Endovascular repair of a complex renal artery aneurysm using Pipeline™ Embolization Device (PED) assisted coil embolization

Jeff Liang[1], Gary Duckwiler[2], Jeremy Middleton[1], John M Moriarty[1], Justin P McWilliams[1*]

1. Division of Interventional Radiology, UCLA Medical Center, David Geffen School of Medicine at UCLA, Los Angeles, CA, USA

2. Division of Interventional Neuroradiology, UCLA Medical Center, David Geffen School of Medicine at UCLA, Los Angeles, CA, USA

* **Correspondence:** Justin P McWilliams, 757 Westwood Plaza, Suite 2125C, Los Angeles, CA 90095, USA
(*JuMcWilliams@medenet.ucla.edu*)

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ABSTRACT

Background: We describe the treatment of a renal artery aneurysm with complex anatomy using coils and the PipelineTM Embolization Device (Medtronic, Irvine, CA), a flow-diverting stent typically used for the treatment of intracranial aneurysms. Methods: A 62-year-old female with history of an asymptomatic right renal artery aneurysm that was discovered incidentally 10 years ago was found to have enlargement of the aneurysm (1.9cm to 2.7cm) on a repeat surveillance CT scan. She was successfully treated with combined Pipeline Embolization Device and coil embolization of the aneurysm sac. Results: Post-procedural angiography showed complete occlusion of the aneurysm with maintenance of perfusion to the entire kidney. Conclusion: Pipeline™ assisted coil embolization may be an option for parenchyma-sparing treatment of renal artery aneurysms with complex anatomy.

CASE REPORT

CASE REPORT

A 62-year-old female with history of an asymptomatic right renal artery aneurysm (RAA) that was discovered incidentally 10 years prior during a CT-scan for abdominal pain was found to have enlargement of the aneurysm (1.9cm to 2.7cm) on a repeat surveillance CT scan, and presented for elective aneurysm embolization. Pre-procedural abdominal CT angiography revealed a wide-necked 2.7cm x 1.5cm aneurysm arising just distal to the first division of the right renal artery with a 5.1mm inflow vessel and a 4.2mm dominant outflow vessel exiting inferior-posteriorly (Fig. 1). Several smaller outflow vessels from the aneurysm sac were also noted (Fig. 1). Due to the wide-necked anatomy of the RAA, the angle between the inflow and outflow vessels, and the significant renal parenchymal supply from the dominant outflow vessel, placement of a flow-diverting stent, in addition to coil embolization, was planned. The patient was premedicated with 450mg Plavix and 650mg aspirin one day prior to the procedure, and a total 6000U heparin was administered during the case. Pre-procedural labs showed GFR within normal limits.

Right common femoral artery access was obtained under ultrasound guidance; the right renal artery was then catheterized, initially using a 5F Cobra-2 catheter (Cook® Medical, Bloomington, IN), and subsequently replaced by an 8F renal double curve (RDC) guide catheter (Cook) and a 5F

Glidecath® (Terumo IS, Somerset, NJ). Angiography confirmed a large aneurysm originating from the first divisional branch of the right renal artery with widely patent outflow vessel supplying a large proportion of the renal parenchyma. Smaller vessels coursing into the superior kidney were identified just proximal to the aneurysm (Fig. 2).

After angiography was performed, dual microcatheters were advanced through the RDC. A Phenom 27 (Cathera Inc., Mountain View, CA) microcatheter combined with Transend (Stryker Neurovascular, Fremont, CA) and eventually a Synchro (Stryker Neurovascular, Fremont, CA) microwire was used to catheterize the dominant outflow vessel of the aneurysm (Fig. 3). Subsequently, a Progreat Alpha 2.0 microcatheter (Terumo IS, Somerset, NJ) was then looped within the aneurysm sac.

