Successful technical and clinical outcome using a second generation balloon expandable coronary stent for transplant renal artery stenosis: Our experience

Jason Salsamendi[1], Keith Pereira[1*], Reginald Baker[1], Shivank S Bhatia[1], Govindarajan Narayanan[5]

1. Department of Interventional Radiology, Jackson Memorial Hospital/University of Miami Hospital, Miami, Florida, USA

* **Correspondence:** Keith Pereira, 1611 Northwest 12th Avenue, WW 279, Miami, FL, USA 33136, USA (*keithjppereira@gmail.com*)

Radiology Case. 2015 Oct; 9(10):9-17 :: DOI: 10.3941/jrcr.v9i10.2535

ABSTRACT

Transplant renal artery stenosis (TRAS) is a vascular complication frequently seen because of increase in the number of renal transplantations. Early diagnosis and management is essential to optimize a proper graft function. Currently, the endovascular treatment of TRAS using angioplasty and/or stenting is considered the treatment of choice with the advantage that it does not preclude subsequent surgical correction. Treatment of TRAS with the use of stents, particularly in tortuous transplant renal anatomy presents a unique challenge to an interventional radiologist. In this study, we present three cases from our practice highlighting the use of a balloon-expandable Multi-Link RX Ultra coronary stent system (Abbott Laboratories, Abbott Park, Illinois, USA) for treating high grade focal stenosis along very tortuous renal arterial segments. Cobalt–Chromium alloy stent scaffold provides excellent radial force, whereas the flexible stent design conforms to the vessel course allowing for optimal stent alignment.

CASE SERIES

CASE SERIES

CASE 1

69-year-old male with a history of chronic hepatitis C, post liver transplant and deceased donor kidney transplantation (DDKT) in June 2014. Patient had an uneventful post-operative course. Doppler ultrasound (US), which was performed a day after surgery, revealed a patent renal artery with a slightly elevated peak systolic velocity (PSV) of 234 cm/s (normal < 180 cm/s) with a baseline creatinine of 1.69 mg/dL (normal <1.1 mg/dL)

Two months after the uneventful surgery, serum creatinine levels were relatively stable, whereas surveillance Doppler US (Fig. 1a) revealed elevated juxtaanastomotic velocities of 544 cm/s, which were consistent with renal arterial stenosis (RAS). In addition, a nuclear medicine renogram was performed which revealed moderate to severely reduced perfusion with cortical retention in the transplant kidney suggestive of a medical renal disease (Fig. 1b). Two weeks after the treatment for T-cell mediated rejection with thymoglobulin, his serum creatinine increased to 3.0 mg/dL and juxtaanastomotic arterial velocities peaked to 650 cm/s.

Considering the worsening graft function, endovascular treatment was attempted (Fig. 1b–d).Patient's consent was obtained pertaining to off-label use of the stent. A carbon dioxide (CO2) digital subtraction angiogram (DSA) confirmed a juxtaanastomotic kink (Fig. 1b). In an attempt to cross the stenosis, a dissection flap was created which propagated to the renal artery bifurcation.

After three days, with the patient on systemically anticoagulation, endovascular intervention was reattempted. A repeat angiogram was performed which confirmed the angiographic findings of juxtaanastomotic stenosis and dissection flap. The transplant renal artery was catheterized beyond both the stenosis and dissection flap. Over a 0.014″ transcend microwire (Boston Scientific, Nastick, MA), a 5 × 13 mm Multi-Link RX Ultra coronary stent (Abbott Laboratories. Abbott Park, Illinois, USA) was placed at the level of the stenosis. During balloon dilatation, the stent migrated slightly to the distal end. A more proximal 4.5 × 13 mm Multi-Link RX Ultra coronary stent was then placed partially overlapping the more distal stent (Fig. 1c). Post-stent renal angiogram demonstrated the resolution of stenosis with the overlapping stents conforming to the tortuous arterial course with no secondary stenosis or kinks along either ends of the stents. The previously noted flow-limiting dissection flap was again seen at the renal bifurcation (Fig. 1d).

Post-procedure Doppler US (Fig. 1e) demonstrated a drop of the juxtaanastomotic velocities to 56 cm/s, whereas serum creatinine improved to 1.4 mg/dL. Velocities along the dissection flap (mid-renal artery) also improved.

