Renal Transplant Dysfunction
EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
1. Elsayes KM, Menias CO, Willatt J, Azar S, Harvin HJ, Platt JF. Imaging of renal transplant: utility and spectrum of diagnostic findings. *Curr Probl Diagn Radiol.* 2011;40(3):127-139.	Review/Other-Dx	N/A	To present a multi-modality review of the spectrum of pathology related to renal transplantation.	No results stated in abstract.	4
2. OPTN/SRTR: Transplant Data 1988-2015. Available at: http://optn.transplant.hrsa.gov/converge/latestData/rptData.asp.	Review/Other-Dx	N/A	Transplant data are analyzed and explained by experts in transplantation.	No results stated.	4
3. Dubovsky EV, Russell CD, Erbas B. Radionuclide evaluation of renal transplants. *Semin Nucl Med.* 1995;25(1):49-59.	Review/Other-Dx	N/A	Review imaging of renal transplants. The article is an update of a more comprehensive previous review (Semin Nucl Med, 181-198, 1988) and emphasizes the changes that have taken place in this field in recent years.	Changes in renal transplant comprise new criteria for the selection of transplant candidates, newer techniques for the diagnosis of medical and surgical complications after transplantation, the use of new tracers (Tc-99m MAG3), and new antirejection regimens.	4
4. Sharfuddin A. Imaging evaluation of kidney transplant recipients. *Semin Nephrol.* 2011;31(3):259-271.	Review/Other-Dx	N/A	To discuss the evaluation of the kidney transplant recipient using these imaging procedures, emphasizing the clinical diagnostic utility and role of each modality.	No results stated in abstract.	4
5. Zarzour JG, Lockhart ME. Ultrasonography of the Renal Transplant. *Ultrasound Clinics.* 2014;9(4):683-695.	Review/Other-Tx	N/A	To review the most common complications affecting the renal transplant, including vascular abnormalities, graft dysfunction (including the use of novel techniques), peritransplant fluid collections, nonvascular urologic complications, and concerns regarding neoplastic risks.	No results stated in abstract.	4
6. Dimitroulis D, Bokos J, Zavos G, et al. Vascular complications in renal transplantation: a single-center experience in 1367 renal transplantations and review of the literature. *Transplant Proc.* 2009;41(5):1609-1614.	Review/Other-Tx	1367 consecutive renal transplantations	To present our single-center experience concerning vascular complications in 1367 consecutive renal transplantations.	We encountered 38 major vascular complications leading to graft loss and 19 transplant renal artery stenoses with successful treatment in the majority of cases. According to these data, we can conclude that renal transplantation is a safe therapeutic procedure for renal failure.	4

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7. Eufrasio P, Parada B, Moreira P, et al. Surgical complications in 2000 renal transplants. *Transplant Proc.* 2011;43(1):142-144.	Review/Other-Tx	318 patients	To evaluate surgical complications among a large series of 2000 renal transplantations.	Among 318 (15.9%) surgical complications, 4.8% of patients had urologic problems. Ureteral stenosis and fistula, stent obstruction, and ureteral necrosis occurred in 2.7%, 1.8%, 0.1%, and 0.2% of patients, respectively. Vascular complications reported in 2.7% of patients included arterial or venous thrombosis (1.0% or 0.4%), both arterial and venous thrombosis (0.1%), renal infarction (0.1%), renal artery aneurysm (0.1%) as well as arterial stenosis (0.5%), kinking (0.4%), or dissection (0.1%). Other complications, not specifically related with transplantation surgery, occurred in 4.4% of patients.	4
8. Akbar SA, Jafri SZ, Amendola MA, Madrazo BL, Salem R, Bis KG. Complications of renal transplantation. *Radiographics.* 2005;25(5):1335-1356.	Review/Other-Dx	N/A	To present both the clinical and imaging features of renal transplantation complications and their interventional management.	Urologic and vascular complications may occur. Vascular complications include renal artery stenosis and renal artery and renal vein thrombosis. US can accurately depict and characterize many of the potential complications of renal transplantation and increasingly magnetic resonance imaging also facilitates this role. In addition, interventional radiologic techniques allow nonsurgical treatment.	4
9. Sharfuddin A. Renal relevant radiology: imaging in kidney transplantation. *Clin J Am Soc Nephrol.* 2014;9(2):416-429.	Review/Other-Dx	N/A	To discuss the evaluation of the kidney transplant recipient using these imaging procedures, emphasizing the clinical diagnostic utility and role of each modality.	No results stated in abstract.	4
10. Brown ED, Chen MY, Wolfman NT, Ott DJ, Watson NE, Jr. Complications of renal transplantation: evaluation with US and radionuclide imaging. *Radiographics.* 2000;20(3):607-622.	Review/Other-Dx	N/A	Review the general surgical techniques of renal transplantation as a basis for understanding potential complications. The most common complications are described, and their appearances on US and radionuclide images are illustrated.	Radionuclide imaging is the most useful modality for assessing renal function. Vascular complications of transplantation include occlusion or stenosis of the arterial or venous supply, arteriovenous fistulas, and pseudoaneurysms. Although the standard for evaluating these vascular complications is angiography, US is an excellent noninvasive method for screening. Other transplant complications such as abnormalities of the collecting system and renal parenchyma are well-evaluated with both radionuclide imaging and US.	4

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11. Buckley AR, Cooperberg PL, Reeve CE, Magil AB. The distinction between acute renal transplant rejection and cyclosporine nephrotoxicity: value of duplex sonography. *AJR Am J Roentgenol.* 1987;149(3):521-525.	Observational-Dx	119 exams in106 patients with normally functioning renal transplants 65 exams in 34 patients with renal transplant dysfunction	To determine the role of pulsed Doppler flow analysis (duplex US) in differentiating acute rejection from cyclosporine nephrotoxicity.	In the healthy control subject, the diastolic/systolic velocity ratios varied in the different arterial segments, ranging from a mean of 0.23 in the segmental arteries to a mean of 0.32 in the arcuate arteries. 17 patients experienced acute rejection: 8/9 with acute vascular rejection had abnormal Doppler ratios; 8 patients with acute cellular rejection had normal ratios. 9 patients with cyclosporine nephrotoxicity all had normal duplex scans. 7 patients with chronic rejection had normal ratios. One patient with hemolytic-uremic syndrome had an abnormal flow pattern. Findings indicate that duplex US may be useful in differentiating acute vascular rejection from cyclosporine nephrotoxicity in the transplanted kidney.	3
12. Steinberg HV, Nelson RC, Murphy FB, et al. Renal allograft rejection: evaluation by Doppler US and MR imaging. *Radiology.* 1987;162(2):337-342.	Observational-Dx	38 renal allograft recipients, 43 Doppler US and 42 MRI exams	Prospective study to compare the efficacy of Doppler US and MRI in evaluating renal allografts, with specific attention to transplant rejection.	Doppler US was significantly superior to MRI in identifying allograft rejection, demonstrating a higher sensitivity (95% vs 70%), specificity (95% vs 73%), and accuracy (95% vs 71%). Because of its low cost and accessibility, Doppler US should become the primary modality for renal transplant screening.	2
13. Rifkin MD, Needleman L, Pasto ME, et al. Evaluation of renal transplant rejection by duplex Doppler examination: value of the resistive index. *AJR Am J Roentgenol.* 1987;148(4):759-762.	Observational-Dx	81 patients 145 exams	To evaluate the ability of the duplex Doppler examination and RI to identify patients with acute rejection.	With a RI >0.90, a 100% PPV was obtained for the diagnosis of acute rejection. A value <0.70 was unlikely to be rejection (NPV, 94%). This approach uses a simple analysis of the waveform. Use of a duplex Doppler examination and the formula described here appears to be an accurate method for the detection of acute rejection and for the differentiation of acute rejection from the various other causes of acute renal failure.	3

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
14. Genkins SM, Sanfilippo FP, Carroll BA. Duplex Doppler sonography of renal transplants: lack of sensitivity and specificity in establishing pathologic diagnosis. *AJR Am J Roentgenol.* 1989;152(3):535-539.	Observational-Dx	77 US exams in 77 renal transplants	Combined retrospective and prospective analysis of duplex Doppler examinations performed over a 2-year period to assess the value of such studies in evaluating renal allograft dysfunction.	When a RI of ≥0.9 was used to indicate acute rejection, US had a sensitivity of only 9% and a specificity of 91% for this diagnosis. In 1/8 cases of cyclosporine, a toxicity and in 3 of 6 examples of ATN, the RI was >0.9. In all 6 instances of chronic rejection, the RI was <0.84. None of 8 patients with evidence of infection had a RI >0.9. The RI range of 12 normally functioning allografts was 0.57-0.69. Correlation between the RI and the severity of arterial and arteriolar changes on biopsy was poor. An increased RI of renal transplant blood flow, as measured by duplex Doppler US, usually signals pathologic changes in an allograft. However, the data indicate that this test is not as sensitive or specific in identifying the cause of transplant dysfunction as has been suggested previously.	2
15. Radermacher J, Mengel M, Ellis S, et al. The renal arterial resistance index and renal allograft survival. *N Engl J Med.* 2003;349(2):115-124.	Observational-Dx	601 patients	To determine whether a renal arterial resistance index of <80 was predictive of long-term allograft survival.	A renal arterial resistance index of 80 or higher measured at least 3 months after transplantation is associated with poor subsequent allograft performance and death.	3
16. McArthur C, Geddes CC, Baxter GM. Early measurement of pulsatility and resistive indexes: correlation with long-term renal transplant function. *Radiology.* 2011;259(1):278-285.	Observational-Dx	178 consecutive patients	Retrospective study to correlate PI and RI measured at early specific intervals after transplantation with 1-year eGFR and death-censored transplant survival to assess the long-term prognostic value of these Doppler indexes.	Within 1 week after transplantation, there was a significant association between PI and 1-year eGFR when analyzed as tertiles (P=.02). Between 1 week and 3 months after transplantation, there was a significant relationship between 1-year eGFR and both PI and RI when comparing the lowest and highest tertiles (47.5 mL/min/1.73 m(2) for PI <1.26 vs 32.7 mL/min/1.73 m(2) for PI >1.49 [P=.01], 42.8 mL/min/1.73 m(2) for RI <0.69 vs 32.3 mL/min/1.73 m(2) for RI >0.74 [P=.03]). Both PI and RI were independent predictors of death-censored transplant survival (HR, 1.68 per unit [P<.001] and 260.4 per unit, respectively [P=.02]). PI and RI in the early post-transplantation period correlate with long-term transplant function and can potentially be used as prognostic markers to aid risk stratification for future transplant dysfunction.	2

