Renovascular Hypertension
EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
1. O'Neill WC, Bardelli M, Yevzlin AS. Imaging for renovascular disease. *Semin Nephrol.* 2011;31(3):272-282.	Review/Other-Dx	N/A	To describe the utility of sonography, CTA, MRA, and conventional angiography for imaging renovascular disease.	No consensus can be drawn from existing data concerning the appropriate screening test for RAS. All modalities are plagued by the lack of a clear understanding of what constitutes a significant stenosis. Operator-dependence and subjectivity in the interpretation are also major problems.	4
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 RAS 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 RAS, 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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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
4. Cooper CJ, Murphy TP, Cutlip DE, et al. Stenting and medical therapy for atherosclerotic renal-artery stenosis. *N Engl J Med.* 2014;370(1):13-22.	Experimental-Tx	947 patients	To determine the effects of renal-artery stenting on the incidence of important cardiovascular and renal adverse events.	Over a median follow-up period of 43 months (interquartile range, 31 to 55), the rate of the primary composite end point did not differ significantly between participants who underwent stenting in addition to receiving medical therapy and those who received medical therapy alone (35.1% and 35.8%, respectively; hazard ratio with stenting, 0.94; 95% CI, 0.76 to 1.17; *P*=0.58). There were also no significant differences between the treatment groups in the rates of the individual components of the primary end point or in all-cause mortality. During follow-up, there was a consistent modest difference in systolic blood pressure favoring the stent group (-2.3 mm Hg; 95% CI, -4.4 to -0.2; *P*=0.03).	1

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5. Herrmann SM, Saad A, Textor SC. Management of atherosclerotic renovascular disease after Cardiovascular Outcomes in Renal Atherosclerotic Lesions (CORAL). *Nephrol Dial Transplant.* 2015;30(3):366-375.	Review/Other-Tx	N/A	To evaluate the current management of atherosclerotic renovascular disease for clinical nephrologists in the context of recent randomized clinical trials and experimental research.	No results stated in abstract.	4
6. 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 2 or 3 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
7. American College of Radiology. *Manual on Contrast Media*. Available at: http://www.acr.org/Quality-Safety/Resources/Contrast-Manual.	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.	No results stated in abstract.	4
8. McDonald RJ, McDonald JS, Newhouse JH, Davenport MS. Controversies in Contrast Material-induced Acute Kidney Injury: Closing in on the Truth? *Radiology.* 2015;277(3):627-632.	Review/Other-Dx	N/A	To review controversies in contrast material - induced AKI.	No results stated in abstract.	4

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9. Hua HT, Hood DB, Jensen CC, Hanks SE, Weaver FA. The use of colorflow duplex scanning to detect significant renal artery stenosis. *Ann Vasc Surg.* 2000;14(2):118-124.	Observational-Dx	58 patients	To review our institutional experience with colorflow duplex scanning in detecting significant RAS and to validate the criteria used: renal artery PSV ≥200 cm/sec and RAR ≥3.5.	Arteriography revealed 32 main renal arteries with ≥60% stenosis. The PSV criterion detected 29, for a sensitivity of 91%, specificity of 75%, PPV of 60%, NPV of 95%, and accuracy of 79%. Using RAR ≥3.5 provided a sensitivity of 72%, specificity of 92%, PPV of 79%, NPV of 88%, and accuracy of 86%. In a subset of 36 kidneys that had hilar scans, the criteria of acceleration time ≥100 cm/sec and index ≤3.78 kHz/sec were evaluated. The acceleration time and acceleration index yielded sensitivity of 50% and 36%, specificity of 86% and 100%, PPV of 70% and 100%, NPV of 73% and 71%, and accuracy of 72% and 75%, respectively. Colorflow duplex scanning is clinically useful in screening for hemodynamically significant RAS. The renal artery PSV criterion is highly sensitive, with a high NPV that obviates the need for arteriography in most cases of a negative duplex.	3