Through the Phenom microcatheter, a 4.5mm x 20mm Pipeline Embolization Device (PED) was deployed, with the distal aspect within the outflow vessel and the proximal aspect carefully positioned to avoid occluding necessary vessels coursing into the superior pole. Due to concern that other patent outflow channels from the aneurysm could cause persistent flow into the aneurysm sac, the sac itself was coiled through the Progreat microcatheter still looped in the aneurysm sac, using a combination of Interlock 018 micro-coils (Boston Scientific, Marlborough, MA) and Ruby LP packing coils (Penumbra, Alameda, CA).

After placement of the PED and coils, completion angiography of the right renal artery was performed, showing cessation of flow into the aneurysm sac with patent flow through the PED and continued perfusion of the entire renal parenchyma (Fig. 4).

One-month follow-up MRA reveals no residual aneurysm, preserved right renal venous outflow, and no evidence of renal infarct or other post embolization complication (Fig. 5).

DISCUSSION

Etiology & Demographics:

RAA is a rare clinical finding seen in less than 0.1% of autopsies and 0.3-2.5% of imaging studies [1,2], and is generally found incidentally during workup of a secondary abdominal condition [3]. The etiology of RAA is often idiopathic; commonly associated comorbidities include hypertension, fibromuscular dysplasia, hypercholesterolemia, smoking, and connective tissue disorders (i.e, Ehlers-Danlos, Marfan syndrome) [1]. RAAs are most frequently discovered during the 5th-6th decade of life, and is seen predominantly in women [1,4].

Clinical & Imaging Findings:

Most patients with RAA are asymptomatic without notable physical exam findings, while 4-23% of patients experience symptoms such as flank pain, hematuria, or abdominal pain [1,4]—rarely, a renal bruit or abdominal mass may be appreciated [1]. Some RAAs are initially detected as a hypoechoic mass with turbulent flow on Doppler ultrasonography; however, vessel thrombosis and calcification may limit the flow signal, making aneurysms difficult to distinguish from other renal masses [5]. CT angiography is often used to con-firm the diagnosis, which will reveal RAAs as an outpouching along the renal artery [6]; less commonly used imaging modalities include non-contrast CT and MR angiography. There is currently limited evidence describing the sensitivity or specificity of Doppler ultrasonography in diagnosing RAA. Most incidences of RAA present unilaterally, most commonly at the bifurcation of the main renal artery; 10-20% of cases are bilateral, and approximately 15% of cases are associated with extra-renal aneurysms, the most common ones being AAA and splenic artery aneurysm [1].

Treatment & Prognosis:

Appropriate management of RAA aims to relieve symptoms and prevent aneurysm rupture, a clinically catastrophic sequela which occurs in an estimated 0.3-3% of patients [1,2,7]. Due to the rarity of RAA, there are not definitive criteria for interventional treatment [8]. Currently accepted indications for intervention include aneurysm size greater than 2 cm, aneurysm in women of childbearing age (believed to be associated with a higher rate of rupture secondary to increased vascular flow and hormonal changes), and symptoms such as pain, hematuria, medically refractory HTN, thromboembolism, dissection, or rupture [1].

While RAA > 2.0cm meet the accepted indications for intervention, some patients may still elect for conservative management. Due to the rarity of RAAs and variable risk fac-tors for rupture among patients, there is limited evidence describing an ideal surveillance interval; however, a single-institution study from 2014 suggests that annual monitoring is safe [9]. Often, patients are monitored with the same imaging modality used to initially diagnosis the RAA [4]. A 2015 multi-institutional study reviewed 865 cases of RAA, including 88 patients with RAA between 2-3cm that were managed nonoperatively, and found no cases of rupture in aneurysms of this size (mean follow-up 29 months) and no significant difference in growth rate between aneurysms > 2.0cm and smaller ones [4]. However, all incidents of rupture recorded in this study occurred in aneurysms > 3.0cm, occurring at an 18% rate (3/17 total cases). The RAA in our case was approaching 3.0cm and had shown interval growth. In collaboration with the patient and her primary physician, we elected for intervention over continued surveillance.