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17. Naesens M, Heylen L, Lerut E, et al. Intrarenal resistive index after renal transplantation. *N Engl J Med.* 2013;369(19):1797-1806.	Observational-Dx	321 patients	To evaluate the prognostic performance of the intrarenal RI with regard to graft function and patient and graft survival in the first years after kidney transplantation.	Allograft recipients with a RI of at least 0.80 had higher mortality than those with a RI of <0.80 at 3, 12, and 24 months after transplantation (HR, 5.20 [95% CI, 2.14 to 12.64; *P*<0.001]; 3.46 [95% CI, 1.39 to 8.56; *P*=0.007]; and 4.12 [95% CI, 1.26 to 13.45; *P*=0.02], respectively). The need for dialysis did not differ significantly between patients with a RI of at least 0.80 and those with a RI of <0.80 at 3, 12, and 24 months after transplantation (HR, 1.95 [95% CI, 0.39 to 9.82; *P*=0.42]; 0.44 [95% CI, 0.05 to 3.72; *P*=0.45]; and 1.34 [95% CI, 0.20 to 8.82; *P*=0.76], respectively). At protocol-specified biopsy time points, the RI was not associated with renal-allograft histologic features. Older recipient age was the strongest determinant of a higher RI (*P*<0.001). At the time of biopsies performed because of graft dysfunction, antibody-mediated rejection or ATN, as compared with normal biopsy results, was associated with a higher RI (0.87 +/- 0.12 vs 0.78 +/- 0.14 [*P*=0.05], and 0.86 +/- 0.09 vs 0.78 +/- 0.14 [*P*=0.007], respectively).	2

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18. Baxter GM, Ireland H, Moss JG, et al. Colour Doppler ultrasound in renal transplant artery stenosis: which Doppler index? *Clin Radiol.* 1995;50(9):618-622.	Observational-Dx	106 patients	Prospective study comparing CDUS with the 'gold standard' of IA-DSA in the evaluation of renal transplant artery stenosis was performed.	Of 106 patients, 31 had a PSV >1.5 ms-1 in the transplant renal artery and were referred for DSA. Of the multiple renal Doppler indices recorded, the PSV in the transplant artery was the best discriminating measurement for the detection of RAS. A PSV of ≥2.5 ms-1 in the transplant renal artery had a sensitivity of 100% and a specificity of 95% for the detection of RAS (>50% diameter reduction). Although a significant difference in PI, RI, Acceleration Index and Acceleration Time was recorded from the intrarenal vessels in the angiographically normal and stenosed groups with Doppler, these measurements were less useful as discriminating diagnostic tests. The PSV in the transplant renal artery is the most sensitive Doppler criterion for RAS and is sensitive and specific enough to be used as a screening test. The intrarenal acceleration time and index should not be used in isolation.	3
19. Krumme B, Grotz W, Kirste G, Schollmeyer P, Rump LC. Determinants of intrarenal Doppler indices in stable renal allografts. *J Am Soc Nephrol.* 1997;8(5):813-816.	Observational-Dx	110 patients	Analysis of potential determinants of Doppler resistance parameters in patients with stable renal allografts to determine whether Doppler indices may be useful in gaining information about graft integrity.	In multivariate regression analysis, RI and PI correlated significantly with age and arterial pulse pressure of the recipient. There was no correlation with donor age, heart rate, mean arterial blood pressure, and cyclosporine trough levels. Furthermore, parameters of kidney function, such as serum creatinine concentration, creatinine clearance rate, 51Cr-ethylenediaminetetraacetate clearance rate, and proteinuria, showed no significant correlation with the Doppler indices. The data indicate that intrarenal Doppler indices of the grafts are hemodynamic indices, primarily depending on the recipient-related vascular compliance rather than on the function of the graft. Therefore, only intraindividual comparison of the Doppler indices may be useful to detect potential changes of graft resistance during long-term follow-up.	3

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20. Patel U, Khaw KK, Hughes NC. Doppler ultrasound for detection of renal transplant artery stenosis-threshold peak systolic velocity needs to be higher in a low-risk or surveillance population. *Clin Radiol.* 2003;58(10):772-777.	Observational-Dx	117 patients	To establish the ideal threshold arterial velocity for the diagnosis of renal transplant artery stenosis in a surveillance population with a low pre-test probability of stenosis.	Of 144 patients transplanted, full data were available in 117 cases. 5 cases had renal transplant artery stenosis-incidence 4.2% [stenosis identified at a mean of 6.5 months (range 2-10 months)]. All 5 cases had a significant arterial pressure gradient across the narrowing and underwent angioplasty. Threshold PSV of ≥2.5 m/s is not ideal [specificity=79% (CI 65%–82%), PPV=18% (CI 6%–32%), NPV=100% (CI 94%–100%)], subjecting many patients to unnecessary angiography-8/117 (6%) in our population. Comparable values if the threshold is set at ≥3.0 m/s are 93% (CI 77-96%), 33% (CI 7%–44%) and 99% (CI 93%–100%), respectively. The clinical outcome of all patients was satisfactory, with no unexplained graft failures or loss.	3
21. de Morais RH, Muglia VF, Mamere AE, et al. Duplex Doppler sonography of transplant renal artery stenosis. *J Clin Ultrasound.* 2003;31(3):135-141.	Observational-Dx	22 patients suspected to have TRAS (10 without and 12 with confirmed significant stenosis) and 19 controls	To evaluate the accuracy of duplex Doppler US in diagnosing TRAS and to determine which parameter is the most reliable for making that diagnosis.	The most accurate parameters to use in diagnosing TRAS were an acceleration time of 0.1 second or higher in the renal and intrarenal arteries, a PSV of >200 cm/sec in the renal artery, and a ratio of PSVs in the renal and external iliac arteries of >1.8. Duplex Doppler US is an excellent method for screening patients suspected to have TRAS and can help select which of those patients should undergo digital subtraction arteriography.	2
22. 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 renal duplex US vs angiography and assess various published Doppler criteria to detect significant RAS.	The mean PSVs and renal-to-aortic ratios 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 renal-to-aortic ratio 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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23. Baxter GM. Imaging in renal transplantation. *Ultrasound Q.* 2003;19(3):123-138.	Review/Other-Dx	N/A	Review of the use/value of imaging in renal transplants.	Renal transplantation is the best treatment option for chronic renal failure, with marked improvement in social activity, work, and family life. In addition to these obvious improvements, it is an extremely cost-effective procedure when successful. US plays a major role in the imaging of these patients, and US (including color Doppler) is helpful to the transplant physician in detecting graft dysfunction and peritransplant collections, some of which may be drained under US guidance. It is also helpful in the diagnosis of chronic vascular complications including transplant artery stenosis and arteriovenous fistula. It has no specific application in the diagnosis of chronic rejection.	4
24. Baxter GM, Morley P, Dall B. Acute renal vein thrombosis in renal allografts: new Doppler ultrasonic findings. *Clin Radiol.* 1991;43(2):125-127.	Review/Other-Dx	2 patients	Report of 2 cases of histologically proven renal vein thrombosis with an 'inverted M' appearance of the diastolic component of the arterial waveform and postulate this as perhaps being more specific for acute renal vein thrombosis.	Both cases of acute renal vein thrombosis showed absence of venous flow at parenchymal and hilar level. The arterial waveform in both cases was remarkably similar with a steep rise and fall of the systolic component. In addition, however, the reverse diastolic component showed an 'inverted M' appearance, a sign previously undescribed in renal vein thrombosis. Real time US alone showed no textural abnormality or increase in renal size appearances that may occur in renal vein thrombosis.	4
25. Lockhart ME, Wells CG, Morgan DE, Fineberg NS, Robbin ML. Reversed diastolic flow in the renal transplant: perioperative implications versus transplants older than 1 month. *AJR Am J Roentgenol.* 2008;190(3):650-655.	Observational-Dx	59 total patients	To evaluate the causes, waveform morphology, and clinical outcomes of high-resistance reversed diastolic flow in transplanted kidneys.	Acute reversed diastolic flow was associated with higher likelihood of graft survival (P=0.001, Fisher's exact test) compared with reversed diastolic flow discovered in the perioperative or long-term group. In the acute group, hematoma, ATN, renal vein thrombosis, and vascular kink produced reversed diastolic flow. The causes of reversed diastolic flow for the perioperative group were ATN, rejection, and renal vein thrombosis; for the long-term group, reasons for diastolic reversal were rejection, glomerulosclerosis, low cardiac output, and diabetic nephrosclerosis.	3

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26. Glebova NO, Brooke BS, Desai NM, Lum YW. Endovascular interventions for managing vascular complication of renal transplantation. *Semin Vasc Surg.* 2013;26(4):205-212.	Review/Other-Tx	N/A	To review the contemporary diagnosis and treatment of these complications using endovascular techniques.	No results stated in abstract.	4
27. Kashi SH, Lodge JP, Giles GR, Irving HC. Ultrasonography of renal allografts: collecting system dilatation and its clinical significance. *Nephrol Dial Transplant.* 1991;6(5):358-362.	Observational-Dx	135 patients	To evaluate the significance of varying degrees of pelvicalyceal dilatation in the presence of good or poor renal function and the long term sequel of early dilatation of the collecting system.	77 allografts (57%) never showed pelvicalyceal dilatation on 342 serial examinations. 42 kidneys (31%) had mild dilatation reported on at least 1 scan, which did not progress. However, 11 mildly dilated allografts developed moderate to severe dilatation on later examinations and these, together with 5 allografts reported as exhibiting moderate to severe hydronephrosis on their first dilated scan, were classed as moderate to severe (n = 16 = 12%). 38 patients (90%) with mild dilatation of the collecting system had no evidence of obstruction. However, in allografts with moderate to severe dilatation and poor or deteriorating function, 10 patients (70%) were found to have ureteric obstruction. There was no significant difference in 1-year graft survival (87% vs 81.8%) and the median serum creatinine at 3 and 12 months after transplantation between nonobstructed 'dilated' and nondilated allografts (149 mumol/l vs 153.7 mumol/l; 139 mumol/l vs 147.3 mumol/l). All 14 obstructed allografts were salvaged with a graft survival of 85.7% at 1 year. Median serum creatine in these patients was significantly elevated at 200 mumol/l and 189 mumol/l at 3 and 12 months; *P*=0.05 and 0.01 compared to dilated nonobstructed allografts.	3