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
10. Motew SJ, Cherr GS, Craven TE, et al. Renal duplex sonography: main renal artery versus hilar analysis. *J Vasc Surg.* 2000;32(3):462-469; 469-471.	Observational-Dx	41 patients	To compare the accuracy of main renal artery Doppler scanning interrogation and hilar analysis to diagnose hemodynamically significant renal artery disease.	Angiography revealed hemodynamically significant fibromuscular dysplasia in 5 kidneys (4 patients), atherosclerotic stenosis ≥60% in 48 kidneys (30 patients), and renal artery occlusion in 4 kidneys (4 patients). Kidneys with significant RAS had a higher PSV (2.54 +/- 0.11 vs 1.28 +/- 0.08, *P*<.001) and acceleration time (82.43 +/- 7.2 vs 30.0 +/- 2.8, *P*<.001) compared with those without stenosis. Compared with angiography, a PSV of 2.0 m/s or more and PST demonstrated a sensitivity of 91%, specificity of 96%, and overall accuracy of 92% for detection of significant RAS. 2 of 5 studies with false-negative results reflected diseased polar vessels. By contrast, acceleration time of more than 100 ms had a sensitivity of 32%, specificity of 100%, and overall accuracy of 54%. ROC curve analysis revealed a PSV of more than 1.8 m/s and an acceleration time of 58 ms or greater as optimal values. With an acceleration time of 58 ms or more, the sensitivity was 58%, and specificity was 96%, with an overall accuracy of 70%. There were no apparent associations between PSV or acceleration time and type or location of renal artery lesion, serum creatinine level, or end-diastolic ratio.	3
11. AbuRahma AF, Srivastava M, Mousa AY, et al. Critical analysis of renal duplex ultrasound parameters in detecting significant renal artery stenosis. *J Vasc Surg.* 2012;56(4):1052-1059, 1060 e1051; discussion 1059-1060.	Observational-Dx	313 patients (606 renal arteries)	To compare RDU imaging vs angiography and assess various published Doppler criteria to detect significant RAS.	The mean PSVs and RARs for normal, <60%, and ≥60% stenosis were 173, 236, and 324 cm/s (*P*<.0001), and 2.2, 2.9, and 4.5, respectively (*P*<.0001). The PSV cutoff value that provided the best overall accuracy for ≥60% stenosis was 285 cm/s, with a sensitivity, specificity, and overall accuracy of 67%, 90%, and 81%, respectively. The RAR cutoff value with the best overall accuracy for ≥60% stenosis was 3.7, with a sensitivity, specificity, and overall accuracy of 69%, 91%, and 82%, respectively.	2

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
12. Labropoulos N, Ayuste B, Leon LR, Jr. Renovascular disease among patients referred for renal duplex ultrasonography. *J Vasc Surg.* 2007;46(4):731-737.	Review/Other-Dx	324 patients	To determine the prevalence of RAS among patients referred to a vascular laboratory in a university hospital, to identify those who are possible candidates for revascularization, and to determine the prevalence of other pathologies incidentally detected.	A total of 324 patients were included from September 1998 to August 2003. Unilateral RAS was found in 14% and bilateral in 7%. Unilateral (1.5%) and bilateral (0.6%) renal artery occlusions were rare. The main reason for referral was uncontrolled (43%) and controlled hypertension (34%). Most patients (63%) were taking 2 or more antihypertensive drugs. The diagnostic yield was 22% among those using 2 drugs and 55% among those using 3 or more. In 46 patients (64%), the RI was <0.8. 7 cases of fibromuscular dysplasia were found (10% of RAS patients or 2% overall). Incidental findings were detected in 24% and were significant enough to alter management in 26% among those with such findings.	4
13. Li JC, Yuan Y, Qin W, et al. Evaluation of the tardus-parvus pattern in patients with atherosclerotic and nonatherosclerotic renal artery stenosis. *J Ultrasound Med.* 2007;26(4):419-426.	Review/Other-Dx	81 patients	To evaluate the differences in the tardus-parvus pattern between atherosclerotic and nonatherosclerotic RAS and to explore the causes of these differences.	Renal angiography revealed 16 moderate RASs, 80 severe RASs, and 15 occlusions. No statistically significant differences were found in the acceleration time between the atherosclerotic and nonatherosclerotic groups in the mild (P=.24), moderate (P=.63), and severe stenotic (P=.41) subgroups; however, there were statistically significant differences in the RI between the atherosclerotic and nonatherosclerotic groups in the mild (P<.001), moderate (P<.01), and severe (P<.001) subgroups. The RI values in the atherosclerotic group were much higher than those in the nonatherosclerotic group for the 3 stenotic subgroups.	4
14. Radermacher J. Echo-doppler to predict the outcome for renal artery stenosis. *J Nephrol.* 2002;15 Suppl 6:S69-76.	Review/Other-Dx	N/A	To describe the ability of echo-Doppler to predict the outcome of RAS.	Not all patients with RAS will benefit from angioplasty or surgery. For this reason it is not sufficient to diagnose the presence of RAS, but one also has to evaluate its functional significance. US detection of RAS can be made with a sensitivity and specificity exceeding 90% by an experienced investigator. A combination of Doppler parameters making use of both direct and indirect signs of stenosis should be used.	4