CASE 2

61-year-old female with a history of hypertension (HTn), lupus nephritis, status post DDKT in October 2014. After an uneventful post-operative course, she presented four months later with fluid overload, including lower extremity swelling, refractory hypertension (blood pressure: 190/90 mm Hg) (normal 120/80 mm Hg) and an elevated serum creatinine of 3.4 mg/dL (normal <1.1 mg/dL). Doppler US revealed juxtaanastomotic RAS and elevated PSV of 491 cm/s (normal < 180 cm/s) (Fig. 2 a). A US-guided renal biopsy was negative for rejection, but resulted in a small arteriovenous fistula in the upper pole of the transplant kidney.

An endovascular treatment was attempted (Fig. 2b–d). DSA confirmed a juxtaanastomotic kink (Fig. 2b). The transplant renal artery was catheterized beyond both the stenosis via a right common femoral artery approach, in a similar fashion as described in case 1. Over a 0.014″ transcend microwire; two 5 × 13 mm Multi-Link RX Ultra coronary stents were placed at the level of the stenosis (Fig. 2c). Post-stent renal angiogram demonstrated the resolution of stenosis with the overlapping stents conforming to the tortuous arterial course (Fig. 2d). The small arteriovenous fistula seen arising from the upper pole of transplanted kidney was not thought to be significant at this time. We decided to monitor with serial US and if there is worsening renal function, to intervene.

Subsequently, her blood pressure dropped to 130/62 (normal 120/80 mm Hg), lower extremity edema resolved and serum creatinine improved to 1.3 mg/dL (normal <1.1 mg/dL). Post-procedure Doppler US (Fig. 2e) demonstrated a drop in the juxtaanastomotic velocities to 249 cm/s (normal < 180 cm/s).

CASE 3

70-year-old female with a history of HTn, diabetes mellitus, status post DDKT in October 2014. Patient had an uneventful post-operative course. Four months later, she presented with increased serum creatinine of 3.3 mg/dL (normal <1.1 mg/dL). Doppler US revealed juxtaanastomotic renal artery stenosis with a slightly elevated PSV of 568 cm/s (normal < 180 cm/s) (Fig. 3a). US-guided renal biopsy was negative for rejection.

An endovascular treatment was attempted (Fig. 3b–f). An angiogram confirmed a juxtaanastomotic kink (Fig. 3b). The transplant renal artery was catheterized beyond both the stenosis via a right common femoral artery approach, in a similar fashion as described in case 1 and 2. Balloon angioplasty was performed (Fig. 3c).A single 5 × 13 mm Multi-Link RX Ultra coronary stent was appropriately positioned (Fig. 3d) and then deployed at the level of the stenosis (Fig. 3e). Post-stent renal angiogram demonstrated the resolution of stenosis conforming to the tortuous arterial course with no secondary stenoses or kinks along either ends of the stents (Fig 3f) and good intrarenal perfusion (Fig. 3g).

Post-procedure serum creatinine improved to 1.1 mg/dL (normal <1.1 mg/dL).

DISCUSSION

Etiology & Demographics

Although the most frequent renal transplantation complications are renal and perirenal fluid collections, vascular complications occur at a rate of 3%–15%. Transplant renal artery stenosis (TRAS) is the most common vascular complication (1%–12%) and often leads to refractory hypertension and eventually graft dysfunction [1].

The cause of TRAS is multifactorial. Early-appearing stenoses are mainly associated with surgical technique because of traumatic intimal injury during harvesting or vessel manipulation, kinking of the artery when it is longer than the vein, or technical problems with the vascular suture. Late-appearing stenosis reflects allograft renal artery hyperplasia or renal and/or iliac atherosclerotic disease as well as immunological factors and cytomegalovirus arteritis [2].

The incidence of renal artery stenosis is more common in cadaver transplant (most common renal transplant), and it manifests as early as 2 days or as late as years after the procedure [2].

Clinical and Imaging Findings

Making a clinical diagnosis of TRAS is difficult as rejection is a strong mimicker. An impaired renal function resulting in renal insufficiency may be the primary manifestation. At times, this condition is incidentally diagnosed during routine post-transplant Doppler US. However, severe hypertension refractory to medical therapy and association with unexplained graft dysfunction is the most common presentation [3].