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28. Furness PN, Philpott CM, Chorbadjian MT, et al. Protocol biopsy of the stable renal transplant: a multicenter study of methods and complication rates. *Transplantation.* 2003;76(6):969-973.	Review/Other-Dx	2,127 biopsy events for major complications and 1,486 events for minor ones	Retrospective audit of a sequential series of protocol biopsies was performed in 4 major transplant centers to determine risk of biopsy of a stable kidney.	The incidence of clinically significant complications after protocol biopsy of a stable renal transplant is low. Direct benefits to the patients concerned (irrespective of the benefit that may accrue in clinical trials) were not formally assessed but seem likely to outweigh the risk of the procedure. Authors believe that it is ethically justifiable to ask renal transplant recipients to undergo protocol biopsies in clinical trials and routine care.	4
29. Schwenger V, Hinkel UP, Nahm AM, Morath C, Zeier M. Real-time contrast-enhanced sonography in renal transplant recipients. *Clin Transplant.* 2006;20 Suppl 17:51-54.	Review/Other-Dx	N/A	Review role of conventional CDUS in diagnosing kidney allograft dysfunction.	CDUS is still limited in interpreting vascular integrity. In contrast-enhanced US is a feasible technique for quantitative analysis of kidney perfusion and early diagnosis of biopsy proven chronic allograft nephropathy. Contrast-enhanced US does not provide only quantitative information on microvascular perfusion of the renal allografts but also represents improved diagnostic significance compared with CDUS for the detection of chronic allograft nephropathy.	4
30. Grzelak P, Szymczyk K, Strzelczyk J, et al. Perfusion of kidney graft pyramids and cortex in contrast-enhanced ultrasonography in the determination of the cause of delayed graft function. *Ann Transplant.* 2011;16(1):48-53.	Observational-Dx	63 patients	To assess the usefulness of a new US technique - contrast-enhanced US examination - using sulphur hexafluoride in the early post-transplant assessment of graft perfusion.	In the examination with contrast-enhanced US in early graft function patients, the regular inflow of contrast medium was demonstrated in all regions of the graft. In patients with delayed graft function, a delay in the inflow of the contrast medium was observed, as well as significant differences in the time of inflow to the regions of interest between those 2 groups. There was a significantly longer inflow time of the contrast medium to the cortex and renal pyramids in patients with acute rejection than in ATN recipients.	2

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31. Grzelak P, Kurnatowska I, Nowicki M, et al. Detection of transplant renal artery stenosis in the early postoperative period with analysis of parenchymal perfusion with ultrasound contrast agent. *Ann Transplant.* 2013;18:187-194.	Observational-Dx	15 patients	To analyze the changes of parenchymal contrast agent perfusion in the kidney graft to detect TRAS in the early post-transplant course.	In patients with TRAS, significantly longer time of contrast agent inflow was observed in comparison to patients without perfusion disturbances (3.47 s vs 1.5 s, $P<0.000$ for cortex; 6.01 vs 2.09 s for pyramids, $P<0.000$). The rate of contrast agent inflow was strongly positively correlated with severity of stenosis assessed on the basis of CTA/MRA examination (R=0.97 for cortex and 0.9 for pyramids; $P<0.001$). 6 months after kidney transplantation, patients with a history of TRAS had significantly higher serum creatinine level than recipients with normal renal artery blood flow (1.76 mg/dL vs 1.53 mg/dL, $P<0.02$). Estimated GFR was decreased to 35.9 ml/min vs 46.5 ml/min, respectively ($P<0.05$).	3
32. Sommerer C, Scharf M, Seitz C, et al. Assessment of renal allograft fibrosis by transient elastography. *Transpl Int.* 2013;26(5):545-551.	Observational-Dx	164 patients and 2 German landrace pigs	To evaluate potentials and limitations of Transient elastography for identifying renal allograft fibrosis.	Kidney stiffness could be determined in all animals at the pole and pars media (29 +/- 10 kPa vs 31 +/- 17 kPa). In human renal allografts kidney stiffness was successfully performed in 94.5% of the test series with reliable results in 72% of the measurements. Mean kidney stiffness at the pole or pars media were comparable (35.0 +/- 19.9 kPa vs 33.2 +/- 18.6 kPa). Significantly higher kidney stiffness was detected in renal allografts with histologically confirmed advanced fibrosis. Body-mass-index, skin-allograft distance, and peri or intrarenal fluid accumulation were important confounders of successful kidney stiffness measurements (body-mass-index: r = -0.31; $P<0.001$; distance: r = -0.50; $P<0.001$). Notably, kidney stiffness did not correlate with renal function.	2
33. Grenier N, Gennisson JL, Cornelis F, Le Bras Y, Couzi L. Renal ultrasound elastography. *Diagn Interv Imaging.* 2013;94(5):545-550.	Review/Other-Dx	N/A	To review the existing US elastography techniques.	Elastography is a new tool under development for renal tissue characterization and needs further validation in clinical practice.	4
34. 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.	N/A	4

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35. Helck A, Bamberg F, Sommer WH, et al. Optimized contrast volume for dynamic CT angiography in renal transplant patients using a multiphase CT protocol. *Eur J Radiol.* 2011;80(3):692-698.	Observational-Dx	36 patients	Prospective, clinically controlled cohort study to examine the feasibility of an optimized multiphase renal-CTA protocol in patients with history of renal transplantation compared with Doppler-US (standard of reference).	Using the best of 12 phases in each patient, optimal attenuation was 353±111 HU, 337±98 HU and 164±51 HU in the iliac arteries, renal arteries, and renal veins, respectively. Mean image quality was 1.1±0.3 (n=36) and 2.1±0.6 (n=30) for the transplant renal arteries and veins, respectively. 6 renal veins were nondiagnostic in multiphase-CTA. In 36 patients, multiphase-CTA showed 13 vascular complications and 10 parenchymal perfusion defects. Doppler US was not assessable in 8 patients. Overall, multiphase-CTA showed 15 cases with pathology (42%) not identifiable with Doppler US. The mean effective radiation dose of the multiphase-CTA protocol was 13.5±5.2mSv. Multiphase-CTA can be sufficiently performed with reduced contrast volume at reasonable radiation dose in renal transplant patients, providing substantially higher diagnostic yield than Doppler US.	3

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
36. Rountas C, Vlychou M, Vassiou K, et al. Imaging modalities for renal artery stenosis in suspected renovascular hypertension: prospective intraindividual comparison of color Doppler US, CT angiography, GD-enhanced MR angiography, and digital substraction angiography. *Ren Fail.* 2007;29(3):295-302.	Observational-Dx	58 patients	To evaluate the diagnostic accuracy of CDUS, CTA, and Gd-enhanced MRA compared with DSA (gold standard) for the detection of RAS in patients with clinically suspected renovascular hypertension.	DSA depicted 132 renal arteries, 16 stenoses, and 4 arteries with fibromuscular dysplasia. CDUS failed to detect 1 main and 14 polar arteries. CTA depicted all main renal arteries and 7/16 polar arteries, but failed to detect stenosis in 2 accessory vessels. Likewise, MRA did not detect stenotic accessory renal arteries, depicted 9/16 polar renal arteries, but missed 2 main renal arteries. All methods depicted the 4 main renal arteries with fibromuscular dysplasia. The overall sensitivity, specificity, and PPV and NPV were 75%, 89.6%, 60% and 94.6%, respectively, for CDUS; 94%, 93%, 71%, and 99%, respectively, for CTA; and 90%, 94.1%, 75%, and 98%, respectively, for Gd-enhanced MRA. CTA and Gd-enhanced MRA have comparable and satisfactory results with respect to the negative predictive accuracy of the suspected RAS. The concept of an imaging algorithm including US as screening test when appropriate and CTA or MRA as the second step-procedure is suggested. Therefore, DSA may be reserved for cases with major discrepancies or therapeutic interventions.	1
37. Gaddikeri S, Mitsumori L, Vaidya S, Hippe DS, Bhargava P, Dighe MK. Comparing the diagnostic accuracy of contrast-enhanced computed tomographic angiography and gadolinium-enhanced magnetic resonance angiography for the assessment of hemodynamically significant transplant renal artery stenosis. *Curr Probl Diagn Radiol.* 2014;43(4):162-168.	Observational-Dx	27 patients	To compare diagnostic accuracy of contrast-enhanced CTA and Gd-enhanced MRA for the assessment of hemodynamically significant TRAS.	The correlation between MRA and DSA measurements of stenosis was r = 0.57 (95% CI:-0.02, 0.87; *P*=0.052) and between CTA and DSA measurements was r = 0.63 (95% CI: 0.14, 0.87; *P*=0.015); the difference between the 2 techniques was not significant (*P*=0.7). Both imaging modalities tended to underestimate the degree of stenosis when compared with DSA. MRA group (sensitivity and specificity: 56% and 100%, respectively) and CTA group (sensitivity and specificity: 81% and 67%, respectively).	2