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15. Viazzi F, Leoncini G, Derchi LE, Pontremoli R. Ultrasound Doppler renal resistive index: a useful tool for the management of the hypertensive patient. *J Hypertens.* 2014;32(1):149-153.	Review/Other-Dx	N/A	To review the main clinical applications of renal RI and will discuss more recent data on its meaning and prognostic usefulness in the management of patients with hypertension.	No results stated in abstract.	4
16. Garcia-Criado A, Gilabert R, Nicolau C, et al. Value of Doppler sonography for predicting clinical outcome after renal artery revascularization in atherosclerotic renal artery stenosis. *J Ultrasound Med.* 2005;24(12):1641-1647.	Observational-Dx	36 patients	To prospectively evaluate the usefulness of Doppler US for predicting blood pressure and renal function improvement after percutaneous renal angioplasty in patients with unilateral atherosclerotic RAS.	In 20/36 patients (55%), the RI was <0.80 before revascularization. After treatment, blood pressure improved in 17 (85%) of those 20 patients and improved in 8 (50%) of 16 patients with an RI of >0.80 (*P*<.05). 25 patients had renal insufficiency pretreatment, and 11 (44%) had a baseline RI of <0.80. Improvement in renal function after angioplasty was shown in 5 (45%) of these 11 patients and in 4 (28.5%) of 14 in the group with high RI (*P*>.05, not significant). On analysis of acceleration, blood pressure improved in 9 (69%) of 13 patients with acceleration of >3 m/s(2) and in 16 (69.5%) of 23 with acceleration of <3 m/s(2) (*P*>.05). In patients with renal insufficiency, 5 (50%) of 10 cases with normal baseline acceleration and 4 (27%) of 15 with low acceleration showed improvement in renal function (*P*>.05).	2
17. Krumme B, Hollenbeck M. Doppler sonography in renal artery stenosis--does the Resistive Index predict the success of intervention? *Nephrol Dial Transplant.* 2007;22(3):692-696.	Review/Other-Dx	N/A	To comment on the contradictory findings of recent papers and to shed some light on the mystification of intrarenal RI, with special attention paid to its use as a predictive parameter for the outcome of intervention in patients with RAS.	The current controversy must be solved by further studies.	4