Doppler US and biopsy can be used in straightforward cases and magnetic resonance angiography or computerized tomography angiography can be used as adjuncts in more technically challenging cases. Doppler US may demonstrate

stenotic segments as the focal areas of color aliasing because of an increased flow velocity. Doppler criteria for significant stenoses include peak systolic velocities >200 cm/s and a velocity gradient between stenotic and prestenotic segments of >2:1. In the renal parenchyma, tardus-parvus waveform abnormalities can be observed. Although renal MAG-3 scans may show reduced perfusion, these findings are nonspecific and overlap with those of graft failure. The gold standard remains DSA with the potential to intervene at the time of angiography, the downside being its invasive nature and contrast toxicity in these patient subset with borderline renal function [1,4]. MR angiography has the advantage that it can be performed without contrast material [3].

Treatment and prognosis

Treatment options for TRAS include both surgical and endoluminal options. Revision open surgery is actually considered as a rescue therapy and is reserved for the cases of unsuccessful angioplasty or with severe complicated stenosis because of the high reported rate of significant complications. Endovascular treatment options include percutaneous transluminal angioplasty and/or stenting [5].

The endovascular treatment of TRAS with a high technical success rate (89%–100%) and low rate of complications (upto 5%, which include arterial rupture, dissection, and thrombosis) is now considered the treatment of choice with the advantage that it does not preclude subsequent surgical correction [6,7]. The current debate centers on the use of drug eluting technologies vs. conventional stents and balloons in management of renal artery stenosis, both native and transplant. In general the kinks in transplant renal arterial anatomy do not present a favorable anatomy for placement of conventional stents (bare metal or balloon mounted). In our experience it has been difficult to negotiate the sharp kinks .One of the major drawbacks of endovascular treatment is restenosis, 10%–56% with balloon angioplasty and 5.5%–10% with stenting [8]. Secondary stenting can be used as a bail out (e.g., in intraprocedural dissections or in the cases of restenosis) [9]. Restenosis has been known to be related to inflammatory changes related to the presence of a metallic stent. A stent with a rigid profile lacking conformability will create significant geometric changes to the native vessel possibly leading to early restenosis and/or vascular kinking along the stent margins [10].

The initial treatment of the transplant renal arteries in all three cases was challenging as the stenosis was secondary to a severe vascular kink. The extreme angulation along the renal artery course required a stent that is both low profile and flexible to track across the stenosis. This has been a limitation with renal artery stenting with rigid balloon-expandable stents. The Multi-Link Ultra coronary stent is a second generation coronary stent specifically designed to maintain radial force while also remaining flexible. The Multi-Link Ultra stent consists of corrugated rings each bridged together by flexible segments. The corrugated rings provide the appropriate radial force to treat the stenosis, whereas the bridging segments provide flexibility. This important combination of radial force and flexibility allowed for the successful treatment of TRAS and kink while preserving the overall arterial course without acute angulations transmitted to the ends of the coronary stents [10,11].

Our three patients had successful technical and clinical outcomes in TRAS in a tortuous proximal renal arterial anatomy (Summary in Table 1). As the stenoses appeared to be secondary to arterial kinking, angioplasty was not thought to be a helpful initial treatment option. Multi-Link RX Ultra coronary stents were utilized for their outward radial force to treat the focal stenosis and for the flexible design allowing for stent conformation to the tortuous vascular course. The successful treatment of TRAS using these coronary stents in all three patients highlights the utility of this stent system.

Differential Diagnosis

Post-transplant renal complications can be divided into two types, anatomic complications because of surgical technique (vascular, urologic, fluid collections) and those because of allograft Dysfunction/ Rejection [12,13].

i. Anatomic complications:

a. Vascular complications:

Occur in 1%–2 % and include renal artery stenosis, infarction, arteriovenous fistulas, pseudoaneurysm, and renal vein thrombosis [14].

Renal artery thrombosis is a complication most commonly seen in the hospitalization period immediately after transplantation. At Doppler US, an infarct appears as a poorly marginated, hypoechoic avascular mass involving a portion of the kidney of segmental or the whole kidney of global. At radionuclide studies, a photopenic region may be seen. However, US and scintigraphic features are not specific and significant overlap is seen with rejection. CT and MR can be used to detect perfusion deficits in the renal graft parenchyma, although MR is preferred because of the lack of contrast administration. Dynamic enhanced MR imaging can be useful for diagnosing both segmental and global infarctions as well as renal artery thrombosis Percutaneous angiographic interventional thrombolytic therapy is controversial, yet more effective if treated early. [3]

Arteriovenous fistulas and pseudoaneurysms are rare and occur mainly as a result of percutaneous biopsy when rejection is suspected. Doppler US shows pseudoaneurysms as localized areas of outpouching outside the confines of the normal vessel and arteriovenous fistulas as abnormal high-velocity turbulent flow with aliasing. Most of these complications after biopsy are treated conservatively. However if there is enlargement or clinical manifestation, intervention including Selective transarterial embolization is warranted [3].