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
38. Paven G, Waugh R, Nicholson J, Gillin A, Hennessy A. Screening tests for renal artery stenosis: a case-series from an Australian tertiary referral centre. *Nephrology (Carlton)*. 2006;11(1):68-72.	Observational-Dx	75 consecutive patients who had 79 screening investigations (4 patients had 2 screening tests)	To determine physician preferences and diagnostic accuracy of screening tests for RAS when applied to clinical practice in a large, Australian tertiary referral center.	Case series showed that 19 (24%) patients did not have any screening investigations prior to angiography. Duplex US was the most utilized screening test, being used in 20 (33%) of the remaining 60 screening tests. CTA was used in 19 (32%), MRI in 13 (22%) and renal scintigraphy was used in 4 (7%) screening procedures. MRA was the most accurate screening test with PPV of 92%, followed by duplex US with 88% and CTA was relatively inaccurate, with a PPV of 58% (P=0.036). Clinical suspicion alone was inaccurate with a PPV of 40%, except in previously treated RAS (PPV 89%). Duplex US was the most utilized screening investigation. MRA and duplex US had good PPVs, while CTA may not be as reliable as previously reported when applied to a large, non-selective clinical practice.	3
39. Ledneva E, Karie S, Launay-Vacher V, Janus N, Deray G. Renal safety of gadolinium-based contrast media in patients with chronic renal insufficiency. *Radiology*. 2009;250(3):618-628.	Review/Other-Dx	N/A	To clarify the renal effects of gadolinium-based contrast media in patients with renal insufficiency.	No results stated in abstract.	4

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
40. Broome DR, Girguis MS, Baron PW, Cottrell AC, Kjellin I, Kirk GA. Gadodiamide-associated nephrogenic systemic fibrosis: why radiologists should be concerned. *AJR Am J Roentgenol.* 2007;188(2):586-592.	Observational-Dx	12 patients	Retrospective chart review was performed on patients diagnosed with NSF to identify any common risk factors and determine whether IV gadodiamide is associated with the development of NSF.	All 12 patients had renal insufficiency, 8 with dialysis-dependent chronic renal insufficiency and 4 with acute hepatorenal syndrome. All 12 patients developed skin fibrosis within 2-11 weeks after gadodiamide administration. The odds ratio for development of NSF after gadodiamide exposure was 22.3. No other common event or exposure could be found. 4 patients had abnormal scintigraphic bone scans with skin and muscle uptake and lower-extremity MRI finding of edema in the muscles, intermuscular fascia, and skin. Despite the fact that 10 patients were dialyzed within 2 days of gadodiamide administration, this did not prevent the development of NSF. Development of NSF was strongly associated with gadodiamide administration in the setting of either acute hepatorenal syndrome or dialysis-dependent chronic renal insufficiency.	4
41. Prince MR, Schoenberg SO, Ward JS, Londy FJ, Wakefield TW, Stanley JC. Hemodynamically significant atherosclerotic renal artery stenosis: MR angiographic features. *Radiology.* 1997;205(1):128-136.	Observational-Dx	47 patients underwent MRA of the renal arteries	To identify MRA features of hemodynamically significant RAS.	Poststenotic dilatation of greater than 20% was present in 36 (59%) of 52 hemodynamically significant renal artery stenoses, and severe dephasing was present in 45 (87%) of 52. In patients with unilateral hemodynamically significant stenosis or occlusion, mean ischemic kidney length was reduced to 9.3 cm compared with 10.7 cm for the contralateral normal kidney (P=.009), mean parenchymal thickness was reduced (1.2 vs 1.7 cm; P<.001), and mean parenchymal enhancement was 15% less on the ischemic side (P=.05). Severe dephasing on phase-contrast angiograms was present in 9 (75%) of 12 unilateral hemodynamically significant stenoses but in only 1 contralateral normal renal artery (P<.001). MRA depicts features of RAS that are markers of hemodynamic significance.	2

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
42. Omary RA, Baden JG, Becker BN, Odorico JS, Grist TM. Impact of MR angiography on the diagnosis and management of renal transplant dysfunction. *J Vasc Interv Radiol.* 2000;11(8):991-996.	Observational-Dx	31 patients	To evaluate the impact of MRA on referring physicians' diagnoses and treatment of patients with renal transplant dysfunction.	Pre-MRA and post-MRA questionnaires were prospectively completed on 31 separate patients. The mean gain in diagnostic certainty percentage from MRA was 33% (95% CI, 19%–51%; *P*<.001). MRA changed physicians' initial diagnoses in 20 patients (65%; 95% CI, 47%–79%). Immediate clinical management changed in 16 patients (52%; 95% CI, 35%–68%). Invasive procedures were avoided in 12 patients (39%). MRA has considerable impact on referring physicians' diagnoses and treatment of patients with suspected renal allograft dysfunction.	3
43. Sharafuddin MJ, Stolpen AH, Dixon BS, Andresen KJ, Sun S, Lawton WJ. Value of MR angiography before percutaneous transluminal renal artery angioplasty and stent placement. *J Vasc Interv Radiol.* 2002;13(9 Pt 1):901-908.	Observational-Dx	39 patients had attempted percutaneous renal angioplasty with or without stent placement; 48 renal arteries treated	To determine the benefit of preprocedural 3D Gd-enhanced MRA before PTRA and stent placement in terms of procedural success, iodinated contrast material load, and procedure duration. 2 subgroups: patients who had preprocedural Gd-enhanced MRA ("prior MRA group") and those who did not ("no MRA" group).	Preprocedural planning with use of Gd-enhanced MRA significantly reduces the iodinated contrast material requirement during percutaneous renal artery interventions. It can also significantly shorten procedure duration.	3
44. Law YM, Tay KH, Gan YU, Cheah FK, Tan BS. Gadolinium-enhanced magnetic resonance angiography in renal artery stenosis: comparison with digital subtraction angiography. *Hong Kong Med J.* 2008;14(2):136-141.	Observational-Dx	27 consecutive patients; 39 renal arteries evaluated, 2 blinded reviewers	Retrospective study to evaluate the accuracy of Gd-enhanced MRA in assessing RAS compared to catheter DSA (standard of reference).	MRA and DSA were concordant in 89% of the arteries; MRA overestimated the degree of stenosis in 8% and underestimated it in 3% of them. In the evaluation of clinically significant RAS (≥50%) with MRA, the overall sensitivity, specificity, PPV, and NPV were 97%, 67%, 90%, and 86% respectively. The sensitivity and specificity of MRA in TRAS was 100%. Gd-enhanced MRA is a sensitive noninvasive modality useful in the assessment of clinically significant RAS.	2

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
45. Neimatallah MA, Dong Q, Schoenberg SO, Cho KJ, Prince MR. Magnetic resonance imaging in renal transplantation. *J Magn Reson Imaging.* 1999;10(3):357-368.	Review/Other-Dx	N/A	Review the role of MRI in renal transplantation, technical aspects of image acquisition, and MR findings of post-transplantation complications.	Imaging modalities that are currently used to evaluate transplanted kidneys are US, CT, scintigraphy, intravenous urography, contrast angiography, and MRI. MRI offers multiple advantages. MRI provides cross sectional and vascular information without the risks of ionizing radiation, iodinated contrast, or arterial catheterization.	4
46. Ismaeel MM, Abdel-Hamid A. Role of high resolution contrast-enhanced magnetic resonance angiography (HR CeMRA) in management of arterial complications of the renal transplant. *Eur J Radiol.* 2011;79(2):e122-127.	Observational-Dx	30 renal patients	To assess the accuracy of contrast-enhanced MRA in the detection of arterial complications after renal transplantation.	The high resolution contrast-enhanced MRA shows 93.7% sensitivity, 80% specificity, 88.2% PPV, 88.9% NPV and 88.5% accuracy.	2
47. Helenon O, Attlan E, Legendre C, et al. Gd-DOTA-enhanced MR imaging and color Doppler US of renal allograft necrosis. *Radiographics.* 1992;12(1):21-33.	Review/Other-Dx	21 patients	To correlate the results of imaging with pathologic and histologic data in order to describe MRI and CDUS characteristics of infarcts in renal transplants.	Gd-DOTA-enhanced MR images showed no contrast material uptake in infarcted areas. CDUS characteristics of infarction included absence of Doppler signal and alteration of the cortical echogenic structure, particularly in cases of ischemic necrosis. CDUS allows measurement of vascular resistance and assessment of intrarenal vasculature and the renal pedicle. Gd-DOTA-enhanced MRI is useful in confirming the diagnosis of infarction and provides an accurate evaluation of the extent of the infarct.	4
48. Hricak H, Terrier F, Demas BE. Renal allografts: evaluation by MR imaging. *Radiology.* 1986;159(2):435-441.	Observational-Dx	45 patients with 46 allografts	To prospectively evaluate the value of MRI in assessing renal altografts.	No abnormalities on MRIs were observed in allografts compromised by cyclosporin nephrotoxicity. Hydronephrosis of the renal allograft was easily diagnosed with MR. Perirenal abscess (3 cases) and perirenal hematomas (5 cases), because of their higher MR signal intensity on T1-weighted images (TR = 0.5 sec, TE = 28 msec), could be differentiated from clinically insignificant postoperative fluid seromas (7 cases), lymphoceles (11 cases), and urinoma (1 case).	2
49. Rholl KS, Lee JK, Ling D, Sicard GA, Griffith RC, Freeman M. Acute renal rejection versus acute tubular necrosis in a canine model: MR evaluation. *Radiology.* 1986;160(1):113-117.	Review/Other-Dx	13 dogs	To evaluate the potential of MRI in the differentiation of acute rejection and ATN.	MRI findings correlated with changes in water content in these 3 groups of kidneys. Kidneys undergoing acute rejection showed a marked increase in water content compared with kidneys in the other 2 groups. No change in fat content was found in any group.	4