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18. Chi YW, White CJ, Thornton S, Milani RV. Ultrasound velocity criteria for renal in-stent restenosis. *J Vasc Surg.* 2009;50(1):119-123.	Observational-Dx	67 patients with renal stents and 55 patients without renal stents	To determine Duplex US criteria for renal artery in-stent restenosis.	In the 67 patients with renal stents and 55 patients without renal stents, a statistically significant correlation was found for both PSV and RAR in detecting renal in-stent restenosis and RAS as defined by quantitative angiography (*P*=.02). For any level of angiographic stenosis ≥50%, the in-stent restenosis group had relatively higher PSV and RAR compared with the nonstented group. ROC curves indicated that PSV ≥395 cm/s or RAR ≥5.1 were the most predictive of angiographically significant in-stent restenosis ≥70%.	3
19. Del Conde I, Galin ID, Trost B, et al. Renal artery duplex ultrasound criteria for the detection of significant in-stent restenosis. *Catheter Cardiovasc Interv.* 2014;83(4):612-618.			To define velocity criteria by US for the detection of hemodynamically significant (>60%) renal artery in-stent restenosis.	A cohort of 132 stented renal arteries that had angiographic comparisons was analyzed. 88 renal arteries demonstrated 0%–59% stenosis while 44 renal arteries revealed 60%–99% stenosis by angiography. Both the mean PSV and the RAR were significantly higher in renal arteries with 60%–99% restenosis compared with those with 0%–59% restenosis (PSV: 382 cm/sec +/- 128 vs 129 cm/sec +/- 62, *P*<0.001; RAR: 5.3 +/- 2.4 vs 2.1 +/- 1.0, *P*<0.001). The optimal PSV and RAR cutoffs for detecting 60%–99% in-stent restenosis were calculated by ROCs curve analysis. The velocity criteria that are associated with these results will be discussed.	

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20. 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
21. 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.	Meta-analysis	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, 3D MRA performed significantly better than the other diagnostic tests. CTA and gadolinium-enhanced 3D 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.	M
22. 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 5, and did not change in 13 patients.	4

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23. Bolduc JP, Oliva VL, Therasse E, et al. Diagnosis and treatment of renovascular hypertension: a cost-benefit analysis. *AJR Am J Roentgenol.* 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 RI 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
24. 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
25. 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

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26. Soulez G, Therasse E, Qanadli SD, et al. Prediction of clinical response after renal angioplasty: respective value of renal Doppler sonography and scintigraphy. *AJR Am J Roentgenol.* 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 RI of <0.65 (OR = 3.7) after captopril administration and a kidney longer than 93 mm (OR = 7.8). The 2 best combined criteria to predict the favorable therapeutic outcome were a bilateral RI of <0.75 before captopril administration combined with a unilateral RI of <0.70 after captopril administration (sensitivity, 76%; specificity, 58%) or a bilateral RI 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 RIs before and after captopril administration were useful in predicting the outcome after renal angioplasty. Renal scintigraphy had no significant predictive value.	3
27. 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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28. 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
29. 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
30. 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 noncontrast 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 nonenhanced MRA for all the readers.	1
31. 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 successfully had DSA; 3 reviewers	Multicenter, blinded, prospective study to determine the accuracy of contrast-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 MRA examinations (1.9%–2.8%) were technically inadequate. Interobserver agreement for detection of significant steno-occlusive disease was good (79.9% agreement).	1