Venous thrombosis is rare, but if it occurs, the kidney is usually unsalvageable. It is diagnosed by means of color flow Doppler ultrasonography [13,14].

b. Urologic complications:

Occur in about 4%–8% of patients and include urine leaks and stenoses. Urine leaks occur at the ureterovesical junction and result from disruption of the anastomotic connection of the ureter to the graft, generally within the first 2 months after transplantation. Ultrasonography demonstrates a well-defined

perigraft fluid collection with no septations that increases in size rapidly. Radionuclide studies with imaging in delayed phase show extravasation of radiotracer into an initially cold spot .Drainage may be performed with US guidance. The fluid is sent for analysis as a higher creatinine level of the fluid compared with its serum concentration could differentiate urinoma from a lymphocele. Small urine leaks may be treated with percutaneous nephrostomy and stent placement for about 6–8 weeks to allow complete healing of the ureter, failing which, reimplantation of the ureter may be required [3,14].

Ureteral stenosis is seen to affect the distal third of the ureter. US can help detect the hydronephrosis. Delayed imaging during scintigraphy may demonstrate urinary obstruction and help to evaluate renal function. Percutaneous nephrostomy is used to relieve obstruction and allow the deployment of other radiologic interventions such as ureteral stent placement and balloon urethroplasty using balloon dilation. [1,3]

c. Peritransplant fluid collections:

These have been reported in up to 50% of renal transplantations and include urinomas, hematomas, lymphoceles, and abscesses. US characteristics of peritransplant fluid collections may vary from being anechoic in seromas, hypoechoic with internal echoes /debris in abscess or even echogenic in acute hematomas, however are nonspecific, but US is useful with percutaneous aspiration and drainage. Recurrence is particularly seen in lymphoceles because of which sclerosant therapy may be needed [12,13,15].

ii. Allograft dysfunction /rejection:

The two most important parenchymal abnormalities that occur are acute tubular necrosis (ATN) and rejection, ATN occurs right after the transplantation and resolves within 2 weeks. Rejection is related primarily to activation of T cells, which, in turn, stimulate specific antibodies against the graft. Hyperacute rejection of the renal allograft happens in the operating room within hours of the transplant. No treatment exists, and nephrectomy is indicated. Acute rejection appears within the first 6 months after transplantation. Acute rejection is treated with intravenous steroids with a success of 60%–70% [12,15,16].

US findings may be variable. It may be normal or increased or decreased renal echogenicity and the loss of corticomedullary differentiation. Nuclear medicine scintigraphy may be useful in differentiation as ATN shows normal early flow to the kidney in contrast to rejection. Consequently, renal biopsy is usually required for a specific diagnosis and further treatment [3].

TEACHING POINT

Early diagnosis and management of Transplant renal artery stenosis (TRAS) is essential to optimize proper graft function. Currently, the endovascular treatment of TRAS is considered the treatment of choice. The use of a balloon-expandable Multi-Link RX Ultra coronary stent system for treating a high grade focal stenosis along a commonly seen tortuous renal arterial segment seems to allow for a flexible stent design that conforms to the vessel course allowing for optimal stent alignment.

