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Renal Transplant Complications—A Pictorial Review

Navya Christopher[1] Gopinath Periaswamy[1] Venkatesh Kasi Arunachalam[1] Santhosh Poyyamoli[1] Pankaj Mehta[1] Mathew Cherian[1]

[1] Department of Radiology, Kovai Medical Center and Hospital, Avanashi Road, Coimbatore, India

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Address for correspondence Venkatesh Kasi Arunachalam, DMRD, DNB, FRCR, Consultant Radiologist, Department of Radiology, KMCH, Avanashi Road, Coimbatore, 641014, India (e-mail: drkasivenkatesh@yahoo.co.in; radvenki79@gmail.com).

Abstract

Renal transplantation is the most effective treatment for end-stage renal disease, with advanced immunosuppressive therapy and better surgical techniques resulting in better survival of the graft. Despite the advances, complications do occur in the postoperative period and timely diagnosis of the complications is vital for prompt management and salvage of the transplant. This pictorial essay aims to classify the complications of renal transplantation, describe the various imaging modalities used to detect complications, and provide a brief overview of the role of interventional radiology in their management. The complications can be broadly divided into perinephric fluid collections, vascular, collecting system, and parenchymal complications. Imaging including ultrasonography, computed tomography, magnetic resonance imaging, and newer methods like elastography, magnetic resonance imaging arterial spin labeling, diffusion-weighted imaging, diffusion kurtosis imaging, blood oxygenation-level dependent, and magnetic resonance elastography can be used in the diagnosis of these complications. Interventional radiology has advanced a lot in managing them; hence, interventional techniques can be the first choice of treatment in institutions where robust interventional radiology setup is available.

Keywords
- renal transplantation
- urinoma
- lymphocele
- hematoma
- pseudoaneurysm
- interventional radiology

Introduction

Renal transplantation is currently the most effective treatment for patients with end-stage renal disease, which can drastically improve the survival of patients, as compared to long-term dialysis.[1] The recent advances in surgical techniques, immunosuppression, and follow-up imaging have enabled prolonged graft survival. Early detection of renal transplant dysfunction is crucial to prevent permanent graft damage.[2] Serum creatinine and estimated glomerular filtration rate are common clinical tools for surveillance; however, their alterations are often delayed till advanced and irreversible damage occurs.[3] The gold standard for diagnosing transplant dysfunction is renal biopsy, which can identify interstitial fibrosis, tubular atrophy, glomerulosclerosis, and vascular occlusive changes[4]; however, postbiopsy complications are of concern.

The imaging, therefore, plays a key role in the routine evaluation of postrenal transplant patients. Various imaging methods in the postoperative period help in the early detection of complications and reasons for rejection and guide prompt management. With the recent development of interventional techniques, many complications can be managed conservatively with minimally invasive percutaneous procedures also, avoiding open surgery.

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This pictorial essay aims to classify the complications of renal transplantation, describe the various imaging modalities used to detect complications, and provide a brief overview of the role of interventional radiology in their management. All the images have been obtained from a single center which is one of the major transplantation centers in India. All renal transplant patients undergo a ultrasonography (USG) and comprehensive Doppler evaluation on postoperative day 1. The sonographic examination includes a gray-scale evaluation of the graft and perigraft area. The doppler examination includes both color and spectral doppler evaluation of the transplant kidney. Further imaging is based on a clinical follow-up including daily monitoring of laboratory values. If clinical parameters are abnormal, repeat sonography is performed, and depending on the results, computed tomography (CT), magnetic resonance imaging (MRI), or angiography is done.

Surgical Technique

The knowledge of surgical techniques of transplant surgery is important for the accurate interpretation of radiological findings. The transplant kidney is usually placed extraperitoneally in the right iliac fossa (less commonly left iliac fossa) with end-to-side or end-to-end anastomosis of the donor renal artery and vein to the recipient external iliac vasculature.[5] Urinary drainage is commonly restored using ureteroneocystostomy, in which the donor ureter is implanted into the anterior or lateral bladder wall.

Multimodality Imaging of Renal Transplant

The multimodality approach of imaging renal transplant is essential for the early detection of complications and reasons for rejection and for guiding proper management.

The diagnostic imaging modalities used in renal transplant assessment are as follows.[6]

Ultrasonography

USG (including B-mode, color, and spectral Doppler) is routinely performed as the first-line imaging modality for the comprehensive evaluation of renal transplant in the postoperative period, being an easily available, noninvasive, nonionizing, relatively inexpensive, and repeatable method.[7] This enables an optimal evaluation of the anatomical complications of the transplant.

Ultrasound evaluation should be initially performed with B-mode to look for transplant morphology in terms of the size of the transplant kidney, parenchymal echotexture and cortico-medullary differentiation (CMD), pelvicalyceal system, and adjacent collections. This is followed by color Doppler evaluation with routine and power Doppler settings to look for the overall vascularity, status of the vascular pedicle, course, and patency of intrarenal vessels and to detect focal lesions if any.

Spectral Doppler evaluation includes the acquisition of velocity waveforms and peak velocities from arterial and venous anastomotic sites, transplant main renal vessels, and segmental and arcuate arteries of upper, mid, and lower poles. The presence of forward diastolic flow is an important sign of normal arterial waveform. Acceleration index, acceleration time, and resistivity index (RI) are calculated. RI values are key prognosticators of the overall health of renal transplant, with a normal RI range of 0.6 to 0.8, and RI of more than 0.8 is a nonspecific determinant of transplant dysfunction.[8] Advanced techniques like ultrasound elastography (►**Fig. 1**) enable the assessment of tissue stiffness and are a reliable surrogate marker for early detection of fibrosis in renal transplant, by showing significant differences in shear wave elastography score between a stable and malfunctioning allograft.[9]

Depending upon the initial ultrasound findings and clinical setting, subsequent imaging studies including CT, MRI, angiography, or radio-nuclide scans may be advised.

Computed Tomography

CT plays an important complementary role in the evaluation of renal transplants. Noncontrast scans can provide useful information about the transplant and peritransplant regions in patients with suboptimal ultrasound scan quality due to poor window and detect urolithiasis and renal parenchymal calcifications. It also gives information about the nature and extent of collections in the perigraft area if present. CT angiography provides the most detailed assessment of the renal vascular system and its associated complications. Excretory phase images help in the diagnosis of urinary leaks and urinoma. Exogenous contrast injected through percutaneous or perurethral catheters (even in patients with deranged renal functions) can help in the evaluation of the pelvicalyceal system and ureter (CT nephrostography) and bladder lumen (CT cystography).[7]

Magnetic Resonance Imaging

In the current scenario, MRI is reserved for selected cases, mainly due to its lack of accessibility and longer scan time. Due to higher soft tissue resolution, MRI can detect focal or diffuse changes in the renal parenchyma, which are not evident on ultrasound. Noncontrast MRI is useful in the detection and characterization of focal lesions, evaluation of hilum, pelvicalyceal system, and anastomotic sites, and peritransplant collections. Transplant renal vessels can be assessed by both noncontrast and contrast-enhanced MR angiography. Contrast-enhanced MR angiography is also advised for focal renal lesions and assessment of transplant renal vessels. MR urography helps to evaluate the pelvicalyceal system, transplant ureter, and urinary bladder and helps in the diagnosis of urinary leak and urinoma formation.

Renal functional MRI is a rapidly growing technique that has huge potential to evaluate the pathophysiology of renal disease. Blood oxygen-level dependent MRI (BOLD MRI); diffusion-weighted MRI (DWI), diffusion-tensor imaging (DTI), intravoxel incoherent motion DWI (IVIM-DWI), diffusion kurtosis imaging (DKI), arterial spin labeling (ASL); diffusion kurtosis imaging (DKI); MR elastography (MRE), magnetization transfer imaging (MTI), and contrast-enhanced

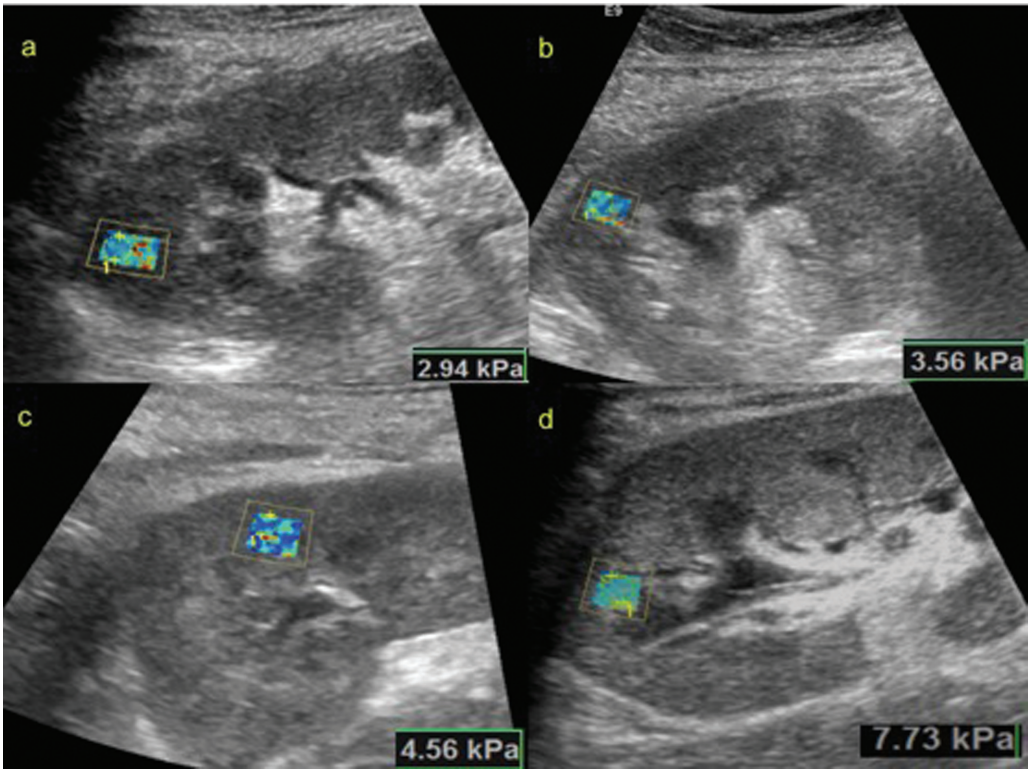

Fig. 1 Ultrasound shear wave elastography images of transplant kidneys showing varying grades of fibrosis: (**a**) no fibrosis (grade 0), (**b**) mild fibrosis (grade 1), (**c**) moderate fibrosis (grade 2), and (**d**) severe fibrosis (grade 3).