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32. 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.	Meta-analysis	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 nonenhanced MRA and 499 with gadolinium-enhanced MRA. The sensitivity and specificity of nonenhanced 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 PPV 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 nongadolinium MRA (49%; 95% CI: 42%–60%) (P<0.001).	M
33. Solar M, Zizka J, Krajina A, et al. Comparison of duplex ultrasonography and magnetic resonance imaging in the detection of significant renal artery stenosis. *Acta Medica (Hradec Kralove).* 2011;54(1):9-12.	Observational-Dx	94 patients	To evaluate duplex US and MRA in detection of hemodynamically significant RAS.	Arterial supply of 186 kidneys in 94 patients was evaluated. DSA revealed significant RAS in 61 kidneys evaluated. Duplex US was not able to examine arterial supply in 18 kidneys of 13 patients. In the detection of significant RAS, duplex US was characterized by sensitivity and specificity of 85% and 84%. MRA achieved satisfactory imaging quality in all but 1 kidney evaluated. The sensitivity and specificity of MRA in the detection of significant RAS was 93% and 93%, respectively.	2
34. Gloviczki ML, Lerman LO, Textor SC. Blood oxygen level-dependent (BOLD) MRI in renovascular hypertension. *Curr Hypertens Rep.* 2011;13(5):370-377.	Review/Other-Dx	N/A	To describe how BOLD MRI methods can allow functional evaluation of regional differences in deoxyhemoglobin levels within the kidney.	No results stated in abstract.	4
35. Gloviczki ML, Saad A, Textor SC. Blood oxygen level-dependent (BOLD) MRI analysis in atherosclerotic renal artery stenosis. *Curr Opin Nephrol Hypertens.* 2013;22(5):519-524.	Review/Other-Dx	N/A	To outline the specifics of renal oxygenation and perfusional, and summarize the fundamentals of BOLD-MRI.	No results stated in abstract.	4

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
36. Niendorf T, Pohlmann A, Arakelyan K, et al. How bold is blood oxygenation level-dependent (BOLD) magnetic resonance imaging of the kidney? Opportunities, challenges and future directions. *Acta Physiol (Oxf).* 2015;213(1):19-38.	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 1 or more urinary abnormalities was noted in 0.95%. Initial review of case reports revealed 6 participants with hypertension secondary to use of birth control pills and 3 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, 1 participant with renovascular disease and 3 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, 1 was positive, and 2 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
37. Wang Y, Truong TN, Yen C, et al. Quantitative evaluation of susceptibility and shielding effects of nitinol, platinum, cobalt-alloy, and stainless steel stents. *Magn Reson Med.* 2003;49(5):972-976.	Experimental-Dx	5 stents	To quantitatively estimate the shielding and susceptibility effects of commonly used metallic stents on MR signal.	The factor characterizing susceptibility effects was estimated from the signal phase of the first experiment, and then the factor characterizing the shielding effects was derived from the second experiment. Susceptibility induced signal loss was negligible (<1%) for nonstainless-steel (nitinol, platinum, and cobalt-alloy) stents and totally destructive (100%) for the stainless steel stent. Signal loss due to RF shielding was 31%–62% for nitinol stents, 14%–50% for platinum stents, 50%–77% for the cobalt-alloy stents (undetermined for the stainless steel stent), varied with stent orientation, diameter, and wall geometry.	2

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
38. Buecker A, Spuentrup E, Ruebben A, Gunther RW. Artifact-free in-stent lumen visualization by standard magnetic resonance angiography using a new metallic magnetic resonance imaging stent. *Circulation.* 2002;105(15):1772-1775.	Experimental-Dx	6 pigs	To investigate the potential of a new dedicated renal MRI stent for artifact-free in-stent lumen visualization in vitro and in a swine model.	Renal arteries were examined with phase-contrast angiography and with flow measurements before and after stent placement in the stented area, respectively. Additionally, a contrast-enhanced, T1-weighted, spoiled-gradient echo sequence after administration of 0.2 mmol gadolinium-diethylenetiamine pentaacetic acid /kg body weight was performed after stent placement. The visibility of artifacts was analyzed on in vitro and in vivo images by 2 investigators who knew the stent positions. Stent positions were determined visually (in vitro) or by x-ray angiography (animal experiments). No artifacts were detected independent of the applied imaging sequence and the stent orientation to the main magnetic field.	2
39. Spuentrup E, Ruebben A, Stuber M, Gunther RW, Buecker A. Metallic renal artery MR imaging stent: artifact-free lumen visualization with projection and standard renal MR angiography. *Radiology.* 2003;227(3):897-902.	Experimental-Dx	6 pigs	To evaluate a dedicated metallic renal artery stent for artifact-free in-stent lumen visualization by using 2 MRA imaging techniques, projection balanced fast filled echo MRA and standard contrast-enhanced MRA.	Artifact-free in-stent lumen visualization was achieved with both projection MRA and contrast-enhanced MRA.	2
40. 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-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 MRA 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 CTA was 91% for reader 1 and 92% for reader 2, and specificity was 99% and 99%, respectively. Differences between the 2 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 CTA (P=.016).	1

