 41%, and better in 7% of cases. CTA was equal to IVDSA in 25% and better in 75% of the cases.	2
68. Berg MH, Manninen HI, Vanninen RL, Vainio PA, Soimakallio S. Assessment of renal artery stenosis with CT angiography: usefulness of multiplanar reformation, quantitative stenosis measurements, and densitometric analysis of renal parenchymal enhancement as adjuncts to MIP film reading. *J Comput Assist Tomogr* 1998; 22(4):533-540.	Observational-Dx	37 patients 78 renal arteries	To evaluate CTA in the assessment of RAS.	MIP films showed 100% sensitivity but only 42%-54% specificity. Combined visual interpretation of MIP films with quantitative measurements yielded best diagnostic performance; 92% sensitivity, 80% specificity and 84% overall accuracy.	2
69. Mallouhi A, Rieger M, Czermak B, Freund MC, Waldenberger P, Jaschke WR. Volume-rendered multidetector CT angiography: noninvasive follow-up of patients treated with renal artery stents. *AJR* 2003; 180(1):233-239.	Observational-Dx	16 patients 16 renal artery stents	To evaluate the role of volume-rendered MDCT angiography for estimating the patency of renal artery stents by comparing three volume-rendering techniques with DSA and multiplanar volume reformations.	Eight restenoses were identified on DSA. Correlations between restenosis severity measured with DSA and those measured with MDCT were significant ($p < 0.001$). Volume rendering with VR(HL) allowed the best correlation with DSA (reviewer 1, $r(2) = 0.86$; reviewer 2, $r(2) = 0.94$) and was significantly better than multiplanar volume reformations ($p = 0.028$). Overall image quality was high with all rendering techniques and with no significant differences ($p > 0.59$, for all comparisons). Stent lumen was well delineated with volume-rendering modalities; however, VR(HL) was significantly better than VR(LH) ($p = 0.033$).	2

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
70. Lufft V, Hoogestraat-Lufft L, Fels LM, et al. Contrast media nephropathy: intravenous CT angiography versus intraarterial digital subtraction angiography in renal artery stenosis: a prospective randomized trial. *Am J Kidney Dis* 2002; 40(2):236-242.	Experimental-Dx	80 patients	Prospective study of patients with RAS randomized to either CTA or DSA. To determine serum creatinine level and single-shot inulin clearance for evaluation of renal function and urine alpha1 microglobin and beta-N- acetyl-glucosaminidase as markers for tubular toxicity.	Mean serum creatinine levels increased from 1.78 +/- 1.61 to 1.92 +/-1.73 mg/dL (157 +/- 142 to 170 +/- 153 micromol/L; P=0.00001) in the CTA group and from 1.52 +/- 1.23 to 1.60 +/- 1.28 mg/dL (134 +/- 109 to 141 +/- 113 micromol/L; P=0.01) in the DSA group. Mean inulin clearance decreased from 63 +/- 28 to 58 +/- 23 mL/min (P=0.01) and 65 +/- 26 to 62 +/- 26 mL/min (P<0.01), median beta-NAG levels increased from 4.6 to 6.0 U/g creatinine (P=not significant) and 2.5 to 8.0 U/g creatinine (P<0.001), and median alpha1-microglobulin levels increased from 13 to 17 microg/g creatinine (P<0.025) and 11 to 21 microg/g creatinine (P=not significant) in the CTA and DSA groups, respectively. CTA used for the detection of RAS is not associated with an increased risk for contrast media nephropathy compared with intra-arterial DSA.	3
71. Mounier-Vehier C, Lions C, Devos P, et al. Cortical thickness: an early morphological marker of atherosclerotic renal disease. *Kidney Int* 2002; 61(2):591-598.	Observational-Dx	49 patients	To evaluate morphological abnormalities on post-stenotic and contralateral kidneys with spiral CTA.	The post stenotic kidneys showed significant cortical atrophy. The contralateral kidneys also underwent cortical disease as judged by comparison with control kidneys. A threshold of 800 mm2 was identified for cortical area and 8 mm for cortical thickness. Cortical measurements are more sensitive than renal lengths.	3