MR renography may constitute different arms of multiparametric functional MRI study of renal transplant.[10]

Digital Subtraction Angiography

In cases of vascular compromise, mainly arterial stenosis or occlusion, DSA can be a valuable contributor to establishing a definitive diagnosis. DSA also confirms postbiopsy complications such as arterio-venous fistula or pseudoaneurysms and guides their interventional management.

Nuclear Medicine

Nuclear scans play a key role in the assessment of graft function and perfusion, especially in the immediate postoperative period, and in patients with contraindications to iodinated and gadolinium-based i.v. contrast agents. This includes renal scintigraphy using Technetium-99m (99mTc)-labeled mercaptoacetyltriglycine (MAG3) or diethylenetriaminepentaacetic acid, which can provide quantitative and qualitative information on cortical perfusion, parenchymal extraction, and excretion.[11]

Complications in Renal Transplantation

The complications following renal transplantation can be broadly divided into perinephric fluid collections, vascular, collecting system, and parenchymal complications (►**Fig. 2**).

Perinephric Fluid Collections

These include hematoma, urinoma, lymphocele, and abscess, and their clinical relevance is according to the size, location, and interval increase.[12] Small collections like hematoma or seroma are expected in the immediate postoperative period and should be followed up for assessing interval change.

Percutaneous aspiration and analysis of the fluid may be necessary for an exact diagnosis.

Hematoma

This is immediate complication, from day 0 to day 5, seen as a complex heterogeneous collection with retracting clots ± septations, echogenic when acute, and less echogenic with time. Acute hematomas show hyperdensity in CT (>30 HU), while MRI typically shows increased T1 signal intensity. Hematoma (►**Figs. 3** and **4**) can be subcapsular or perinephric, the former being crescentic and extending along the renal contour and more likely to cause mass effect on renal parenchyma.[13]

Small hematomas are usually conservatively managed, regular USG follow-up alone is warranted to monitor the resolution of hematomas. Large hematomas causing mass effect on the transplant kidney and renal dysfunction can be evacuated surgically.

Urinoma

Urinomas (►**Fig. 5**) are noted within 10 days of transplantation, usually occur in the setting of inadequate blood supply to the ureter or elevated pressures from obstruction, and can lead to electrolyte imbalance or superinfection. Compared to serum values, fluid analysis from the urinoma shows increased creatinine and potassium. Imaging shows simple collection with fluid attenuation, contrast extravasation at

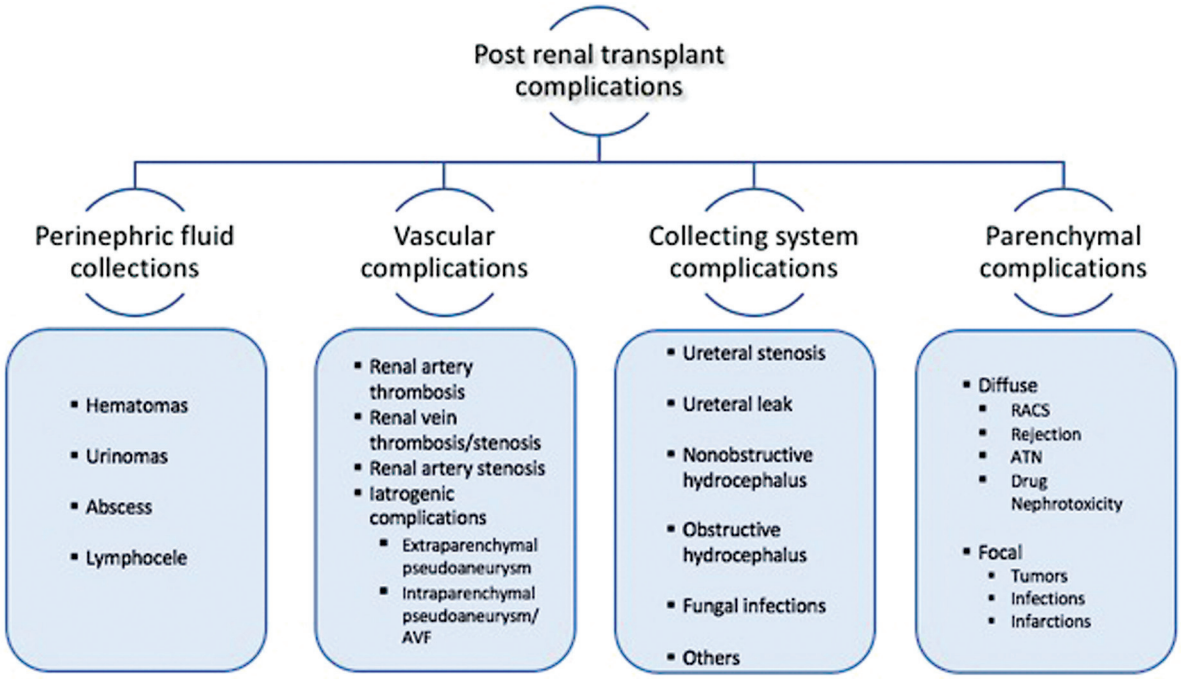

Fig. 2 Classification of postrenal transplant complications.

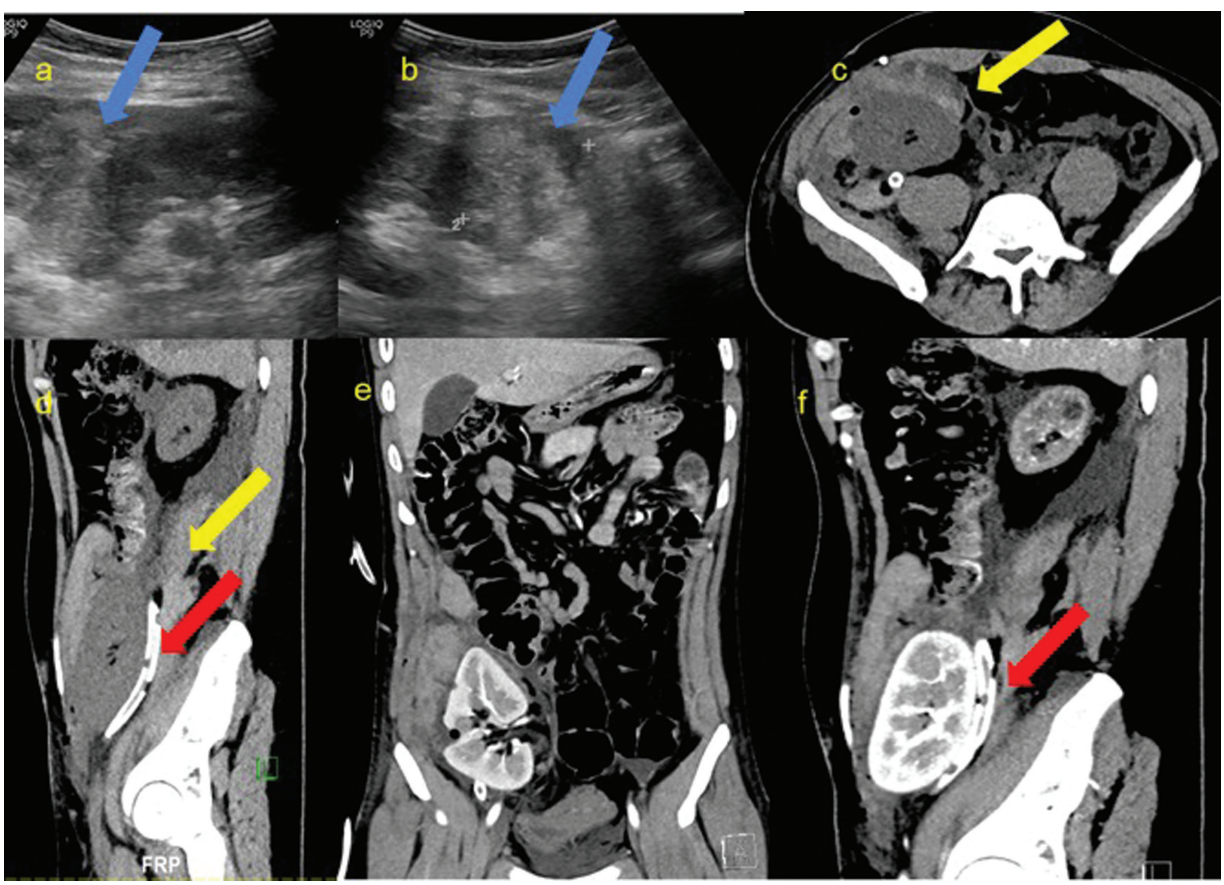

Fig. 3 Images of a 28-year-old male patient (posttransplantation, second postoperative day) presented with abdominal pain and a drop in hemoglobin. Ultrasound images (**a** and **b**) show hyperechoic focus (*blue arrows*) adjacent to the transplanted kidney. Noncontrast CT images (**c** and **d**) show large perinephric hematoma (*yellow arrows*) with the extension of hematoma cranially on both anterior and posterior aspects. In addition, the drain (*red arrows*) was seen along the posterior surface of the transplanted kidney. There was no active contrast extravasation in contrast-enhanced CT images in coronal and sagittal sections (**e** and **f**). The patient was managed conservatively. CT, computed tomography.

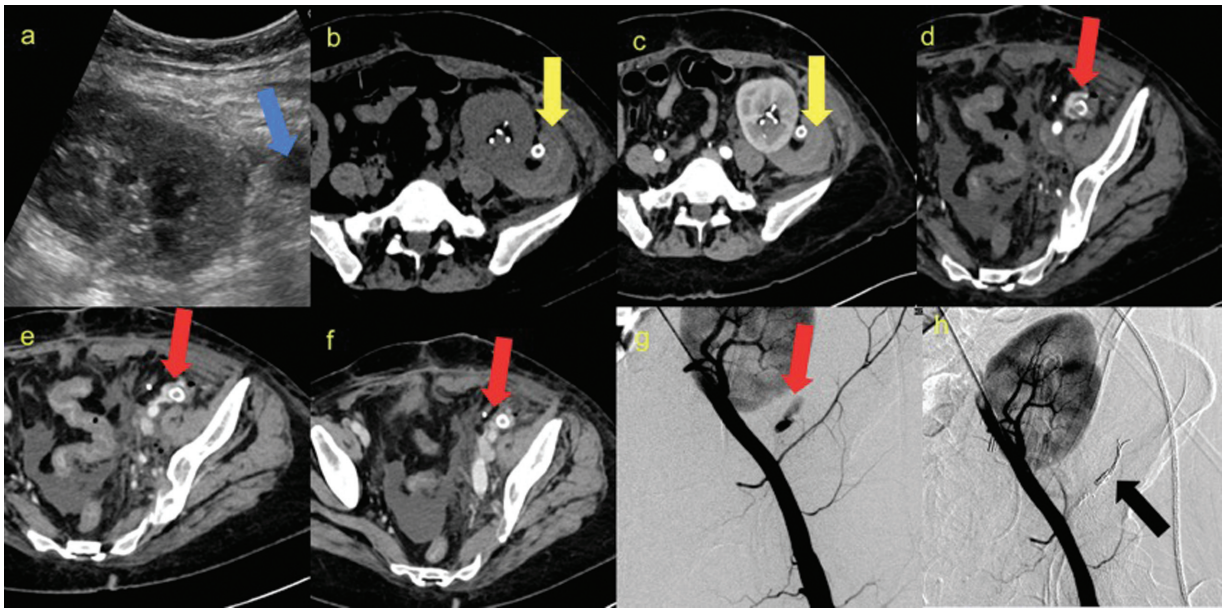

Fig. 4 Images of a 28-year-old male patient (posttransplantation, second postoperative day) presented with abdominal pain and a drop in hemoglobin. Ultrasound images (**a** and **b**) show hyperechoic focus (*blue arrows*) adjacent to the transplanted kidney. Noncontrast CT images (**c** and **d**) show large perinephric hematoma (*yellow arrows*) with the extension of hematoma cranially on both anterior and posterior aspects. In addition, the drain (*red arrows*) was seen along the posterior surface of the transplanted kidney. There was no active contrast extravasation in contrast-enhanced CT images in coronal and sagittal sections (**e** and **f**). The patient was managed conservatively. CT, computed tomography.