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
41. 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 Am J Roentgenol.* 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). 16 had significant (>50% in diameter) stenosis. On helical CTA, 14 of these 16 stenoses were detected; 2 were missed (false-negatives), and 2 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 CTA were 100% and 98%, respectively. Helical CTA detected Conn's syndrome, which was responsible for hypertension, in 2 other patients.	2
42. 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 2 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
43. 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

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
44. 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
45. Francois CJ. Noninvasive imaging workup of patients with vascular disease. *Surg Clin North Am.* 2013;93(4):741-760, vii.	Review/Other-Dx	N/A	To provide an introduction to the use of radiography, US, CT, and MRI for commonly encountered diseases of the aorta, mesenteric arteries, and renal arteries, focusing on how the acuity of presentation and likelihood of disease affects the workup of patients with known or suspected vascular disease.	No results stated in abstract.	4
46. 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 Am J Roentgenol.* 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 3 volume-rendering techniques with DSA and multiplanar volume reformations.	8 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
47. 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
48. 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. 2 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%. 1 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

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
49. 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 3 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
50. 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 nonstenotic 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
51. 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% CI, 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
52. 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.	2 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 2 observers. Of the 13 patients with significant lesions, Observer I identified at least 1 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

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
53. Illescas FF, Ford K, Braun SD, Dunnick NR. Intraarterial digital subtraction angiography in hypertensive azotemic patients. *AJR Am J Roentgenol.* 1984;143(5):1065-1067.	Review/Other-Dx	10 intra-arterial 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
54. 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
55. 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
56. 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
57. 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

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
58. 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
59. 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

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
60. Davenport MS, Khalatbari S, Cohan RH, Dillman JR, Myles JD, Ellis JH. Contrast material-induced nephrotoxicity and intravenous low-osmolality iodinated contrast material: risk stratification by using estimated glomerular filtration rate. *Radiology.* 2013;268(3):719-728.	Review/Other-Dx	17,652 patients	To determine the effect of IV low-osmolality iodinated contrast material on the development of post-CT AKI, stratified by pre-CT eGFR, in patients with stable renal function.	After 1:1 propensity matching, IV low-osmolality iodinated contrast material had a significant effect on the development of post-CT AKI (*P*=.04). This risk increased with decreases in pre-CT eGFR (≥60 mL/min/1.73 m(2): OR, 1.00; 95% CI: 0.86, 1.16; 45-59 mL/min/1.73 m(2): OR, 1.06; 95% CI: 0.82, 1.38; 30-44 mL/min/1.73 m(2): OR, 1.40; 95% CI: 1.00, 1.97; <30 mL/min/1.73 m(2): OR, 2.96; 95% CI: 1.22, 7.17).	4
61. Davenport MS, Khalatbari S, Dillman JR, Cohan RH, Caoili EM, Ellis JH. Contrast material-induced nephrotoxicity and intravenous low-osmolality iodinated contrast material. *Radiology.* 2013;267(1):94-105.	Review/Other-Dx	20,242 patients	To determine whether IV low-osmolality iodinated contrast material is associated with post-CT AKI.	IV low-osmolality iodinated contrast material had a significant effect on the development of post-CT AKI for patients with pre-CT serum creatinine levels of 1.6 mg/dL (141.44 mumol/L) or greater (OR, 1.45; 95% CI: 1.11, 1.89; *P*=.007). This effect strengthened as pre-CT serum creatinine increased. Patients with stable serum creatinine <1.5 mg/dL (132.60 mumol/L) were not at risk for developing contrast material–induced nephrotoxicity (*P*=.25, power >95%). Both endpoints demonstrated similar results (eg, serum creatinine ≥1.6 mg/dL [141.44 mumol/L] by using traditional contrast material–induced nephrotoxicity criteria: OR, 1.64; 95% CI: 1.18, 2.28; *P*=.003). Post-CT AKI was prevalent in both the unenhanced and contrast-enhanced CT subgroups, and it increased with increases in pre-CT serum creatinine. Many risk factors contributed to development of post-CT AKI, regardless of iodinated contrast material.	4