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FIGURES

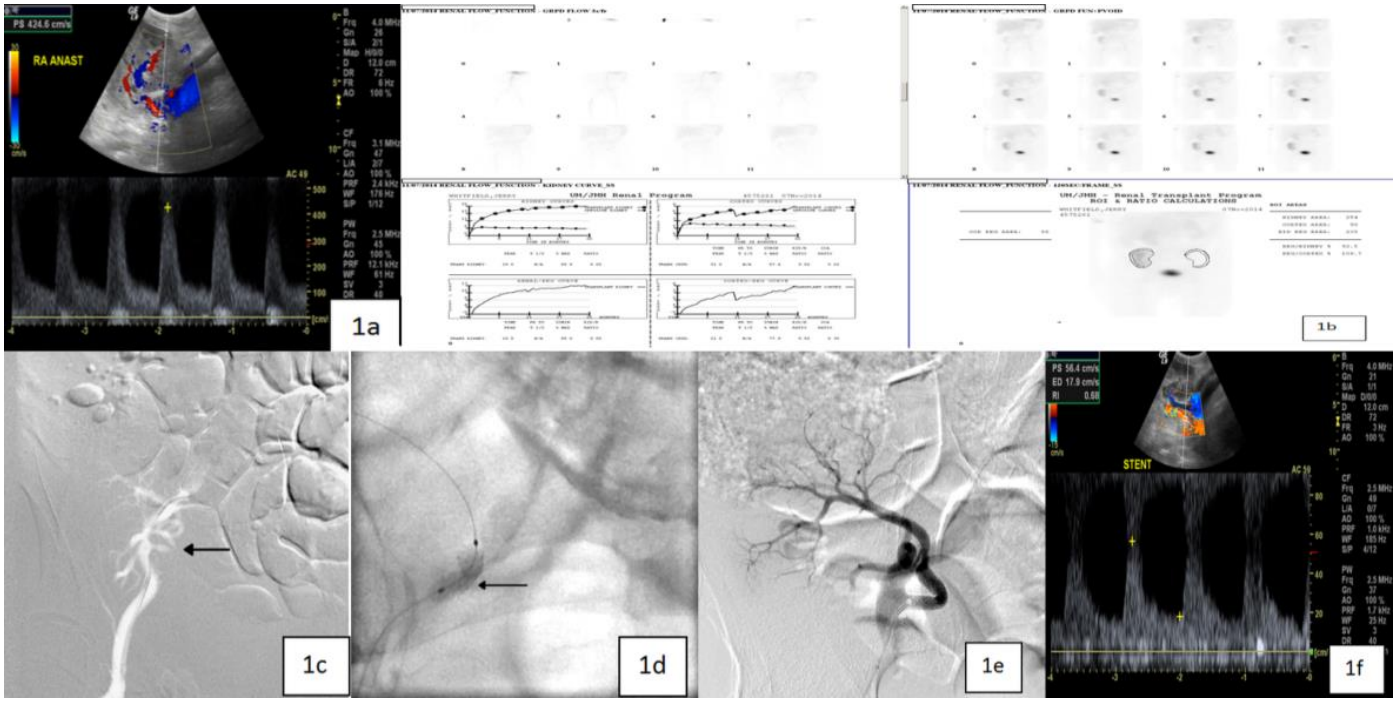

Figure 1: 69-year-old male with chronic Hepatitis C, post liver transplant and DDKT presented with elevated creatinine and renal insufficiency.

Findings: a) Doppler US, oblique view in right iliac fossa showed elevated juxtaanastomotic velocity in the transplant renal artery with high resistance wave forms suggestive of stenosis. b) Nuclear medicine scintigraphic study after injection of technetium 99 MAG3 showed decreased flow to the transplant kidney with cortical retention. The renogram curve delayed time to peak with a plateau. There is increased 20 minute cortical activity at 98% (normal <20 %).c) Initial carbon dioxide digital subtraction Angiogram (DSA) in the right iliac fossa demonstrated a juxtaanastomotic kink (arrow). In an attempt to cross the stenosis, a non-flow limiting dissection flap was created which propagated to the renal artery bifurcation (not shown in images) d) Two overlapping MULTI-LINK RX ULTRA balloon expandable coronary stents (arrow) were deployed, distal measuring 5 mm x 13 mm and proximal 4.5 x 13 mm. The size of the stent was based on measurements made using the diagnostic angiogram. e) Post deployment DSA showed resolution of juxtaanastomotic stenosis with good flow across the juxtaanastomotic stenosis. f) Doppler US, oblique view in right iliac fossa performed 1month post stenting of transplant artery stenosis showed post stent juxtaanastomotic PSV of 56cm/s (normal < 180 cm/s)

Technique: Duplex ultrasonography with GE Logiq E9, 2.5- 4 MHz

DSA protocol: transcatheter injection of 10 ml contrast media at a flow of 2 ml/sec, Visipaque (Iodixanol) 320 (GE Healthcare, Waukesha, WI) performed on a clinical angiography system (Axiom Artis FA/BA; Siemens AG, Erlangen, Germany)