CT or MR urogram, and extra urinary tracer excretion at renal scintigraphy.[14]

Abscess

Fever and leukocytosis in conjunction with a perinephric fluid collection should raise suspicion for superimposed infection. Abscess (►**Fig. 6**) occur weeks to months after transplantation, are typically heterogeneously hypoechoic with internal debris and septa, and show increased blood flow in the thickened wall and septa. Contrast-enhanced CT and MRI reveal areas of peripheral enhancement, with diffusion restriction in nonenhancing areas. CT and MRI are also valuable for evaluating the extent of abscess and involvement of adjacent structures.[15]

Prompt treatment with systemic antibiotics and percutaneous drainage or surgical management is necessary.

Lymphocele

Lymphocele (►**Fig. 7**) typically occurs 2 weeks to 6 months after surgery, is seen as a fluid collection without an epithelial lining, along the graft or pelvic sidewall, and is the most common collection resulting in hydronephrosis.[16] USG

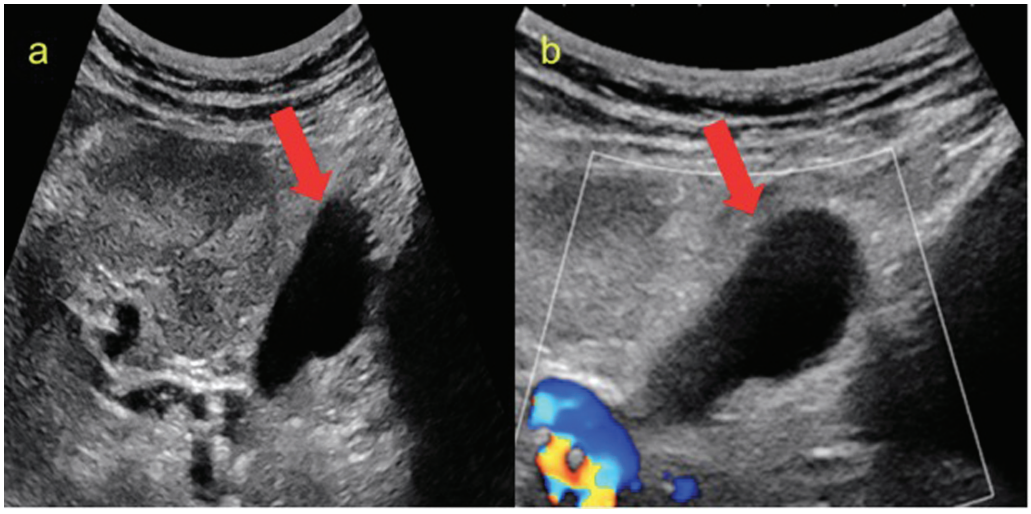

Fig. 5 USG of the transplanted kidney (**a**) and (**b**) in a 33-year-old male patient (renal transplantation—1 week ago) shows well-defined anechoic collection on B scan with no vascularity on the doppler scan adjacent to the lower pole of the kidney (*red arrows*), suggestive of urinoma. Aspiration from the collection shows elevated creatinine compared to serum creatinine, confirming the diagnosis. USG, ultrasonography.

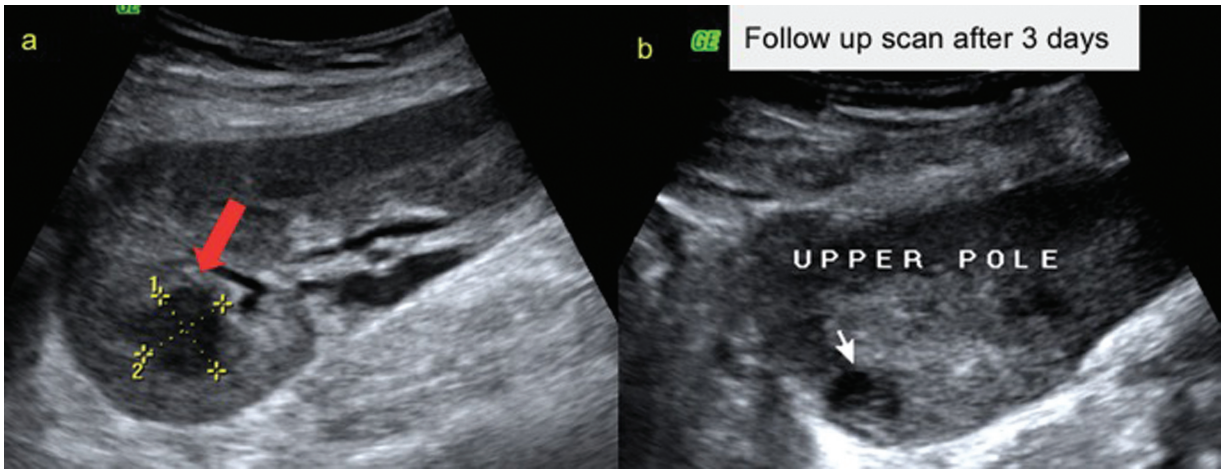

Fig. 6 Ultrasound image (**a**) of a patient who presented with fever shows a hypoechoic lesion with irregular margins, which may represent an abscess (*red arrow*). Antibiotics were started and repeat ultrasound (**b**) after 3 days showed a decrease in the abscess size.

shows well marginated and anechoic collection, occasionally containing thin internal septa. It is characterized by a barely perceptible wall and internal simple fluid attenuation at CT and high T2 signal intensity at MRI.

Treatment includes U.S.-guided percutaneous drainage or laparoscopic peritoneal fenestration. Since percutaneous catheter drainage may result in high rates of reaccumulation (approaching 90%), sclerosing agents such as ethanol, povidone-iodine, or fibrin glue have been used as alternatives with varying degrees of success.

Vascular Complications

Renal Artery Thrombosis

It develops in the early postoperative period, due to hyperacute rejection, anastomotic occlusion, kinking, or intimal flap. Clinical signs include sudden oliguria or anuria with the reduction of graft function. This results in segmental or global renal infarction (►**Fig. 8**) which can be identified by imaging.[14] At USG, segmental infarct appears as a focal ill-defined hypoechoic region, with Doppler showing a corresponding wedge-shaped region of avascularity, and global infarct is seen as absent blood flow throughout the graft. This requires early and accurate diagnosis since immediate intervention is critical for graft salvage. When USG results are nondiagnostic, CT angiography, MR angiography, digital subtraction angiography, or renal scintigraphy may be performed.[17] Angiography shows reduced or absent flow to the graft and an abrupt cutoff in the transplant renal artery. CT and MRI can be used to localize the thrombus within the vessels and also to confirm renal infarcts seen as wedge-shaped areas of hypoattenuation with reduced enhancement. Renal scintigraphy can show reduced or absent graft perfusion on the time-activity curve, although nonspecific for thrombosis, as this can also be seen with rejection.

If graft arterial thrombosis is recognized early, it is usually treated with surgical thrombectomy to restore tissue

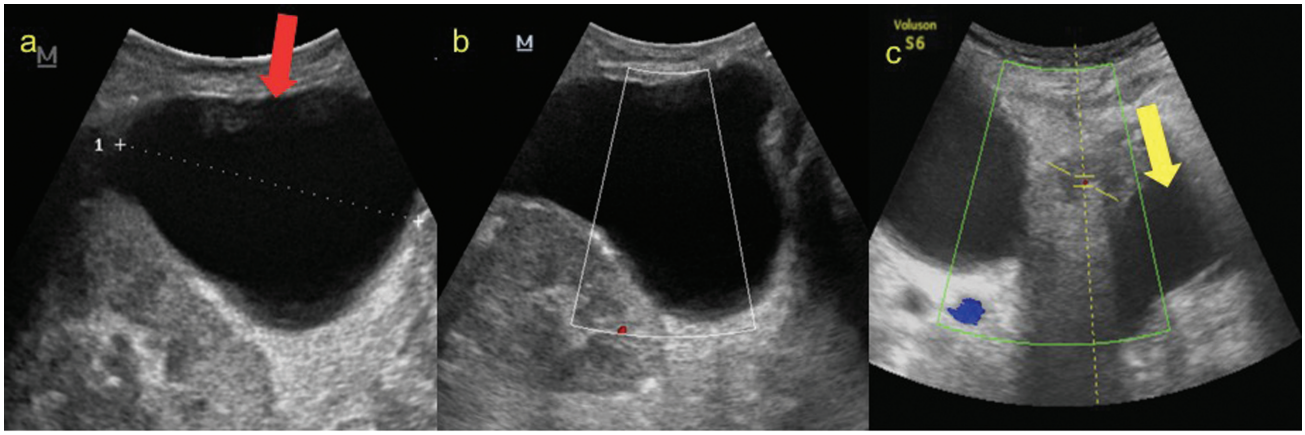

Fig. 7 Ultrasound images of a 53-year-old female patient (3 weeks postrenal transplantation) show thin-walled anechoic collection (*red arrow*) with no solid component/septation (**a**) and no significant intralesional vascularity on doppler scan (**b**) was noted adjacent to the transplanted kidney.(c) shows the relationship of collection to the bladder (yellow arrow) – s/o lymphocele.