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
62. McDonald JS, McDonald RJ, Carter RE, Katzberg RW, Kallmes DF, Williamson EE. Risk of intravenous contrast material-mediated acute kidney injury: a propensity score-matched study stratified by baseline-estimated glomerular filtration rate. *Radiology.* 2014;271(1):65-73.	Review/Other-Dx	12,508 patients	To determine the effect of baseline eGFR on the causal association between IV iodinated contrast material exposure and subsequent development of AKI in propensity score-matched groups of patients who underwent contrast material-enhanced or unenhanced CT.	A total of 12,508 propensity score-matched patients with contrast-enhanced and unenhanced scans met all inclusion criteria. In this predominantly inpatient cohort, the incidence of AKI significantly increased with decreasing baseline eGFR (*P*<.0001). However, this incidence was not significantly different between contrast material and noncontrast material groups in any eGFR subgroup; for the subgroup with eGFR of 90 or greater (n = 1642), OR was 0.91 (95% CI: 0.38, 2.15), *P*=.82; for the subgroup with eGFR of 60-89 (n = 3870), OR was 1.03 (95% CI: 0.66, 1.60), *P*=.99; for the subgroup with eGFR of 30-59 (n = 5510), OR was 0.94 (95% CI: 0.76, 1.18), *P*=.65; and for the subgroup with eGFR of <30 mL/min/1.73 m(2) (n = 1486), OR was 0.97 (95% CI: 0.72, 1.30), *P*=.89.	4
63. McDonald RJ, McDonald JS, Bida JP, et al. Intravenous contrast material-induced nephropathy: causal or coincident phenomenon? *Radiology.* 2013;267(1):106-118.	Review/Other-Dx	157,140 scans among 53,439 unique patients	To determine the causal association and effect of IV iodinated contrast material exposure on the incidence of AKI, also known as contrast material-induced nephropathy.	A total of 157,140 scans among 53,439 unique patients associated with 1,510,001 serum creatinine values were identified. AKI risk was not significantly different between contrast and noncontrast groups in any risk subgroup after propensity score adjustment by using reported risk factors of contrast material–induced nephrotoxicity (low risk: OR, 0.93; 95% CI: 0.76, 1.13; *P*=.47; medium risk: OR, 0.97; 95% CI: 0.81, 1.16; *P*=.76; high risk: OR, 0.91; 95% CI: 0.66, 1.24; *P*=.58). Counterfactual analysis revealed no significant difference in AKI incidence between enhanced and unenhanced CT scans in the same patient (McNemar test: chi(2) = 0.63, *P*=.43) (OR = 0.92; 95% CI: 0.75, 1.13; *P*=.46).	4