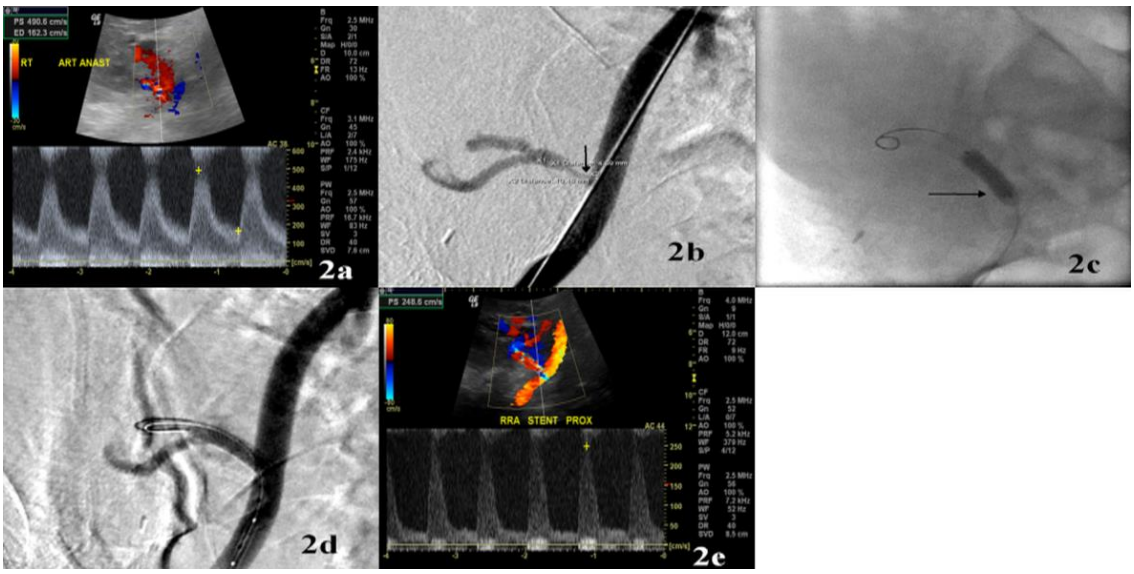

Figure 2: 61-year-old female with lupus nephritis, status post DDKT presented four months later with fluid overload and elevated creatinine.

Findings: a) Doppler US, oblique view in right iliac fossa showed elevated juxtaanastomotic velocity with high resistance wave forms in the transplant renal artery suggestive of stenosis. Intervention was planned. b) DSA in the right iliac fossa demonstrated severe juxtaanastomotic stenosis (arrow) .This image also shows measurements for planning adequate dimensions of the stent. c) Balloon dilatation (arrow) during deployment of two overlapping 5 mm x 13 mm MULTI-LINK RX ULTRA balloon expandable coronary stents d) Post deployment angiogram showed resolution of juxtaanastomotic stenosis with good flow across the stent. d) Doppler US, oblique view in right iliac fossa, one week post stenting of transplant artery stenosis showed improvement in the juxtaanastomotic stenosis with significant drop in PSV.

Technique: Duplex ultrasonography with GE Logiq E9, 2.5- 4 MHz

DSA protocol: transcatheter injection of 10 ml contrast media at a flow of 2 ml/sec, Visipaque (Iodixanol) 320(GE Healthcare, Waukesha, WI) performed on a clinical angiography system (Axiom Artis FA/BA; Siemens AG, Erlangen, Germany)