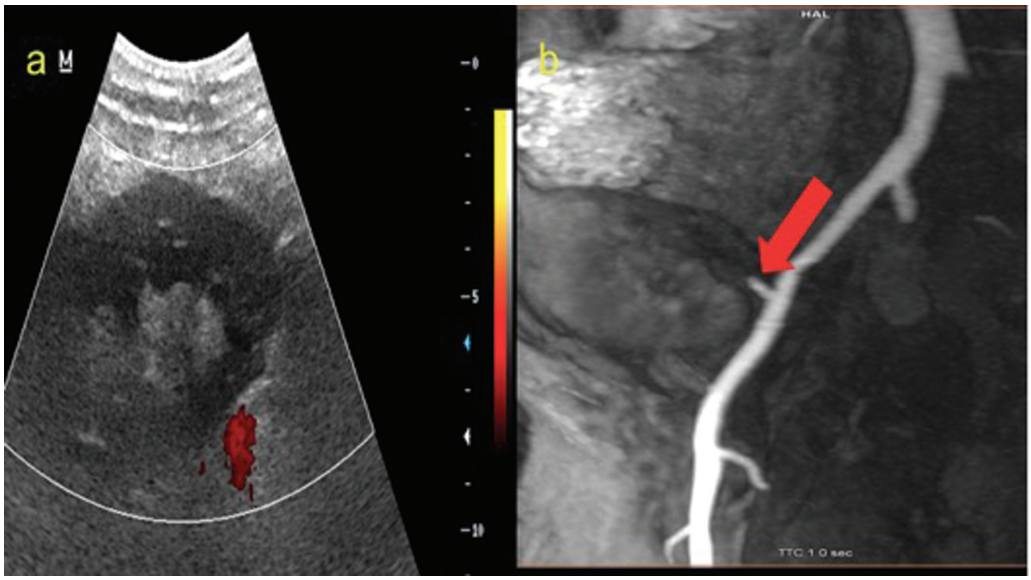

Fig. 8 Power doppler image (**a**) of the transplanted kidney shows the absence of intraparenchymal vascularity in the entire kidney, s/o global infarction. (**b**) Contrast-enhanced MR angiography shows complete occlusion of the renal artery (*red arrow*) distal to its anastomosis. MR, magnetic resonance.

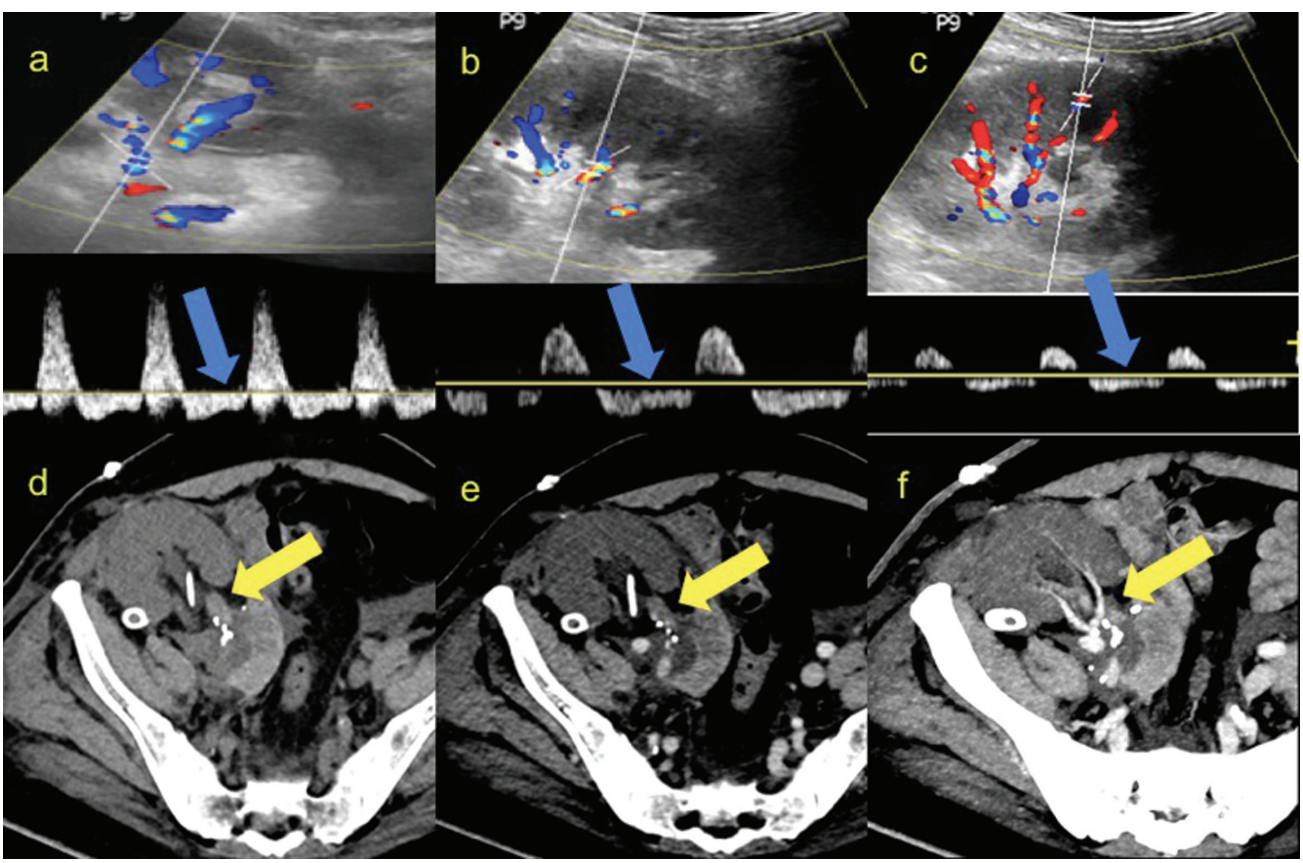

Fig. 9 Spectral doppler images of main (**a**), segmental (**b**), and arcuate (**c**) renal arteries of the transplanted kidney show reversal of flow (*blue arrows*) in the diastolic phase. Noncontrast CT image (d) of the same patient in the axial plane shows a hyperdense main renal vein (MRV). Contrast-enhanced CT images in the axial plane (**e**) and maximum intensity projection (MIP) (f) show a filling defect (*yellow arrows*) in the main renal vein, consistent with MRV thrombosis. CT, computed tomography.

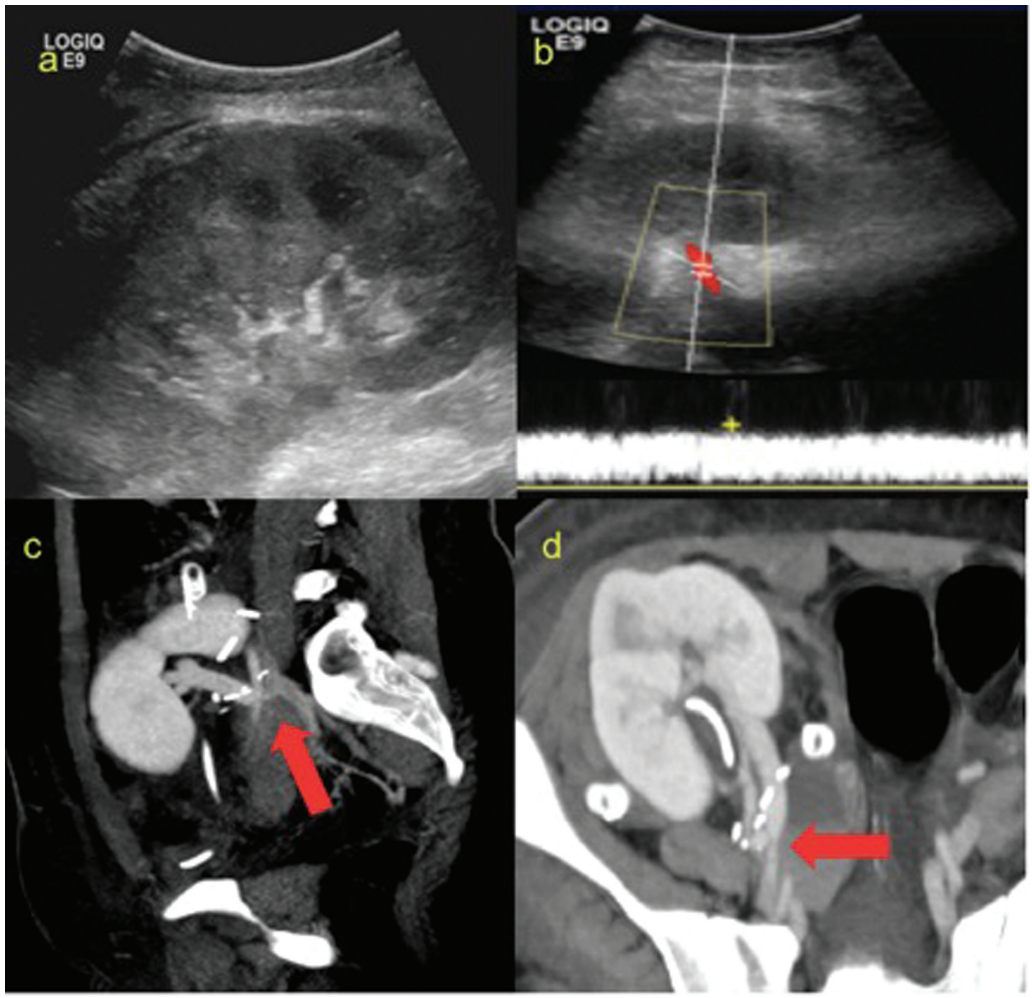

Fig. 10 Ultrasound of the transplanted kidney image (**a**) showed an increase in the size of the transplanted kidney with increased cortical echogenicity. Spectral Doppler (**b**) showed flow within the main renal vein (MRV). However, the confluence of MRV with the external iliac vein (EIV) was not visualized. Contrast-enhanced CT images (**c** and **d**) in oblique sagittal section and MIP format shows tight focal stenosis of MRV (*red arrows*) at its anastomosis with EIV. CT, computed tomography.

perfusion or with catheter-guided fibrinolysis with better outcomes if performed within 24 hours.[18]

Renal Vein Thrombosis/Stenosis

Renal vein thrombosis (►**Fig. 9**) usually occurs within 5 days postsurgery, with peak incidence within the first 48 hours. It usually develops from deep venous thrombosis. Renal vein stenosis (►**Fig. 10**) is a rare complication, seen as anastomotic site narrowing. Early findings at USG include edematous kidney, loss of CMD, perinephric fluid, and reversed diastolic flow in renal artery at Doppler. CT/MRI shows focal or diffuse changes in attenuation due to perfusion abnormalities, and angiography reveals intraluminal filling defects.