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
50. Liu X, Berg N, Sheehan J, et al. Renal transplant: nonenhanced renal MR angiography with magnetization-prepared steady-state free precession. *Radiology.* 2009;251(2):535-542.	Observational-Dx	15 patients, 2 blinded reviewers	Retrospective study to examine nonenhanced MRA with SSFP with inversion recovery for assessing renal arteries in patients with renal transplants.	Thirteen recipients of renal transplants underwent SSFP MRA before contrast material-enhanced MRA. 3 stenoses (2 mild, 1 severe) were identified at SSFP MRA in agreement with findings at contrast-enhanced MRA. There was no significant difference in image quality between the 2 methods. Results suggest SSFP MRA permits image quality of renal transplant arteries and detection of arterial stenosis comparable with those at contrast-enhanced MRA.	2
51. 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 SSFP sequence, compared with contrast-enhanced MRA, which is the reference standard to detect and quantify renal artery stenoses.	Evaluation involved 114 renal arteries, 51 celiac trunks, and 51 superior mesenteric arteries. 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 superior mesenteric artery. At artery-by-artery analysis, sensitivity, specificity, accuracy, and NPV of the balanced SSFP 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 superior mesenteric artery. 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 SSFP sequence.	3
52. Glockner JF, Takahashi N, Kawashima A, et al. Non-contrast renal artery MRA using an inflow inversion recovery steady state free precession technique (Inhance): comparison with 3D contrast-enhanced MRA. *J Magn Reson Imaging.* 2010;31(6):1411-1418.	Observational-Dx	64 patients	To assess the performance of a3D noncontrast respiratory-triggered SSFP pulse sequence for detection of RAS.	The 67 patients had 168 main and accessory renal arteries, with significant (>50%) stenosis in 34 arteries on contrast-enhanced MRA or conventional angiography. The 2 noncontrast MRA readers had sensitivity and specificity for detection of significant stenosis of 94%/82% and 82%/87% respectively on a per renal artery basis.	2

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
53. Maki JH, Wilson GJ, Eubank WB, Glickerman DJ, Millan JA, Hoogeveen RM. Navigator-gated MR angiography of the renal arteries: a potential screening tool for renal artery stenosis. *AJR Am J Roentgenol.* 2007;188(6):W540-546.	Observational-Dx	40 patients	To determine how well unenhanced navigator-gated SSFP MRA performs as a screening test for the detection of RAS.	15 of the 40 patients had >50% RAS as determined on contrast-enhanced MRA. Sensitivity for detecting RAS with navigator-gated SSFP was 100%; specificity, 84%; NPV, 100%; and PPV, 79%. The average mean stenosis difference between navigator-gated SSFP and CE-MRA was 10% +/- 9%.	2
54. 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 SSFP 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 greater than 50% were 75%, 99%, 75%, and 99%, respectively. We show that SSFP 3D unenhanced MRA is a very promising technique for patients with suspected renovascular disease and could be used as an alternative if Gd-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
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 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
56. Wyttenbach R, Braghetti A, Wyss M, et al. Renal artery assessment with nonenhanced steady-state free precession versus contrast-enhanced MR angiography. *Radiology.* 2007;245(1):186-195.	Observational-Dx	53 patients	To prospectively assess the diagnostic accuracy of nonenhanced 3D SSFP MRA for detection of RAS, with breath-hold contrast material-enhanced MRA performed as the reference standard.	108 renal arteries with 20 significant (≥50%) stenoses were detected with contrast-enhanced MRA. At artery-by-artery analysis, sensitivity, specificity, accuracy, and NPV of nonenhanced SSFP MRA for RAS detection were 100%, 93%, 94%, and 100%, respectively, for observer 1 and 95%, 95%, 95%, and 99%, respectively, for observer 2. Corresponding patient-by-patient values were 100%, 92%, 94%, and 100%, respectively, for observer 1 and 100%, 95%, 96%, and 100%, respectively, for observer 2. Overestimation of stenosis grade with SSFP MRA resulted in 6 and 4 false-positive findings for readers 1 and 2, respectively. Mean maximal visible lengths of the renal arteries were 69.9 mm at contrast-enhanced MRA and 61.1 mm at SSFP MRA (P<.001). Both techniques yielded good to excellent image quality.	2
57. Xu JL, Shi DP, Li YL, Zhang JL, Zhu SC, Shen H. Non-enhanced MR angiography of renal artery using inflow-sensitive inversion recovery pulse sequence: a prospective comparison with enhanced CT angiography. *Eur J Radiol.* 2011;80(2):e57-63.	Observational-Dx	60 patients	To prospectively evaluate the diagnostic value of nonenhanced inflow-sensitive inversion recovery MRA for the detection of RAS, with enhanced CTA performed as the reference standard.	126 main renal arteries were visualized on enhanced CT and nonenhanced MRA images, respectively. The Spearman rank correlation was 0.773 (P<.001) for renal artery depiction, 0.998 (P<.001) for renal arteries grading and 0.833 (P<.001) for RAS detection between the 2 modalities. The sensitivity, specificity, PPV and NPV of inflow-sensitive inversion recovery MRA for RAS detection demonstrated 100%, 99.0%, 92.0% and 100%, respectively.	2

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
58. Lanzman RS, Voiculescu A, Walther C, et al. ECG-gated nonenhanced 3D steady-state free precession MR angiography in assessment of transplant renal arteries: comparison with DSA. *Radiology*. 2009;252(3):914-921.	Observational-Dx	20 patients	To evaluate noncontrast material-enhanced SSFP MRA in the assessment of transplant renal arteries by using DSA as the reference standard.	1 patient was excluded because SSFP MRA failed to adequately visualize the allograft vasculature owing to low cardiac output. The mean image quality assessed by both readers was 3.98 +/- 0.16 (standard deviation), 3.5 +/- 0.68, 2.71 +/- 1.12 and 2.03 +/- 1.09 for segments I, II, III, and IV, respectively (kappa = 0.80). DSA helped identify 8 relevant (≥50%) stenoses in 6 transplant renal arteries. Kinking of the transplant artery without relevant stenosis was found in 7 patients. The degree of stenosis was overestimated in 3 patients by using SSFP MRA. As compared with DSA, the sensitivity, specificity, and accuracy of SSFP MRA to help detect relevant TRAS were 100% (6 of 6), 88% (14 of 16), and 91% (20 of 22), respectively.	2
59. Vermathen P, Binser T, Boesch C, Eisenberger U, Thoeny HC. Three-year follow-up of human transplanted kidneys by diffusion-weighted MRI and blood oxygenation level-dependent imaging. *J Magn Reson Imaging.* 2012;35(5):1133-1138.	Observational-Dx	9 patients	To prospectively determine the 3-year stability and potential changes of functional parameters in renal allograft recipients obtained from DWI and blood oxygenation level-dependent MRI.	The parameters were stable after 32 months in 8 of the 9 patients, who had well-functioning allografts. Mean diffusion values were very similar in the first and second scan. Coefficients of variation within and coefficients of variation between for ADC values were ≤3.5% and 5.9%, respectively, in cortex and medulla, but were higher for perfusion contribution (15%–18%). Coefficients of variation within and coefficients of variation between of R2 were also low (medulla: coefficients of variation within) = 10.8%, coefficients of variation between = 11.4%; cortex: coefficients of variation within and coefficients of variation between = 7.2%). R2 increased significantly (P=0.035) in cortex but not in medulla, suggesting reduced cortical oxygen content. 1 subject with decreased GFR demonstrated strongly altered parameters.	2

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
60. Han F, Xiao W, Xu Y, et al. The significance of BOLD MRI in differentiation between renal transplant rejection and acute tubular necrosis. *Nephrol Dial Transplant.* 2008;23(8):2666-2672.	Observational-Dx	110 patients	To identify the significance of blood oxygen level-dependent MRI in differentiation of acute rejection (AR) and ATN in patients within 6 months after kidney transplantation.	The mean cortical R2* level was significantly higher in the ATN group (15.25 +/- 1.03/s) compared to the normal group (13.35 +/- 2.31/s, *P*=0.028) and acute rejection group (12.02 +/- 1.72/s, *P*=0.001). There was a significant difference also between the acute rejection group and normal group on cortical R2* levels (*P*=0.013). The mean medullary R2* level was significantly lower in the acute rejection group (14.02 +/- 2.68/s) compared to the normal group (16.66 +/- 2.82/s, *P*<0.001) and ATN group (19.47 +/- 1.62/s, *P*<0.001). There was also a significant difference between the ATN group and normal group on medullary R2* levels (*P*=0.011). There were no correlations between characteristics such as patient age, postoperation time, postbiopsy time, Scr level, HB level, urine output volume, MAP level, CNI trough concentration and R2* levels, except between MAP level and cortical R2* level (*P*=0.029).	2
61. Sadowski EA, Djamali A, Wentland AL, et al. Blood oxygen level-dependent and perfusion magnetic resonance imaging: detecting differences in oxygen bioavailability and blood flow in transplanted kidneys. *Magn Reson Imaging.* 2010;28(1):56-64.	Observational-Dx	17 patients	To assess kidney transplants with normal function, ATN and acute rejection using contrast enhanced perfusion and blood oxygen level-dependent MRI.	There was a significant difference between medullary R2 values in the group with acute rejection (R2=16.2/s) compared to allografts with ATN (R2=19.8/s; *P*=.047) and normal-functioning allografts (R2=24.3/s; *P*=.0003). There was a significant difference between medullary perfusion measurements in the group with acute rejection (124.4+/-41.1 ml/100 g per minute) compared to those in patients with ATN (246.9+/-123.5 ml/100 g per minute; *P*=.02) and normal-functioning allografts (220.8+/-95.8 ml/100 g per minute; *P*=.02).	1

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
62. Sadowski EA, Fain SB, Alford SK, et al. Assessment of acute renal transplant rejection with blood oxygen level-dependent MR imaging: initial experience. *Radiology.* 2005;236(3):911-919.	Observational-Dx	20 patients	To prospectively assess the oxygenation state of renal transplants and determine the feasibility of using blood oxygen level-dependent MRI to differentiate between ATN, acute rejection, and normal function.	R2* values for the medulla were significantly lower in the acute rejection group (R2* = 15.8/sec +/- 1.5) than in normally functioning transplants (R2* = 23.9/sec +/- 3.2) and transplants with ATN (R2* = 21.3/sec +/- 1.9). The differences between the acute rejection and normal function groups (P=.001), as well as between the acute rejection and ATN groups (P<.001), were significant. Acute rejection could be differentiated from normal function and ATN in all cases by using a threshold R2* value of 18/sec. R2* values for the cortex were higher in ATN (R2* = 14.2/sec +/- 1.4) than for normally functioning transplants (R2* = 12.7/sec +/- 1.6) and transplants with rejection (R2* = 12.4/sec +/- 1.2). The difference in R2* values in the cortex between ATN and rejection was statistically significant (P=.034), although there was no threshold value that enabled differentiation of all cases of ATN from cases of normal function or acute rejection.	3
63. Juillard L, Lerman LO, Kruger DG, et al. Blood oxygen level-dependent measurement of acute intra-renal ischemia. *Kidney Int.* 2004;65(3):944-950.	Review/Other-Dx	8 pigs	To determine if blood oxygen level-dependent can detect the characteristic of renal hypoxia induced by RAS.	During the control period, blood oxygen level-dependent signals were not significantly different between the right and the left kidneys. In the occluded kidney, blood oxygen level-dependent signal of the cortex (19.3 +/- 1.9/s) and the medulla (17.3 +/- 2.0/s) increased during occlusion gradually and significantly (P<0.0001) to a maximum (at total occlusion) of 33.8 +/- 2.0/s (+79%) and 29.8 +/- 2.3/s (+78%), respectively, and returned to baseline values during recovery. Study shows that the blood oxygen level-dependent technique can noninvasively detect change in intra-renal oxygenation during an acute reduction of renal blood flow. This study provides a strong rationale for developing the blood oxygen level-dependent method for the detection and evaluation of renal hypoxia induced by RAS, which may be potentially applicable in humans.	4