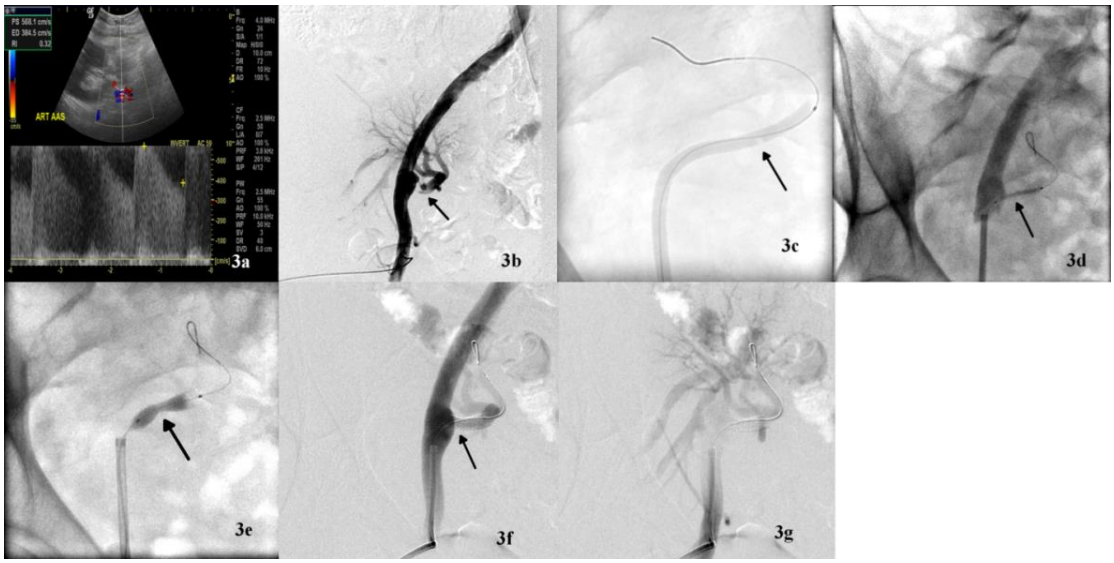

Figure 3: 70-year-old female with a history of HTn, DM, status post DDKT in October 2014 presented four months later with elevated creatinine.

Findings: a) Doppler US, oblique view in right iliac fossa showed elevated juxtaanastomotic velocity with high resistance wave form in the transplant renal artery suggestive of stenosis. b) DSA in the right iliac fossa demonstrated near total stenosis of the juxtaanastomotic transplant renal artery (arrow). c) Balloon dilatation (arrow) performed prior to stent deployment using a 4 mm angioplasty balloon (ev3 Neurovascular, Irvine, CA). d) Careful positioning of the stent (arrow) at the site of stenosis. e) Waist at the site of stenosis was distinctly visualized (arrow) during deployment of two overlapping 5 mm x 13 mm MULTI-LINK RX ULTRA balloon expandable coronary stents. f, g) Post deployment DSA in the right iliac fossa showed resolution of juxtaanastomotic stenosis with good flow across the proximal renal artery and good intrarenal flow

Technique: Duplex ultrasonography with GE Logiq E9, 2.5- 4 MHz

DSA protocol: transcatheter injection of 10 ml contrast media at a flow of 2 ml/sec, Visipaque (Iodixanol) 320(GE Healthcare, Waukesha, WI) performed on a clinical angiography system Axiom Artis FA/BA (Siemens AG, Erlangen, Germany)

	Age /Sex	**Reason for transplant**	**Clinical features**	**Serum creatinine (nl < 1.1 mg/dL)**	**US (V_{ja} - normal <180 cm/s)**	**Size of Stent**	**Clinical status (Post stent)**	**Serum creatinine (Post stent)**	**US (Post stent)**
1	**69, male**	Chronic Hepatitis C with renal failure	Asymptomatic	3	RAS with V_{ja} 650 cm/sec	One 5 mm x 13 mm and one 4.5 mm x 13 mm (overlapping)	No change	1.4	Patent stent V_{ja} 52 cm/s
2	**61, female**	Hypertension (HTn), lupus nephritis	Lower extremity edema, refractory HTn	3.4	RAS with V_{ja} 491 cm/sec	Two 5 mm x 13 mm (overlapping)	Edema resolved, BP normalized	1.3	Patent stent V_{ja} 249 cm/sec
3	**70, female**	HTn, Diabetes mellitus (DM)	Asymptomatic	3.3	RAS with V_{ja} 568 cm/sec	Single 5 mm x 13 mm	No change	1.1	Patent stent V_{ja} 229 cm/s

Table 1: Summary of clinical presentation and endovascular management of three patients.
Juxtaanastomotic velocity - Vja

DIFFERENTIAL DIAGNOSIS OF EARLY POST-TRANSPLANT DYSFUNCTION
1. Anatomic complications :(Surgical technique)
Vascular complications: RAS, renal artery thrombosis, pseudoaneurysms and arteriovenous fistulas, renal vein thrombosis
Urologic complications: Urine leaks occur at the ureterovesical junction
Fluid Collections: Lymphocele
2. Allograft dysfunction /rejection: (Immunologic)
Hyperacute rejection
Acute rejection