Surgical venous thrombectomy, or if the clot burden is less, catheter-directed thrombolysis can be employed.[19]

Renal Artery Stenosis

RAS (►**Fig. 11**) is the most common vascular complication, affecting about 3% of all cases, manifesting 3 months to 2 years after transplantation.[20] Direct signs in USG are the elevation of peak systolic velocity (PSV) in tRA $>$ 250 cm/s and aliasing at the site of narrowing, ratio of PSV in tRA with respect to iliac artery $>$ 1.8. Other Doppler criteria include RI $<$ 0.56, acceleration index (AI) $<$300 cm/s^2, and acceleration time (AT) $>$ 0.07 sec.[21] When other signs are absent, the absolute PSV of 340 to 400 cm/s at the anastomosis can be a more reliable cutoff for tRA stenosis. Indirect signs are seen distal to the site of stenosis, including tardus-parvus waveform and relatively reduced RI. CT/MRI angiography shows the site of focal arterial narrowing. Pseudotransplant renal artery stenosis refers to thrombosis or stenosis of iliac artery or aorta proximal to transplant renal artery (►**Fig. 12**).

Percutaneous transluminal angioplasty (PTA) represents the first-line treatment option of RAS, aimed to recover renal function. In cases of restenosis, PTA with stent deployment should be considered. The use of cutting-balloon angioplasty in pressure-resistant stenosis has also been studied, with good results at mid-term follow-up.[22]

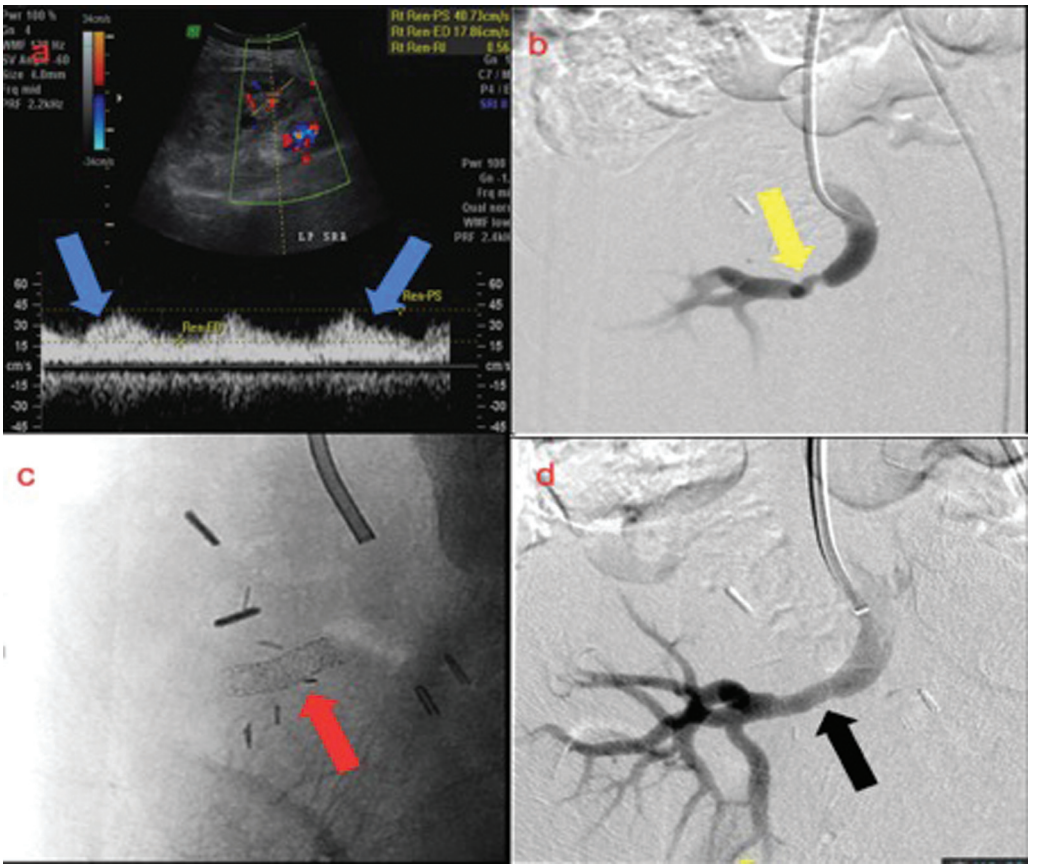

Fig. 11 Spectral doppler image (**a**) of the transplanted kidney shows parvus tardus waveform (*blue arrows*) in an intraparenchymal renal arterial branch. Selective renal artery digital subtraction angiography (DSA) (**b**) shows tight focal stenosis (*yellow arrow*) in the mid-segment of the renal artery. Fluoroscopy image (**c**) after placement of a balloon expandable bare metal stent (*red arrow*). DSA post stenting (**d**) shows a nearly complete revascularization of the transplant renal artery (*black arrow*).

Iatrogenic Vascular Complications

Extraparenchymal Pseudoaneurysm

It arises from the iliac vessels involved in anastomosis and is a rare complication after transplantation, detected as a cystic lesion which shows the color flow and to-and-fro spectral pattern on a Doppler study. To prevent the rupture of pseudoaneurysm, endovascular methods like stent-graft placement, ultrasound-guided thrombin injection, or coil embolization can be used.[23]

Intraparenchymal Pseudoaneurysm and Arteriovenous Fistula

These may develop as complications of the diagnostic procedures or biopsies performed before transplantation, intraoperatively, or as part of a posttransplantation protocol. It is important to distinguish between arteriovenous fistula (AVF) and pseudoaneurysm. Both can appear as focal areas with disorganized blood flow extending beyond the margins of the normal vessel at USG.

AVF (►**Figs. 13** and **14**) shows a feeding segmental or interlobar artery with a turbulent high-velocity low-resistance flow, paired with a vein showing aliasing and arterialized waveform.[14] Large or symptomatic AVF causing significant hematuria or hypertension occurs in only 1 to 2% of cases and can be treated with catheter embolization.[24] Most other cases of AVF are asymptomatic with no clinically significant hemodynamic effects and can be treated conservatively and followed up with USG, with 70% regressing or resolving spontaneously.

Pseudoaneurysm (►**Fig. 15**) appears as a mildly complex cystic structure that can mimic a simple renal cyst. Doppler reveals to-and-fro pattern of blood flow in the neck of the cystic structure and yin-yang sign of swirling blood within the sac. It may require intervention, particularly if large (>2 cm) or progressively growing in size.[14] CT/MR angiography plays an important role in delineating the anatomy of AVF or characterizing a pseudoaneurysm if endovascular intervention using superselective transcatheter embolization is planned.

Collecting System Complications

Ureteral Stenosis

It occurs in 2 to 10% of all transplanted kidneys and is generally classified as early (≤ 3 months) and late (> 3 months).[25] Early stenosis is usually located at vesicoureteric junction, whereas late stenosis is at a more proximal site and is caused by fibrosis resulting from ischemia or rejection.

Interventional management consists of percutaneous nephrostomy, balloon dilatation, insertion of a double-J stent, and rarely, metallic stent placement.

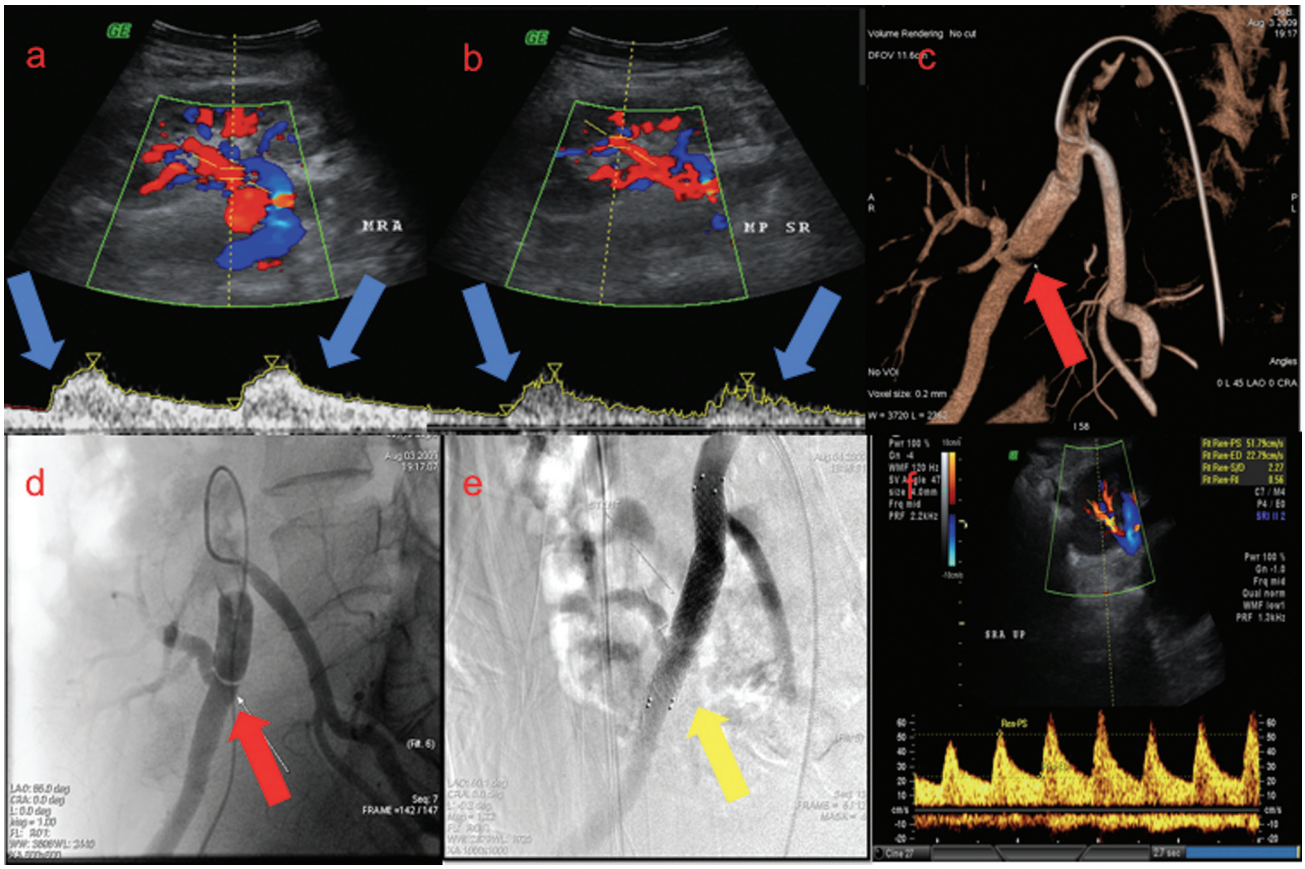

Fig. 12 Doppler images (**a** and **b**) of a posttransplant patient with worsening renal function show parvus tardus waveform in main and intraparenchymal renal arteries. Virtual reconstructed CT image (**c**) shows external iliac artery dissection (*red arrow*) immediately proximal to the renal artery anastomosis. The same finding was demonstrated in DSA of the right external iliac artery (**d**). The dissection was treated with stenting with a self-expandable bare metal stent (right brace), and poststenting DSA (**e**) shows recanalized right external iliac artery with filling of the transplant renal artery. Poststenting intraparenchymal arterial spectral doppler image (**f**) shows a typically normal waveform. CT, computed tomography; DSA, digital subtraction angiography.