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EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
72. Steinwender C, Schutzenberger W, Fellner F, et al. 64-Detector CT angiography in renal artery stent evaluation: prospective comparison with selective catheter angiography. *Radiology* 2009; 252(1):299-305.	Observational-Dx	86 patients	To prospectively assess the diagnostic accuracy of 64-detector CT renal artery angiography for the evaluation of renal artery in-stent restenosis by using selective catheter renal artery angiography as the reference standard.	At CT renal artery angiography, 93 (98%) of 95 stents were assessable for diagnosis. Two stents could not be evaluated owing to hardening artifacts affected by vessel calcifications. All 9 cases of significant in-stent restenosis seen at selective catheter renal artery angiography were correctly diagnosed by using CT renal artery angiography, giving a sensitivity of 100% and a NPV of 100%. One case of nonsignificant in-stent restenosis seen at selective catheter renal artery angiography was interpreted as significant by using CT renal artery angiography, giving a specificity of 99% and a PPV of 90%. In 4/78 patients without in-stent restenosis saw at selective catheter renal artery angiography, CT renal artery angiography showed nonsignificant in-stent restenosis, giving a specificity of 95% and a PPV of 56%. 64-detector CT renal artery angiography can provide an excellent noninvasive technique to help detect and evaluate in-stent restenosis within the renal artery stents used in the study.	2
73. Eklof H, Ahlstrom H, Magnusson A, et al. A prospective comparison of duplex ultrasonography, captopril renography, MRA, and CTA in assessing renal artery stenosis. *Acta Radiol* 2006; 47(8):764-774.	Observational-Dx	58 patients	To prospectively compare the diagnostic accuracy of duplex US, captopril renography, CTA, and 3D gadolinium-enhanced MRA in diagnosing hemodynamically significant RAS. Standard of reference was measurement of trans-stenotic pressure gradient.	The prevalence of RAS was 77%. US had sensitivity of 73%, specificity of 71%. Captopril had sensitivity of 52%, specificity of 63%. CTA had sensitivity of 94%, specificity of 62%. MRA had sensitivity of 93%, specificity of 91%.US had a lower sensitivity than CTA and MRA (P<0.001) but higher than captopril renography (P=0.013). MRA and CTA were much better than duplex US and captopril renography.	2
74. American College of Radiology. *Manual on Contrast Media*. Available at: http://www.acr.org/~/link.aspx?_id=29C40D1FE0EC4E5EAB6861BD213793E5&_z=z.	Review/Other-Dx	N/A	Guidance document on contrast media to assist radiologists in recognizing and managing risks associated with the use of contrast media.	N/A	4

Evidence Table Key

Study Quality Category Definitions

- *Category 1* The study is well-designed and accounts for common biases.
- *Category 2* The study is moderately well-designed and accounts for most common biases.
- *Category 3* There are important study design limitations.
- *Category 4* The study is not useful as primary evidence. The article may not be a clinical study or the study design is invalid, or conclusions are based on expert consensus. For example:
  a) the study does not meet the criteria for or is not a hypothesis-based clinical study (e.g., a book chapter or case report or case series description);
  b) the study may synthesize and draw conclusions about several studies such as a literature review article or book chapter but is not primary evidence;
  c) the study is an expert opinion or consensus document.

Dx = Diagnostic

Tx = Treatment

Abbreviations Key

ACEI = Angiotensin converting enzyme inhibition

CT = Computed tomography

CTA = Computed tomography angiography

DSA = Digital-subtraction angiography

DTPA = Diethylenetiamine pentaacetic acid

ECG = Electrocardiogram

IV = Intravenous

IV-DSA = Intravenous-digital-subtraction angiography

IVU = Intravenous urogram

MDCT = Multidetector computed tomography

MIP = Maximum intensity projection

MRA = Magnetic resonance angiography

NPV = Negative predictive value

NSF = Nephrogenic systemic fibrosis

OR = Odds ratio

PPV = Positive predictive value

PTA = Percutaneous transluminal angioplasty

RAS = Renal artery stenosis

ROC = Receiver-operator characteristic

SD = Standard deviation

US = Ultrasound