Table 2: Differential diagnosis of early post-transplant dysfunction

	US (Gray scale and Doppler)	**Nuclear medicine scintigraphy**	**CT/MR**	**Intervention (Diagnostic / therapeutic)**
Renal artery Stenosis (RAS)	Stenotic segments as focal areas of color aliasing Doppler criteria for significant stenosis are PSV > 180 cm/sec, a velocity gradient between stenotic and prestenotic segments of more than 2:1. Intrarenal tardus-parvus waveform abnormalities maybe seen	May show reduced perfusion, however nonspecific and overlap with those of graft failure	MRA may be useful in detecting RAS. CTA may not be ideal due to risk of contrast nephrotoxicity in already compromised renal function.	DSA is gold standard in diagnosis with the potential to intervene at the time of angiography Endovascular treatment with angioplasty +/- stent
Renal artery thrombosis	Focal: poorly marginated, hypoechoic avascular segmental mass Global: Diffusely hypoechoic kidney	Photopenic region, nonspecific and significant overlap with rejection	MR can be useful for diagnosing both segmental and global infarctions	Percutaneous thrombolytic therapy is controversial, yet more effective if treated early
Pseudo-aneurysms and arteriovenous fistula	Pseudoaneurysms: localized areas of outpouching outside the confines of the normal vessel Arteriovenous fistulas: abnormal high-velocity turbulent flow with aliasing.	-	May show same findings as US ,used as a problem solving tool	Most post biopsy complications treated conservatively. If enlargement or clinical manifestation, trans arterial embolization can be performed
Urine leaks	Well-defined perigraft fluid collection with no septations	Delayed phase may show extravasation of radiotracer into an initially cold spot	Well-defined perigraft fluid collection with no septations	US guided drainage may be useful. Small urine leaks treated with percutaneous nephrostomy and stent
Ureteral stenosis	Detect hydronephrosis	to evaluate renal function Delayed imaging may demonstrate urinary obstruction	Detect hydronephrosis	Percutaneous nephrostomy to relieve obstruction and allow balloon ureteroplasty
Fluid Collections: Lymphocele, Hematoma, Abscess	Nonspecific: vary from anechoic to hypoechoic to echogenic.	-	Nonspecific characteristics of collection	US guided aspiration and drainage. Lymphocele recurrence : sclerosant therapy
Hyperacute rejection	US may be normal or increased or decreased renal echogenicity with loss of corticomedullary differentiation	Maybe useful in differentiation of ATN v/s rejection ATN shows normal early flow to the kidney	-	US/ CT guided renal biopsy for specific diagnosis

Table 3: Differential diagnosis of early Post transplant dysfunction and imaging features

ETIOLOGY	Early appearing stenosis : traumatic intimal injury due to surgical technique , Kinking of the artery when longer than the vein, vascular suture.
	Late appearing stenosis: Allograft renal artery hyperplasia , renal and/or iliac atherosclerotic disease , immunological factors and cytomegalovirus
INCIDENCE	1-12%
GENDER RATIO	None
AGE PREDILECTION	None
RISK FACTORS	None
TREATMENT	Surgical and endoluminal options. Endovascular treatment options include percutaneous transluminal angioplasty (PTA) and/or stenting
PROGNOSIS	Endovascular treatment has a high technical success rate (89% -100%) and low rate of complications (Up to 5%-arterial rupture, dissection, thrombosis)
FINDINGS IN IMAGING	Doppler US: stenotic segments as focal areas of color aliasing due to increased flow velocity, tardus-parvus waveform in parenchyma
	MRA: Advantageous due to lack of need contrast
	DSA : Gold Standard

Table 4: Summary of post-transplant renal artery stenosis.

ABBREVIATIONS

CTA = Computed tomographic angiography
CT = Computed tomography
DDKT = Deceased donor kidney transplantation
DSA = Digital subtraction angiography
MRI = Magnetic resonance imaging
PSV = Peak systolic velocity
PTA = Percutaneous transluminal angioplasty
TRAS = Transplant renal artery stenosis
US = Doppler Ultrasound
Vja = Juxtaanastomotic velocity at renal artery anastomosis

KEYWORDS

Transplant renal artery stenosis; Tortuous proximal renal arterial anatomy; Second generation balloon expandable coronary stent; Endovascular treatment; Percutaneous transluminal angioplasty (PTA) and/or stenting

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