Ureteral Leak

This is an early complication caused by ischemia of the distal third of ureter or by technical failure during the ureteroneocystostomy anastomosis.

Although leaks are usually treated with reconstructive surgery, percutaneous deployment of an 8 – 12 Fr nephrostomy/DJ stenting in the transplant kidney may be used as a first-line treatment, to divert urine away

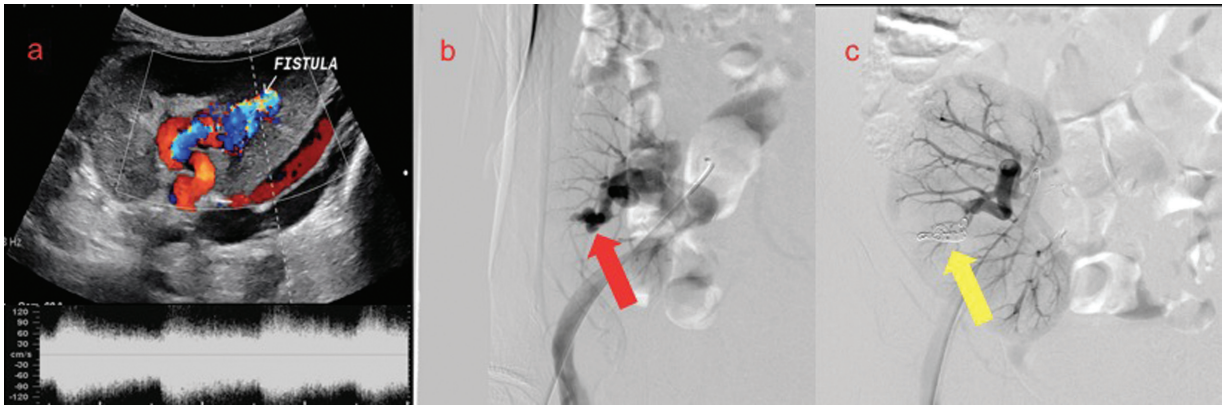

Fig. 13 USG (**a**) color Doppler image shows aliasing flow in the interpolar region of postbiopsy transplant kidney (*white arrow*), suggesting AV fistula. The preprocedural angiographic image (b) shows the AV fistula (red arrow). It was treated with coiling, and the postprocedural (c) DSA shows complete obliteration of the AV fistula with coil mass in the feeding artery (*yellow arrow*). AV, arteriovenous; DSA, digital subtraction angiography; USG, ultrasonography.

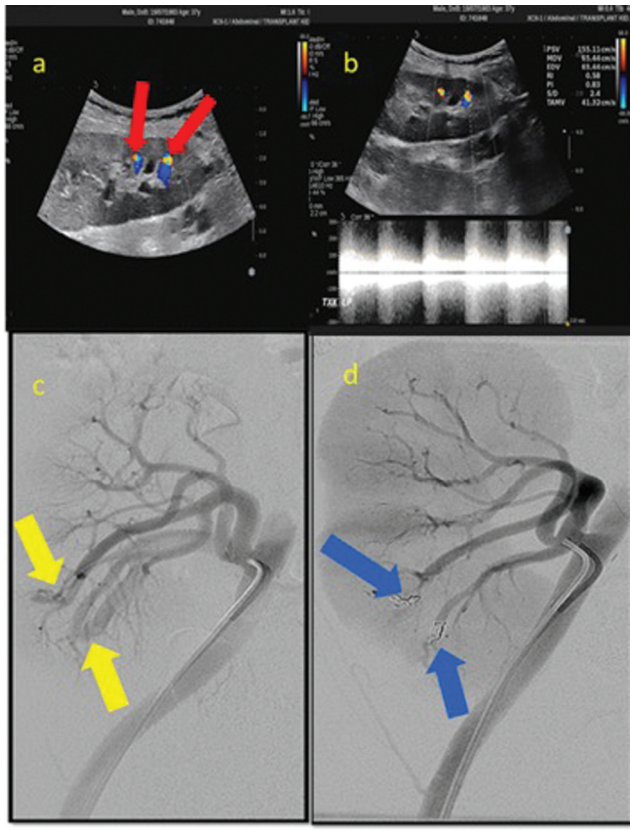

Fig. 14 Doppler images (**a** and **b**) of the transplanted kidney show two foci of aliasing flow in its lower half (*red arrow*) with turbulent flow, suggesting two AV fistulae. The preprocedural angiographic image shows both the AV fistulae (*yellow arrows*). They were treated by superselective catheterization of the feeding arteries with a microcatheter followed by coil embolization, and the postprocedural (**d**) DSA image shows complete obliteration of the AV fistulae (*blue arrows*). AV, arteriovenous; DSA, digital subtraction angiography.

from the leak site, thus causing spontaneous closure of the ureteral defect.[26]

Flaccid or Nonobstructive Hydronephrosis

Mild pelvicaliectasis can occur due to the dependent orientation of the allograft in the iliac fossa, and there is an increased tendency for vesicoureteral reflux (►**Fig. 16**).

Obstructive Hydronephrosis

Hydronephrosis secondary to obstruction (►**Fig. 17**) occurs usually within 6 months. Early presentation is due to anastomotic edema or compression from extrarenal collections, and late causes are strictures in distal ureter secondary to ischemia.

Interventional radiology management includes urinary diversion using percutaneous nephrostomy insertion and once renal function has improved definitive surgical treatment could be done.

Fungal Infections

A fungus ball appears as a focal rounded, weakly shadowing or echogenic structure in a dilated pelvicalyceal system.

Others

Other complications include pyonephrosis, renal stones, and transitional cell carcinoma.

Parenchymal Complications

Diffuse

Renal Allograft Compartment Syndrome

It is a rare syndrome that occurs due to intracompartment hypertension secondary to mismatch between the organ's size and extraperitoneal space. It is seen with extraperitoneal/ retroperitoneal graft placement and results in graft ischemia. Contrast-enhanced ultrasound (CEUS)diagnosis of renal allograft compartment syndrome is made by absent or diffusely reduced cortical flow in the graft in USG, usually manifesting within 2 hours of transplantation.[27]

Immediate recognition of this entity is critical, as the graft may be salvaged by immediate resurgery.

Rejection

The imaging manifestations of rejection are nonspecific, including cortical thickening, loss of CMD, reduced cortical flow, and raised intrarenal arterial RI.[28] CEUS allows the evaluation of microvascular renal perfusion, with delayed cortical perfusion noted in acute rejection. CT shows similar appearances in rejection and acute tubular necrosis (ATN), seen as edematous enlargement of the graft with patchy enhancement. MRI with DWI, BOLD, and ASL techniques can provide information on allograft oxygenation and perfusion.

Acute Tubular Necrosis

ATN is more common in transplants from a deceased donor and shows similar features as rejection, seen as perfusion abnormalities and marked cortical retention with 99mTc MAG3.

Drug Nephrotoxicity

Calcineurin inhibitors used as maintenance therapy for immunosuppression (e.g., cyclosporine, tacrolimus) can cause chronic nephrotoxic effects with irreversible damage. Distinguishing between these and other causes of renal dysfunction is challenging.

The aim of imaging in all these diffuse parenchymal complications (►**Fig. 18**) is to exclude other treatable complications like vascular and perinephric fluid collections. Most of these diffuse renal parenchymal complications appear similarly in all imaging modalities and biopsy is the mainstay method for the diagnosis.

Focal

Tumors

Transplant recipients have three to five times increased risk of malignancy than the general population, with an increased incidence of cancers like nonmelanomatous skin cancer, lymphoma, and colon cancer.[29]

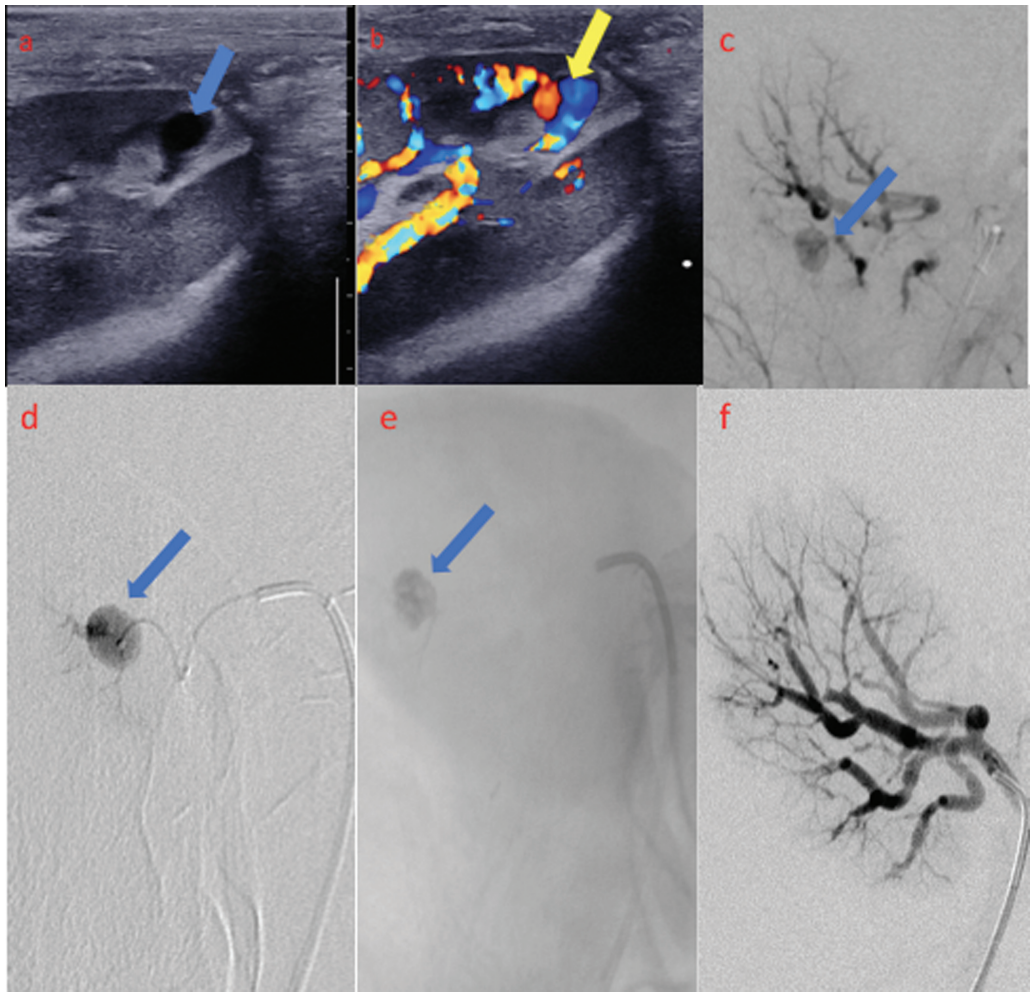

Fig. 15 USG (**a**) and (**b**), 2D and Doppler images of transplanted kidney show well-defined saccular outpouching (*blue arrow*) in the arcuate branch of the lower pole of transplant kidney with classical "yin –yang" sign (*yellow arrow*). The pseudoaneurysm is visible on the DSA (**c**) (*blue arrow*). Superselective catheterization of the pseudoaneurysm branch and embolisation with 50% NBCA glue (**d** and **e**). Postembolisation DSA (**f**) showed complete obliteration of the pseudoaneurysm. DSA, digital subtraction angiography; NBCA, N-butyl cyanoacrylate.