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
64. Eisenberger U, Binser T, Thoeny HC, Boesch C, Frey FJ, Vermathen P. Living renal allograft transplantation: diffusion-weighted MR imaging in longitudinal follow-up of the donated and the remaining kidney. *Radiology.* 2014;270(3):800-808.	Observational-Dx	13 healthy kidney donors and their correspondin g 13 allograft recipients	To determine whether DWI-MRI in living renal allograft donation allows monitoring of potential changes in the nontransplanted remaining kidney of the donor because of unilateral nephrectomy and changes in the transplanted kidney before and after transplantation in donor and recipient, respectively, and whether DWI-MRI parameters are correlated in the same kidney before and after transplantation.	Total ADC values in nontransplanted kidney of donors increased from a pre-explantation value of (188 +/- 9 [standard deviation]) to (202 +/- 11) x 10(-5) mm(2)/sec in medulla and from (199 +/- 11) to (210 +/- 13) x 10(-5) mm(2)/sec in cortex 1 week after donation (P<.004). Medullary, but not cortical, total ADC values stayed increased up to 1 year. Total ADC values in allografts in recipients were stable. Compared with values obtained before transplantation in donors, the corticomedullary difference was reduced in allografts (P<.03). Cortical total ADC values correlated with eGFR rate in recipients (R = 0.56, P<.001) but not donors. Cortical total ADC values in the same kidney before transplantation in donors correlated with those in recipients on day 8 after transplantation (R = 0.77, P=.006). Perfusion fraction did not show significant changes.	2
65. Park SY, Kim CK, Park BK, Kim SJ, Lee S, Huh W. Assessment of early renal allograft dysfunction with blood oxygenation level-dependent MRI and diffusion-weighted imaging. *Eur J Radiol.* 2014;83(12):2114-2121.	Observational-Dx	34 patients (early dysfunction, 24; normal, 10)	To investigate blood oxygenation level-dependent MRI and DWI at 3 T for assessment of early renal allograft dysfunction.	In all renal allografts, cortical or medullary R2* and ADC values were moderately correlated with eGFR (P<0.05). Early dysfunction group showed lower R2* and ADC values than normal function group (P<0.05). Acute rejection or ATN had lower R2* values than normal allografts (P<0.05), and acute rejections had lower cortical ADC values than normal allografts (P<0.05). No significant difference of R2* or ADC values was found between acute rejection and ATN (P>0.05).	3

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
66. Lanzman RS, Ljimani A, Pentang G, et al. Kidney transplant: functional assessment with diffusion-tensor MR imaging at 3T. *Radiology.* 2013;266(1):218-225.	Observational-Dx	40 patients (23 with good or moderate allograft function, 17 with heavily impaired renal function)	To evaluate the feasibility of diffusion-tensor (DT) imaging at 3 T for functional assessment of transplanted kidneys.	Mean fractional anisotropy of the renal medulla and cortex was significantly higher in group A (0.39 +/- 0.06 and 0.17 +/- 0.4) compared with group B (0.27 +/- 0.05 and 0.14 +/- 0.03) (*P*<.001 and *P*=.009, respectively). Mean ADCs of renal cortex and medulla were significantly higher in group A than in group B (*P*=.007 and *P*=.01, respectively). In group B, mean medullary fractional anisotropy was significantly lower in patients whose renal function did not recover (0.22 +/- 0.02) compared with those with stable allograft function at 6 months (0.29 +/- 0.05, *P*<.001). There was significant correlation between eGFR and medullary fractional anisotropy (r = 0.65, *P*<.001), cortical ADC (r = 0.43, *P*=.003), and medullary ADC (r = 0.35, *P*=.01).	3
67. Aktas A. Transplanted kidney function evaluation. *Semin Nucl Med.* 2014;44(2):129-145.	Review/Other-Dx	N/A	To review imaging modalities used to assess transplanted kidney function evaluation.	No results stated in abstract.	4
68. Yazici B, Oral A, Gokalp C, et al. Evaluation of Renal Transplant Scintigraphy and Resistance Index Performed Within 2 Days After Transplantation in Predicting Long-Term Graft Function. *Clin Nucl Med.* 2015;40(7):548-552.	Observational-Dx	119 patients	To evaluate the predictive value of renal transplant scintigraphy and RI for long-term graft function.	Differences of the mean values of T(1/2) of graft washout (1/2), time difference between peak renal perfusion and arterial count ([INCREMENT]P), and accumulation index (R20/3) were significantly high in patients with high follow-up serum creatinine (>1.5 mg/dL) (*P*<0.01). The correlation of these tests with the follow-up serum creatinine levels was significant (*P*<0.01). The number of recipients with high perfusion curve grade was also significant in the follow-up groups with high serum creatinine levels. However, difference of the mean value of RI was insignificant between the follow-up groups, and there was no correlation between the RI and serum creatinine levels.	3

Renal Transplant Dysfunction
EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
69. Heaf JG, Iversen J. Uses and limitations of renal scintigraphy in renal transplantation monitoring. *Eur J Nucl Med.* 2000;27(7):871-879.	Observational-Dx	213 consecutive transplants	To investigate the value of thrice weekly technetium-99m mercaptoacetyltriglycine renography after renal transplantation.	The initial renogram grade was primarily a marker of ischemic damage, being poorer with cadaver donation, long cold ischemia (>24 hours), and high donor and recipient age. High primary renogram grade predicted primary graft non-function, long time to graft function, low discharge Cr EDTA clearance and low 1- and 5-year graft survival. Discharge renogram grade predicted late (>6 months) graft loss. Renogram grade was highly correlated (P<0.001) with creatinine and creatinine clearance, and changes in renogram grade were correlated with changes in renal function. A change in renogram grade of 0.5 was non-specific, while a change of 1 or more predicted clinical complications in 95% of cases. The NPV was low (58%).	3
70. Yazici B, Yazici A, Oral A, Akgun A, Toz H. Comparison of renal transplant scintigraphy with renal resistance index for prediction of early graft dysfunction and evaluation of acute tubular necrosis and acute rejection. *Clin Nucl Med.* 2013;38(12):931-935.	Observational-Dx	107 patients including 153 studies	To discuss whether RI and renal scintigraphy obtained within 48 hours after operation could predict the early graft dysfunction.	Scintigraphic parameters were significantly higher in patients with delayed graft function and slow graft function than in patients with immediate graft function. These parameters in delayed graft function were also considerably different from those in slow graft function. The mean RI was significantly high in delayed graft function, but there was no difference between slow graft function and immediate graft function. In diagnostic groups, the mean values of all tests were significantly different between normal functioning grafts and pathological grafts (ATN + acute rejection). There was no significant difference between acute rejection and ATN. However, renal scintigraphy has higher sensitivity and specificity for acute rejection as compared with RI of Doppler US.	3

Renal Transplant Dysfunction
EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
71. Marini M, Fernandez-Rivera C, Cao I, et al. Treatment of transplant renal artery stenosis by percutaneous transluminal angioplasty and/or stenting: study in 63 patients in a single institution. *Transplant Proc.* 2011;43(6):2205-2207.	Observational-Tx	62 patients	To evaluate technical procedures, clinical success, and follow-up of renal transplant patients with stenosis in the TRAS after endovascular treatment.	PTA/stent placement success was 90.3%. 79 PTAs with 11 stents were primary interventions with 6 PTAs and 4 stent procedures subsequently performed due to restenosis (mean time to event, 1.5 months). The median follow-up was 39 months (range, 1–236). The mean preprocedure creatinine level was 2.8 +/- 1.7 mg/dL, and the 1-month postprocedure value was decreased to 2.1 +/- 1.2 mg/dL (P<.001). Systolic arterial blood pressure fell from 147.2 +/- 18.7 mm Hg to 131.6 +/- 14.2 mm Hg (P<.001) and diastolic blood pressure from 84.4 +/- 9.8 mm Hg to 76 +/- 9.4 mm Hg (P<.001). Postprocedure number of antihypertensive drugs was reduced from 2.3 +/- 1.1 to 1.6 +/- 1 (P<.0001). The patency rates were: 95 +/- 2.8% at 1 month, 87.9 +/- 4.3% at 3 months, and 85 +/- 4.7% at 12 months. Secondary patency was 100% with no restenosis on follow-up. Allograft survival after primary and secondary PTA/stenting was 97% at 1, 93% at 3.89% at 5, and 85% at 10 years. The complication included 2 renal artery thromboses, a dissection treated with stents, and a late arterial graft pseudoaneurysm.	2