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
64. 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 noncontrast enhanced MRA might provide sufficient information of RAS.	The significant RAS was visually evaluated by comparing noncontrast 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 noncontrast 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%. Noncontrast MRA is a noninvasive and effective method that allows evaluation of the RAS.	3
65. 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 Am J Roentgenol.* 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 (? = 0.51; $P<0.001$), but in only 1 case (1.3%) we found mismatch of more than 1 severity stenosis grade (stenoses >75%). Sensitivity, specificity, and PPV and NPV of unenhanced MRA to detect renal artery stenoses >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
66. Braidy C, Daou I, Diop AD, et al. Unenhanced MR angiography of renal arteries: 51 patients. *AJR Am J Roentgenol.* 2012;199(5):W629-637.	Observational-Dx	51 patients	To assess the feasibility and performance of an unenhanced 3D balanced steady-state free precession sequence, compared with contrast-enhanced MRA, which is the reference standard to detect and quantify RAS.	Evaluation involved 114 renal arteries, 51 celiac trunks, and 51 SMAs. By use of contrast-enhanced MRA, 20 significant stenoses were found for renal arteries, 10 stenoses and 3 occlusions for celiac trunk, and 3 stenoses for SMA. At artery-by-artery analysis, sensitivity, specificity, accuracy, and NPV of the balanced steady-state free precession sequence in detecting stenosis were respectively 85%, 96%, 94%, and 96% for renal arteries; 100%, 97%, 98%, and 100% for celiac trunk; and 100%, 100%, 100%, and 100% for SMA. No significant difference of signal quality was found for the entire examination and for the different segments evaluated except for hilar and intrarenal branches, which showed better signal quality on balanced steady-state free precession sequence.	3
67. Albert TS, Akahane M, Parienty I, et al. An international multicenter comparison of time-SLIP unenhanced MR angiography and contrast-enhanced CT angiography for assessing renal artery stenosis: the renal artery contrast-free trial. *AJR Am J Roentgenol.* 2015;204(1):182-188.	Experimental-Dx	75 patients	To assess determine if time-SLIP unenhanced MRA is accurate and robust for assessing the renal arteries for stenosis in comparison with contrast-enhanced CTA.	Unenhanced MRA image quality was excellent for 56/75 patients (75%) and good for 16/75 patients (21%). CTA was used as the reference standard and showed that 23/161 renal arteries (14.3%) had stenosis >50%. Unenhanced MRA correctly classified 17 of the 23 renal arteries with >50% stenosis and correctly classified 128 of the 138 renal arteries as not having disease (≤50% stenosis) to yield a sensitivity of 74%, specificity of 93%, and accuracy of 90% (chi(2) = 0.56; *P*=0.45, no statistically significant difference). Of the 16 misclassified arteries, only 3 had a clinically relevant misclassification (CTA ≥70% stenosis and unenhanced MRA ≤50% stenosis or unenhanced MRA ≥70% stenosis and CTA ≤50% stenosis). On average, measured stenotic severity (n = 28 arteries) was similar for unenhanced MRA (64% +/- 17%) and CTA (62% +/- 16%) (*P*=0.51).	1

Renovascular Hypertension
EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
68. Caridi JG, Stavropoulos SW, Hawkins IF, Jr. CO2 digital subtraction angiography for renal artery angioplasty in high-risk patients. *AJR Am J Roentgenol.* 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). 4 kidney transplantation patients had ostial stenosis and the remaining 17 patients had nonostial stenosis. For all patients except 1, 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). 1 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

Renovascular Hypertension
EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
69. 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. 1 patient with acute and chronic rejection of a renal transplant and 1 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
70. American College of Radiology. ACR Appropriateness Criteria® Radiation Dose Assessment Introduction. Available at: http://www.acr.org/~/media/ACR/Documents/AppCriteria/RadiationDoseAssessmentIntro.pdf. Accessed March 1, 2017.	Review/Other-Dx	N/A	Guidance document on exposure of patients to ionizing radiation.	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.
- M = Meta-analysis

Dx = Diagnostic

Tx = Treatment

Abbreviations Key

ACEI = Angiotensin converting enzyme inhibition

AKI = Acute kidney injury

BOLD = Blood oxygen level-dependent

CI = Confidence interval

CT = Computed tomography

CTA = Computed tomography angiography

DSA = Digital subtraction angiography

ECG = Electrocardiogram

eGFR = Estimated glomerular filtration rate

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

OR = Odds ratio

PPV = Positive predictive value

PSV = Peak systolic velocity

PTA = Percutaneous transluminal angioplasty

RAR = Renal artery-to-aortic ratio

RAS = Renal artery stenosis

RI = Resistive index

ROC = Receiver-operator characteristic

SD = Standard deviation

US = Ultrasound