Renal Cell Carcinoma

The renal allograft carries an additional risk of malignancy associated with chronic immunosuppression and unregulated oncogenic viral infections. These include renal cell carcinoma and urothelial malignancies, particularly in patients with BK virus infection.[30] Renal cell carcinoma (RCC) in transplant kidney shows similar imaging features as that of RCC in native kidney, appearing heterogeneous with increased vascularity.

Posttransplant Lymphoproliferative Disorder

Postttransplant lymphoproliferative disorder (PTLD; ►**Fig. 19**) can be nodal or extranodal disease, seen as solitary or multiple low-attenuation masses at CT involving the transplant kidney and other solid organs. The lesion in the renal allograft appears as a mass replacing or encasing the hilum (faceless kidney sign) and leading to outflow obstruction.[31] Imaging shows hydronephrosis with or without vascular encasement. MRI shows T1 and T2 hypointense lesions with no significant enhancement. Increased fluorodeoxyglucose (FDG) uptake is usually observed at FDG-positron emission tomography scan.

Infections-Early/Intermediate/Late

Infections in renal transplant patients are based on the time period from transplantation. In the 1st month, the patients will acquire nosocomial and procedure-related infections, while in the intermediate period (1–6 months), they are more prone to opportunistic infections. After 6 months, the community-acquired infections are more common in the postrenal transplant patients. The main role of imaging the graft with suspected infection is to exclude complications. At USG, perinephric or parenchymal fluid collections with internal echoes and peripheral hypervascularity suggest abscess. The renal collecting system may show echogenic debris or mobile masses, representing pyonephrosis or fungus ball, respectively.[32] At CECT or MRI, a striated nephrogram can be seen. Rarely, necrotizing infections by gram-

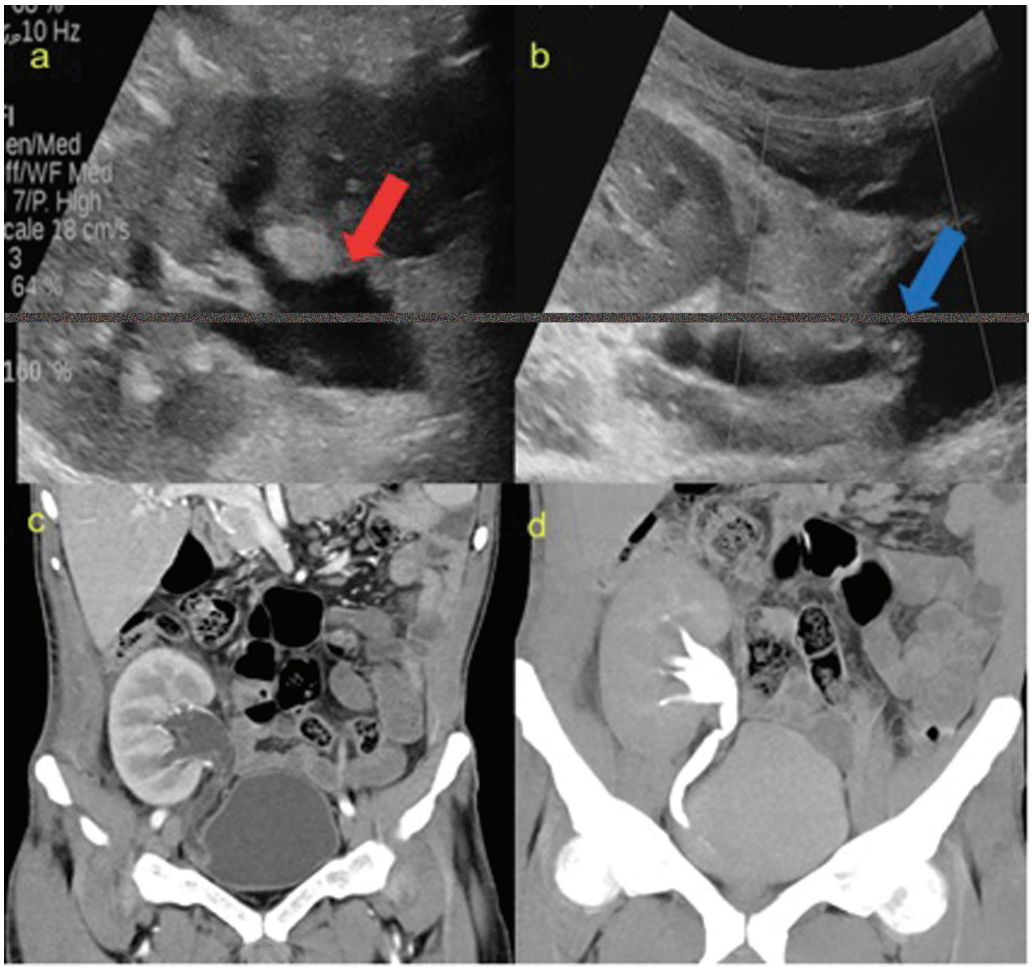

Fig. 16 Ultrasound images (**a** and **b**) show dilatation of the pelvicalyceal system (*red arrow*) and ureter till the vesico ureteric junction (*blue arrow*). Contrast-enhanced CT images in the coronal plane in arterial (a) and (b) delayed phases show a transplanted kidney in RIF with nonobstructive hydroureteronephrosis. CT, computed tomography; RIF, renal interstitial fibrosis.

negative bacteria may progress rapidly to emphysematous pyelonephritis (►**Fig. 20**), which may be life-threatening and often requires graft nephrectomy. On USG, in emphysematous pyelonephritis, gas in the parenchyma of the renal graft produces an echogenic line with distal reverberation artifacts.

Infarction

Renal infarcts can be global or segmental and require early and accurate diagnosis since immediate intervention is critical for graft salvage as discussed earlier.

Conclusion

Renal transplantation is the most effective treatment for end-stage renal disease. Advanced immunosuppressive therapy and better surgical techniques have resulted in better survival of the grafted kidney. In spite of all these advances, complications do occur in the early or late postoperative period. Radiological imaging using traditional methods like USG, CT, and MRI and newer methods like elastography, MRI ASL, DWI, DKI, BOLD, and MRE can be used in the diagnosis of these complications. Timely diagnosis of these complications helps to manage them better and salvage the transplant kidney. Interventional radiology has advanced a lot in managing these complications making them the first choice where robust interventional radiology setup is available.

Teaching Points

1. Renal transplantation complications can be broadly divided into perinephric fluid collections, vascular, collecting system, and parenchymal complications.
2. Urinomas are noted within 10 days of transplantation and lymphocele typically occurs 2 weeks to 6 months after surgery. Urinomas are usually treated with reconstructive surgery, percutaneous deployment of nephrostomy/nephroureterostomy in the transplant kidney and treatment for lymphocele includes US-guided percutaneous drainage or laparoscopic peritoneal fenestration.
3. In the Doppler assessment of renal artery stenosis, direct signs include elevation of PSV in tRA >250 cm/s, aliasing

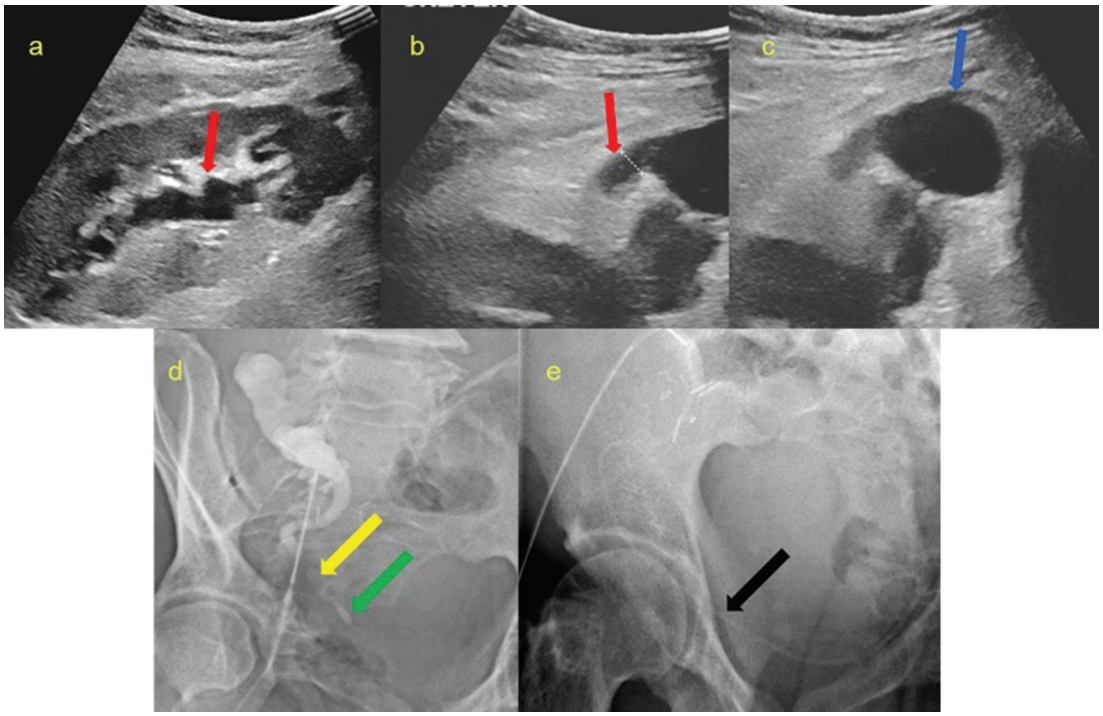

Fig. 17 Images of 40-year-old male patient who underwent transplantation 3 weeks ago presented increased creatinine values. Ultrasound images (**a–c**) show mild hydroureteronephrosis (*red arrow*). An anechoic collection (*blue arrow*) was noted at midureter level with compression over the ureter causing upstream hydroureteronephrosis. Percutaneous nephrostogram (**d**) shows similar findings with narrowing at midureter level (*yellow arrow)* and normal sized distal ureter (*green arrow*). Fluoroscopic image (**e**) shows DJ stent (*black arrow*) across the compressed portion of the ureter, and the collection causing compression was aspirated. The patient creatinine level was improved. The collection turned out to be lymphocele. DJ, double J.