Renal Transplant Dysfunction
EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
72. Sharma S, Potdar A, Kulkarni A. Percutaneous transluminal renal stenting for transplant renal artery stenosis. *Catheter Cardiovasc Interv.* 2011;77(2):287-293.	Observational-Tx	8 patients	To document the immediate and intermediate term clinical results of renal stenting in this rare subset of RAS.	All patients had live donor renal transplant using end to end anastomosis 2 to 11 (6.25 +/- 3.24) months prior to intervention. Angiography revealed discrete stenosis at the anastomotic site. Intrarenal stenting performed from femoral access using 6 F accessories produced excellent angiographic results. There were no access site or procedure related complications. The intervention produced excellent immediate and intermediate term clinical results. In 3 patients, there was stabilization of renal function during 62 +/- 9.16 months of follow-up with decrease in serum creatinine by 38.86 +/- 6.62 %; *P*=0.0476. In 4 patients with refractory hypertension, excellent blood pressure control was achieved with a reduction in mean blood pressure by 25.95 +/- 5.48 mm Hg (from 122.4 +/- 5.7 to 96.45 +/- 2.45 mm Hg; *P*=0.0002) during 65.25 +/- 23.79 months follow-up. There was decrease in antihypertensive drug requirement from 3.75 +/- 0.5 to 1.75 +/- 0.5. During follow-up, Doppler US documented a high PSV in 1 asymptomatic patient with well controlled blood pressure and preserved renal function. Sustained benefits of percutaneous revascularization were supported by normal Doppler parameters in the remaining patients.	2

Renal Transplant Dysfunction
EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
73. Audard V, Matignon M, Hemery F, et al. Risk factors and long-term outcome of transplant renal artery stenosis in adult recipients after treatment by percutaneous transluminal angioplasty. *Am J Transplant.* 2006;6(1):95-99.	Observational-Tx	29 renal allograft recipients, 58 controls	Retrospectively review records of renal allograft recipients treated with PTA in order to determine the predisposing factors for TRAS.	Predisposing factors for TRAS included cytomegalovirus infection (41.4% vs 12.1% P=0.0018) and initial delayed graft function (48.3% vs 15.5% P=0.0018), respectively in the TRAS and the control group. Acute rejection occurred more frequently in patients from the TRAS group (48.3%) compared with the control group (27.6%), although the difference was not significant (P=0.06). In a multivariate analysis, only cytomegalovirus infection (P=0.005) and delayed graft function (P=0.009) appear to be significantly and independently associated with TRAS. The long-term graft survival was significantly higher in the control group, compared with the TRAS group (P=0.03). Study suggests that cytomegalovirus infection and delayed graft function are 2 reliable risk factors for TRAS. Despite treatment by PTA with primary successful results, TRAS significantly affects long-term graft outcome.	2

Renal Transplant Dysfunction
EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
74. Beecroft JR, Rajan DK, Clark TW, Robinette M, Stavropoulos SW. Transplant renal artery stenosis: outcome after percutaneous intervention. *J Vasc Interv Radiol.* 2004;15(12):1407-1413.	Observational-Tx	21 interventions performed in 18 allografts	Retrospective review to assess the outcome of PTA and stent placement as the primary treatment for TRAS.	The technical success rate of PTA/stent placement was 100% and the clinical success rate was 94% (17/18 allografts). The mean preintervention serum creatinine level among 12 allografts presenting with elevated creatinine levels was 2.8 mg/dL +/- 1.4 (SD), compared with a 1-month postintervention mean of 2.2 mg/dL +/- 0.7 (*P*=.03). Of 6 allografts that presented with hypertension, significant improvement was seen between the preintervention and 1-month postintervention mean systolic (174 mm Hg vs 135 mm Hg, *P*=.003) and diastolic (99 mm Hg vs 82 mm Hg, *P*=.02) pressures. These patients required a mean of 2.3 medications for blood pressure control before intervention, compared with a mean of 1.0 medications at 1 month after intervention (*P*=.002). Primary patency rates at 3, 6, and 12 months (+/-95% CI) were 94% +/- 6%, 72% +/- 12%, and 72% +/- 12%, respectively. Secondary patency rates at 3, 6, and 12 months (+/-95 CI) were 100%, 85% +/- 10%, and 85% +/- 10%, respectively. Mean follow-up time was 27 months. Of the 8 allografts that underwent stent placement, all 8 remained patent at last follow-up (mean, 18.3 months +/- 9.2). 1 major complication of a puncture site pseudoaneurysm occurred (5%). Primary treatment of TRAS with PTA with or without stent placement has good intermediate-term patency and is associated with significant early improvement in blood pressure and creatinine level.	2

Renal Transplant Dysfunction
EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
75. Geddes CC, McManus SK, Koteeswaran S, Baxter GM. Long-term outcome of transplant renal artery stenosis managed conservatively or by radiological intervention. *Clin Transplant.* 2008;22(5):572-578.	Observational-Tx	43 patients: 27 had percutaneous intervention (including 10 patients with >1 intervention) and 16 were managed conservatively	Patients diagnosed with TRAS were analyzed to report long-term clinical outcomes.	Patients in the intervention group had lower mean eGFR (36.3 mL/min/1.73 m(2) vs 46.3 mL/min/1.73 m(2); *P*=0.07) at baseline. 5 transplants in the intervention group failed (including 2 as a direct result of intervention) and 1 in the conservative group failed. There was no significant difference in the rate of deterioration in renal function (mean slope of eGFR minus 0.8 mL/min/yr and minus 1.0 mL/min/yr in the intervention and conservative groups, respectively; *P*=0.79). There was no significant difference in blood pressure or number of anti-hypertensive agents between the groups at any time point. Baseline Doppler US indices showed no significant correlation with slope of eGFR in either group. Data demonstrate that selected patients with TRAS can be managed without intervention and that this approach is associated with good long-term outcome. Selection of appropriate patients for intervention remains difficult and larger randomized studies are required.	2
76. Ghazanfar A, Tavakoli A, Augustine T, Pararajasingam R, Riad H, Chalmers N. Management of transplant renal artery stenosis and its impact on long-term allograft survival: a single-centre experience. *Nephrol Dial Transplant.* 2011;26(1):336-343.	Observational-Tx	67 patients	Retrospective study to compare management strategies and outcomes of TRAS and its impact on long-term allograft survival.	44, 9 and 14 patients were managed with primary PTRA, surgical intervention and conservative treatment, respectively. Uncontrolled hypertension was the most common presentation noted in 74.62%. Post-anastamotic single stenosis was the commonest occurrence (n=53). Angioplasty had the highest 1- and 5-year graft survival rate of 91% and 86%, respectively. The worst prognosis was noted in patients treated with secondary PTRA after failed surgery or secondary surgery after failed primary PTRA. TRAS is a recognized complication resulting in loss of renal allografts. Early Doppler US is a good primary diagnostic tool. Early intervention is associated with a good long-term graft function.	2

Renal Transplant Dysfunction
EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
77. Hagen G, Wadstrom J, Magnusson M, Magnusson A. Outcome after percutaneous transluminal angioplasty of arterial stenosis in renal transplant patients. *Acta Radiol.* 2009;50(3):270-275.	Observational-Tx	24 patients 28 stenoses treated	To evaluate the technical and clinical success rate of renal transplant patients with stenosis in the transplant renal artery or in the iliac artery after PTA.	The immediate technical success rate after PTA was 93%. The clinical success rate after 1 month was 58%, increasing to 75% after 3 months. The technical success rate is not equivalent to the clinical success rate when treating TRAS with PTA. Furthermore, there is a delay in clinical response, sometimes of 3 months, after a technically successful PTA.	2
78. Henning BF, Kuchlbauer S, Boger CA, et al. Percutaneous transluminal angioplasty as first-line treatment of transplant renal artery stenosis. *Clin Nephrol.* 2009;71(5):543-549.	Observational-Tx	11 patients with TRAS	To determine whether PTA should be first-line treatment of TRAS.	The immediate success rate for PTA was 92.3% (12/13). The beneficial effect of PTA of TRAS on renal function is long-lasting. Therefore, PTA, usually combined with stent placement, should be first-line treatment in TRAS in all patients. Surgical revascularization is only warranted, if PTA fails.	2
79. Pappas P, Zavos G, Kaza S, et al. Angioplasty and stenting of arterial stenosis affecting renal transplant function. *Transplant Proc.* 2008;40(5):1391-1396.	Observational-Tx	24 patients	To evaluate the efficacy of percutaneous angioplasty and stenting in cases of artery stenosis of the transplanted kidney or proximal iliac artery stenosis causing transplant dysfunction and/or increase of the arterial blood pressure.	Successful angioplasty and stenting were performed in 22 patients. The method was technically feasible in 100%. The procedure-related morbidity was 0%. During the follow-up period (range: 3 to 104 months), 2 patients died with normal transplant function, 2 suffered transplant failure, and the remaining 18 still have normal transplant function and easily controlled hypertension. Percutaneous angioplasty and stenting in cases of arterial stenosis affecting the renal transplant function are safe and effective procedures. Even more, the strong clinical suspicion must lead to angiographic investigation regardless of the results of other imaging approaches.	2

Renal Transplant Dysfunction
EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
80. Peregrin JH, Stribrna J, Lacha J, Skibova J. Long-term follow-up of renal transplant patients with renal artery stenosis treated by percutaneous angioplasty. *Eur J Radiol.* 2008;66(3):512-518.	Observational-Tx	58 PTRA in 55 adults (3 times Re-PTRA)	To evaluate if PTRA in patients with transplanted kidney and TRAS can have long-term effect on hypertension and renal function.	PTRA technical success was 88.4%. In 51 kidney recipients at the end of follow-up, blood pressure improved in 65.2% of patients (mean arterial pressure decreased from 123+/-13.1 to 107+/-12.1 mmHg), but no patient remained normotensive medication free. Graft function improved in 44.8% of patients and was stabilized in 20.7% of them (average creatinine clearance before PTRA: 0.48+/-0.29, after PTRA: 0.78+/-47 ml/s). PTRA complications were observed in 25.5% of procedures, most often with no clinical sequel. Thirty days mortality was 1.8% (1 patient). PTRA results in kidney recipients are valuable mainly in preserving graft function.	2
81. Polak WG, Jezior D, Garcarek J, et al. Incidence and outcome of transplant renal artery stenosis: single center experience. *Transplant Proc.* 2006;38(1):131-132.	Review/Other-Tx	793 kidney allograft recipients	Retrospective study to examine incidence, analyze the treatment options, and ascertain the outcomes of TRAS.	Screening CDUS showed hemodynamic changes in 6 patients with the definitive diagnosis confirmed by angiography in all patients. 1 patient with an anastomotic stenosis was treated with a surgical operation and 6 patients, PTA, with stenting in 3 cases. Both surgical as well as PTA treatment were successful in all but 1 patient, who underwent PTA alone, developed chronic renal insufficiency necessitating hemodialysis and finally lost his allograft. In the other patients all symptoms resolved after treatment and the patients are doing well with functioning allografts. Although TRAS was an uncommon complication, if recognized promptly it could be treated by surgery or PTA with a high success rate.	4
82. Seratnahaei A, Shah A, Bodiwala K, Mukherjee D. Management of transplant renal artery stenosis. *Angiology.* 2011;62(3):219-224.	Review/Other-Tx	N/A	Review the existing data and analyze management of TRAS as reported in multiple case series including findings from the authors' center.	PTA has now become the initial treatment of choice for TRAS. However, there are conflicting data regarding the efficacy of PTA, with growing evidence showing lack of significant benefit in blood pressure or renal function in patients undergoing PTA vs medical management. However, there have been no randomized control studies that have established the superiority of either method.	4

Renal Transplant Dysfunction
EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
83. Valpreda S, Messina M, Rabbia C. Stenting of transplant renal artery stenosis: outcome in a single center study. *J Cardiovasc Surg (Torino).* 2008;49(5):565-570.	Observational-Tx	32 interventions in 30 allografts	To retrospectively evaluate the clinical outcome of patients with TRAS or post-PTA recurrent TRAS treated by endoluminal stenting.	The technical success rate of stenting was 100% with a single major complication event (a puncture site pseudoaneurysm). Mean follow-up time was 7.1 years; of the 30 allograft that underwent stent placement, all were patent at the last follow-up, with 5 restenosis (15.6%) of which only 1 needed to be retreated endoluminally. A reduction of the mean serum creatinine levels and of the number of blood pressure medications was observed. There was no difference in the survival curve of the grafts without TRAS compared to those with stenting treated TRAS. The treatment of the TRAS with selective or primary stenting is safe with a long-term patency rate. The efficacy of the stenting in this study is suggested by a decrease in mean systolic and diastolic blood pressure, serum creatinine levels and number of blood pressure medications.	3
84. Voiculescu A, Schmitz M, Hollenbeck M, et al. Management of arterial stenosis affecting kidney graft perfusion: a single-centre study in 53 patients. *Am J Transplant.* 2005;5(7):1731-1738.	Observational-Tx	53 patients	To assess the clinical and duplex US findings and outcome in patients with stenosis of the TRAS or the aorto-iliac segment proximal to the graft (TRAS) treated with dilatation (PTA), stenting and surgery.	52 patients underwent invasive treatment (21 PTA, 10 PTA/stenting and 21 surgery) after which hypertension and creatinine significantly improved. PI increased. Restenosis occurred in 16 (52%) cases of the interventional (PTA 62% and PTA/stenting 30%) and in 3 (14%) of the surgical group (P=0.011). Hypertension and graft dysfunction due to perfusion problems are rare. Clinical findings are nonspecific but duplex US findings are helpful to select patients for angiography. Invasive treatment leads to clinical improvement. Surgery yields better results than PTA, but additional stenting will probably improve the outcome of angioplasty.	2

Renal Transplant Dysfunction
EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
85. Touma J, Costanzo A, Boura B, Alomran F, Combes M. Endovascular management of transplant renal artery stenosis. *J Vasc Surg.* 2014;59(4):1058-1065.	Observational-Tx	17 patients	To assess the safety and efficiency of TRAS endovascular therapy.	A total of 17 patients (10 men, 7 women) presenting with TRAS were referred to our institution. During the early post-transplantation process (<15 days), 35.2% of patients presented. The median time to presentation was 40 days. The predominant presentation was graft function alteration (82.3%). Percutaneous balloon angioplasty was performed in 5 patients (29.4%), while stenting was performed in the remaining 12 patients (70.6%). The stenosis-free primary patency rate and freedom from reintervention rate were 76.5% and 88.2%, respectively. The median follow-up was 19.6 months with 88.2% graft survival. There were no mortalities throughout the follow-up period. Serum creatinine levels decreased significantly from 186 mumol/L (range, 148-310 mumol/L) preoperatively to 160 mumol/L (range, 127-236 mumol/L at discharge (*P*=.0036). The GFRs increased from 32.1 mL/min (range, 21.4-45.8 mL/min) to 41.7 mL/min (range, 27.5-52.4 mL/min; *P*=.004). Systolic and diastolic blood pressure varied from 140 mm Hg (range, 137–157 mm Hg) and 75 mm Hg (range, 70–80 mm Hg), to 135 mm Hg (range, 130–147 mm Hg and 80 mm Hg (range, 73–80 mm Hg), respectively (*P*=.11 and *P*=.36). The preoperative number of antihypertensive medications was 2 (range, 1–3) and remained unchanged (*P*=.33).	2
86. Abate MT, Kaur J, Suh H, Darras F, Mani A, Nord EP. The use of drug-eluting stents in the management of transplant renal artery stenosis. *Am J Transplant.* 2011;11(10):2235-2241.	Observational-Tx	12 patients	To examine the use of drug-eluting stents in eligible patients with hemodynamically significant TRAS.	TRAS was detected within the first year posttransplantation in a majority of these patients (83%) and manifested as hypertension (100%), allograft dysfunction (100%) and edema (58%). Procedural success rate was 100%. Patients were followed for a mean period of 16 +/- 10 months. Blood pressure improved from a mean of 156/82 to 138/73 mmHg at the end of the follow-up period. In 11/12 patients, serum creatinine improved from 3.1 +/- 1.3 mg/dL to 2.3 +/- 0.5 mg/dL at the end of the follow-up period.	2

Renal Transplant Dysfunction
EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
87. Biederman DM, Fischman AM, Titano JJ, et al. Tailoring the endovascular management of transplant renal artery stenosis. *Am J Transplant.* 2015;15(4):1039-1049.	Observational-Tx	45 patients	To analyze the different types of endovascular interventions (EVIs) in de novo TRAS and its anatomical subtypes to examine any variation in recovery of allograft function, blood pressure control, endovascular intervention patency and allograft survival with respect to endovascular intervention type (drug-eluting stent, bare-metal stent, PTA).	There was significant improvement in allograft function and mean arterial blood pressure control across all interventions (pre-endovascular intervention-creatinine: 2.8 +/- 1.4, post-endovascular intervention-creatinine: 2.1 +/- 0.7, $P<0.001$; pre-endovascular intervention-mean arterial blood pressure: 117 +/- 16, post-endovascular intervention-mean arterial blood pressure: 112 +/- 17, $P=0.03$) with no significant difference among EVI types. There was no significant difference in allograft survival with respect to endovascular intervention type. Patency was significantly higher in endovascular interventions performed with drug-eluting stents and bare-metal stent compared to PTA ($P=0.001$). In the postanastomotic TRAS subtype, patency rates were significantly higher in drug-eluting stents compared to bare-metal stent ($P=0.012$) in vessels of comparable reference diameter (≤5 mm).	2
88. Douis H, Shabir S, Lipkin G, Riley P. Drug-eluting stent insertion in the treatment of in-stent renal artery restenosis in three renal transplant recipients. *J Vasc Interv Radiol.* 2008;19(12):1757-1760.	Review/Other-Tx	3 case reports	To report our experience in 3 renal transplant recipients who underwent drug-eluting stent insertion for instent stenosis in previously stent-implanted transplant renal arteries.	No results stated in abstract.	4
89. deSouza NM, Reidy JF, Koffman CG. Arteriovenous fistulas complicating biopsy of renal allografts: treatment of bleeding with superselective embolization. *AJR Am J Roentgenol.* 1991;156(3):507-510.	Review/Other-Dx	7 patients	A report on patients in which superselective transcatheter embolization in renal allograft was used effectively as a means of controlling bleeding while allowing maximal conservation of renal pamenchyma.	Bleeding was effectively controlled in all patients. None of the patients showed an increase in serum creatinine level after embolization, and in 4, significant improvement was seen. Nuclear medicine studies showed no loss of renal function and a dramatic improvement in 1 patient. No complications due to the procedure were seen. Study suggests that superselective embolization with coaxial catheter techniques is an effective method of treating bleeding from postbiopsy arteriovenous fistulas in renal transplants with minimal loss of renal parenchyma.	4

Renal Transplant Dysfunction
EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
90. Fossaceca R, Guzzardi G, Cerini P, et al. Management of postbiopsy arteriovenous fistulas in transplanted kidneys and effectiveness of endovascular treatment: a single-center experience. *Ann Vasc Surg.* 2014;28(2):452-456.	Observational-Tx	17 patients	To evaluate the best therapeutic management of postbiopsy arteriovenous fistulas in transplanted kidneys.	Asymptomatic arteriovenous fistulas resolved spontaneously, while the endovascular treatment in symptomatic arteriovenous fistulas showed a complete technical and clinical success with prompt remission of the presented symptoms. We observed a statistically significant reduction in serum creatinine at 7 days and 6 and 12 months postoperatively (mean creatinine--preoperative: 3.23 +/- 1.4 mg/dL; 7 days: 2.25 +/- 0.8 mg/dL; 6 months: 1.65 +/- 0.28 mg/dL; 12 months: 1.4 +/- 0.26 mg/dL; in all cases $P<0.05$).	2

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

ADC = Apparent diffusion coefficient

ATN = Acute tubular necrosis

CDUS = Color Doppler US

CI = Confidence interval

CT = Computed tomography

CTA = Computed tomography angiography

DSA = Digital-subtraction angiography

DWI = Diffusion-weighted imaging

eGFR = Estimated glomerular filtration rate

Gd = Gadolinium

HR = Hazard ratio

HU = Hounsfield Units

IA-DSA = Intra-arterial digital subtraction angiography

MRA = Magnetic resonance angiography

MRI = Magnetic resonance imaging

NPV = Negative predictive value

NSF = Nephrogenic systemic fibrosis

PI = Pulsatility index

PPV = Positive predictive value

PSV = Peak systolic velocity

PTA = Percutaneous transluminal angioplasty

PTRA = Percutaneous transluminal renal angioplasty

RAS = Renal artery stenosis

RI = Resistive index

SSFP = Steady-state free precession

TRAS = Transplant renal artery stenosis

US = Ultrasound