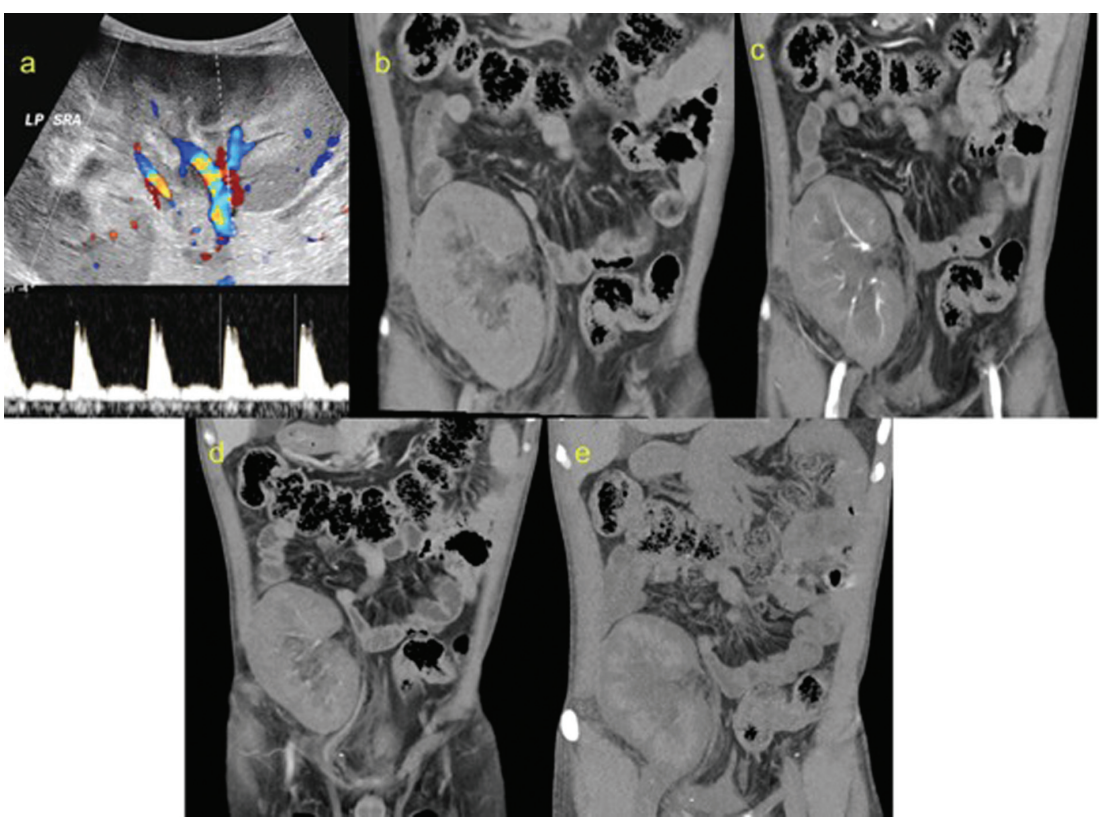

Fig. 18 Ultrasound image (**a**) shows enlarged transplant kidney with increased cortical echogenicity and increased RI on spectral doppler. CT images in coronal plane in plain (**b**), arterial (**c**), venous (**d**), and delayed (**e**) phases show transplant kidney in RIF with diffuse poor enhancement of renal parenchymal suggesting diffuse renal parenchymal disease. The parenchymal changes in this patient was attributed to drug toxicity. CI, confidence interval; CT, computed tomography; RI, resistivity index; RIF, renal interstitial fibrosis.

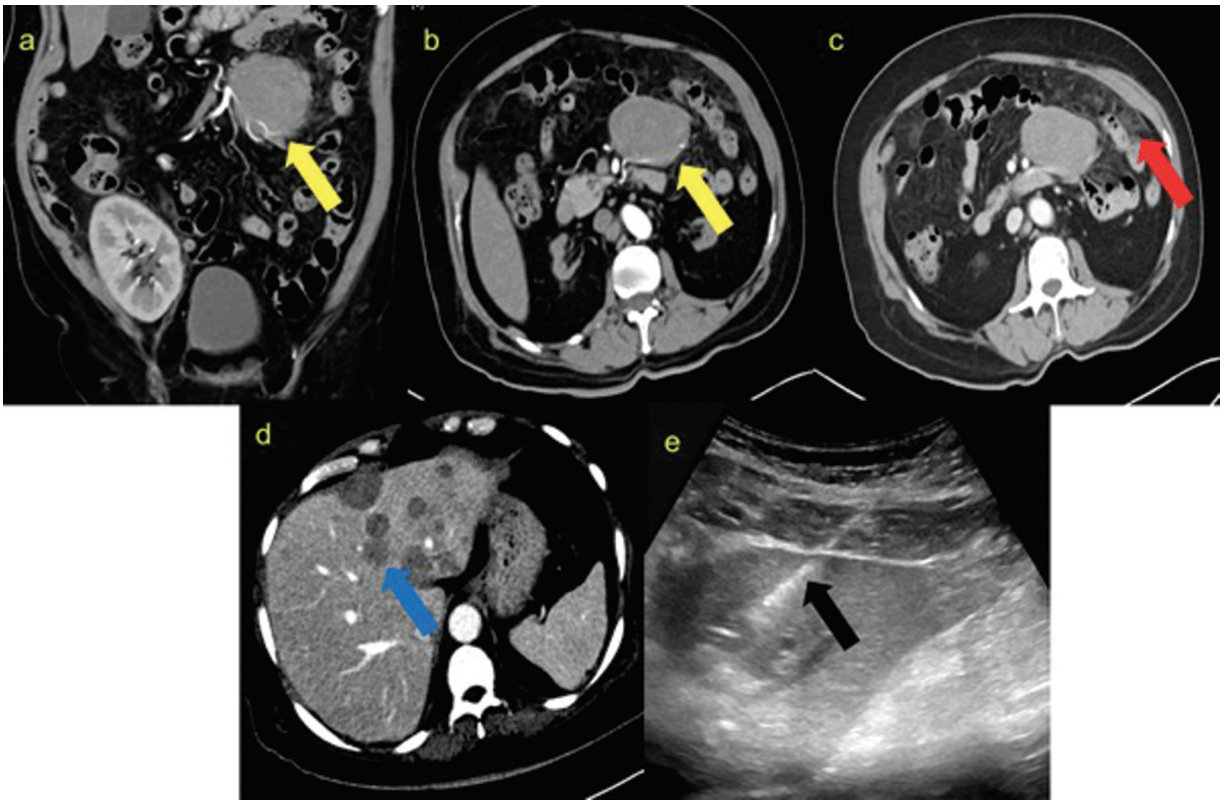

Fig. 19 Contrast CT coronal and axial images show transplant kidney in RIF (**a**) and hypodense lesion (*yellow arrows*) in the jejunal mesentery and omental nodularity (*red arrow*) (**b**) and (**c**), and multiple hypodense lesions (*blue arrows*) in the liver (**d**). Under ultrasound guidance (**e**), a percutaneous tru-cut biopsy (*black arrow*) was taken from the focal lesion in the liver, and posttransplant lymphoproliferative disorder (PTLD) was diagnosed on histopathologic examination. CT, computed tomography; RIF, renal interstitial fibrosis.

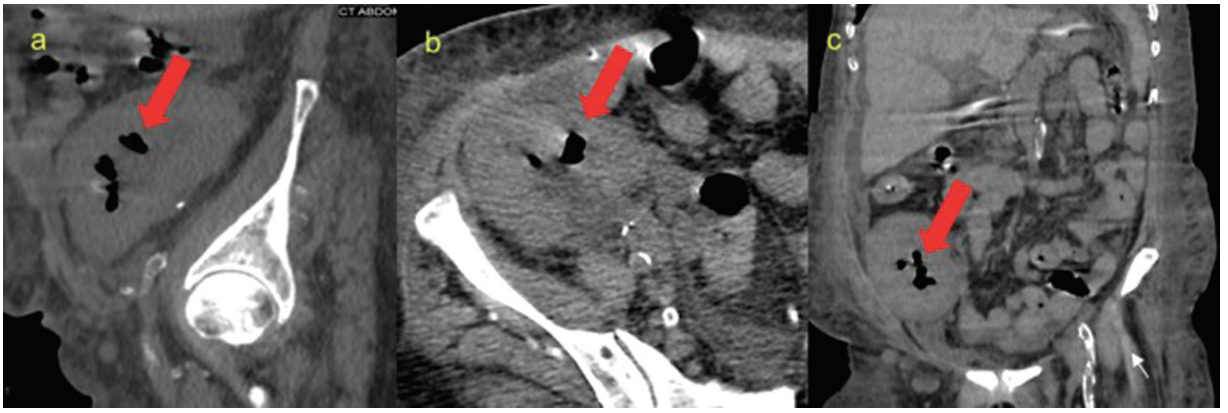

Fig. 20 Plain CT images in sagittal (**a**), axial (**b**), and coronal (**c**) planes show a transplanted kidney in RIF. Few air foci (*red arrows*) were noted within the pelvicalyceal system of the transplanted kidney suggesting emphysematous pyelonephritis. CT, computed tomography; RIF, renal interstitial fibrosis.

at the site of narrowing, RI <0.56, AI <300 cm/sec^2, and AT >0.07 seconds. Indirect signs include distal to the site of stenosis, including tardus-parvus waveform and relatively reduced RI.

4. AVF shows a feeding segmental or interlobar artery with a turbulent high-velocity low-resistance flow, paired with a vein showing aliasing and arterialized waveform.
5. Pseudoaneurysm appears as a mildly complex cystic structure that can mimic a simple renal cyst. Doppler reveals to-and-fro pattern of blood flow in the neck of the cystic structure and yin-yang sign of swirling blood within the sac.

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Conflict of Interest
None declared.

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