Patients who elect for interventional treatment of RAA historically underwent open re-pair; however, minimally invasive endovascular procedures, include stent graft placement and coil embolization, have become increasingly popular in recent years. Studies comparing outcomes in open vs endovascular repair have found no significant difference in mortality, perioperative morbidity, freedom from re-intervention, or decline in renal function; however, endovascular treatment is associated with a shorter length of hospital stay [1,10]. Following repair, graft patency is generally monitored using Doppler ultrasonography; initial surveillance intervals occur more frequently (1-6 months), and may be extend-ed to annually in uncomplicated cases [11].

The choice of endovascular treatment for RAA is often determined by renovascular anatomy. Simple aneurysms with a narrow neck are effectively treated with coil embolization [12]. However, the RAA in this case demonstrated four complex anatomic features:

1) a wide aneurysm neck, making it higher risk for branch artery occlusion during embolization and subsequent renal infarction [13,14];

2) angulation between primary inflow and outflow vessels;

3) the large proportion of the renal parenchyma supplied by the dominant outflow vessel, necessitating maintenance of patency;

4) the presence of additional side branches within and just proximal to the aneurysm.

The risk of branch occlusion can be mitigated by the use of covered stents to maintain flow in the parent vessel, but tradition-al stent grafts are often too stiff to be deployed in a tortuous or angulated vessel [15,16]. Therefore, we elected to use the Pipeline™ Embolization Device (PED) (Medtronic, Irvine, CA), a type of flow diverting stent typically used in neurovascular cases that possesses greater flexibility than the traditional stent graft while maintaining low porosity [14,16]. However, this device is not without drawbacks—two main technical challenges we faced with the PED included accessing the outflow vessel through a large, wide-necked aneurysm, and placing the device in a location that avoids occluding proximal branches of the inflow vessel. Accessing the outflow vessel was accomplished via the microcatheter coiling technique [17,18], and device placement was performed carefully with the awareness of the PED foreshortening phenomenon [19]; the final angiography result demonstrated complete aneurysm occlusion without evidence of distal branch occlusion (Fig. 4).

Few cases of PED use in visceral aneurysms have been described in literature [13–15]; to our knowledge, this is the second documented case of using the PED for the treatment of RAA, with the first reported in 2016 [13]. The two studies differ slightly in the anatomy of the aneurysm treated and the resultant embolization technique, but post-procedural and follow-up imaging in both cases demonstrated persistent aneurysm occlusion. These cases demonstrate the potential utility of PED assisted coil embolization technique in renal artery aneurysms unsuitable to traditional endovascular management.

Differential Diagnosis:

Renal artery pseudoaneurysms appear similar to aneurysms on imaging, and are distinguishable primarily through patient history. While true aneurysms are often asymptomatic and associated with chronic conditions, pseudoaneurysms typically arise in the setting of trauma, and represent accumulated blood that extravasated through an injured arterial wall [5]. Other causes of pseudoaneurysm formation include vasculitis and amphetamine use. Since renal artery pseudoaneurysms often present acutely, they are high risk for rupture and are indicated for treatment regardless of size [5].

On ultrasonography, the differential diagnosis of renal artery aneurysms also includes nonvascular lesions such as perihilar cysts or tumors. While the presence of a flow signal on doppler ultrasound may help differentiate between these structures, thrombosed or calcified aneurysms may appear similar to nonvascular lesions. In these cases, CTA or MRA may be required to establish the diagnosis.

TEACHING POINT

Renal artery aneurysms >2.0cm may be treated safely and efficaciously with endovascu-lar methods to avoid the risk of aneurysm rupture. Flow diverting stents, such as the Pipe-line Embolization Device, can be a useful adjunct for renal-sparing aneurysm embolization in cases with complex and tortuous renovascular anatomy.

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FIGURES

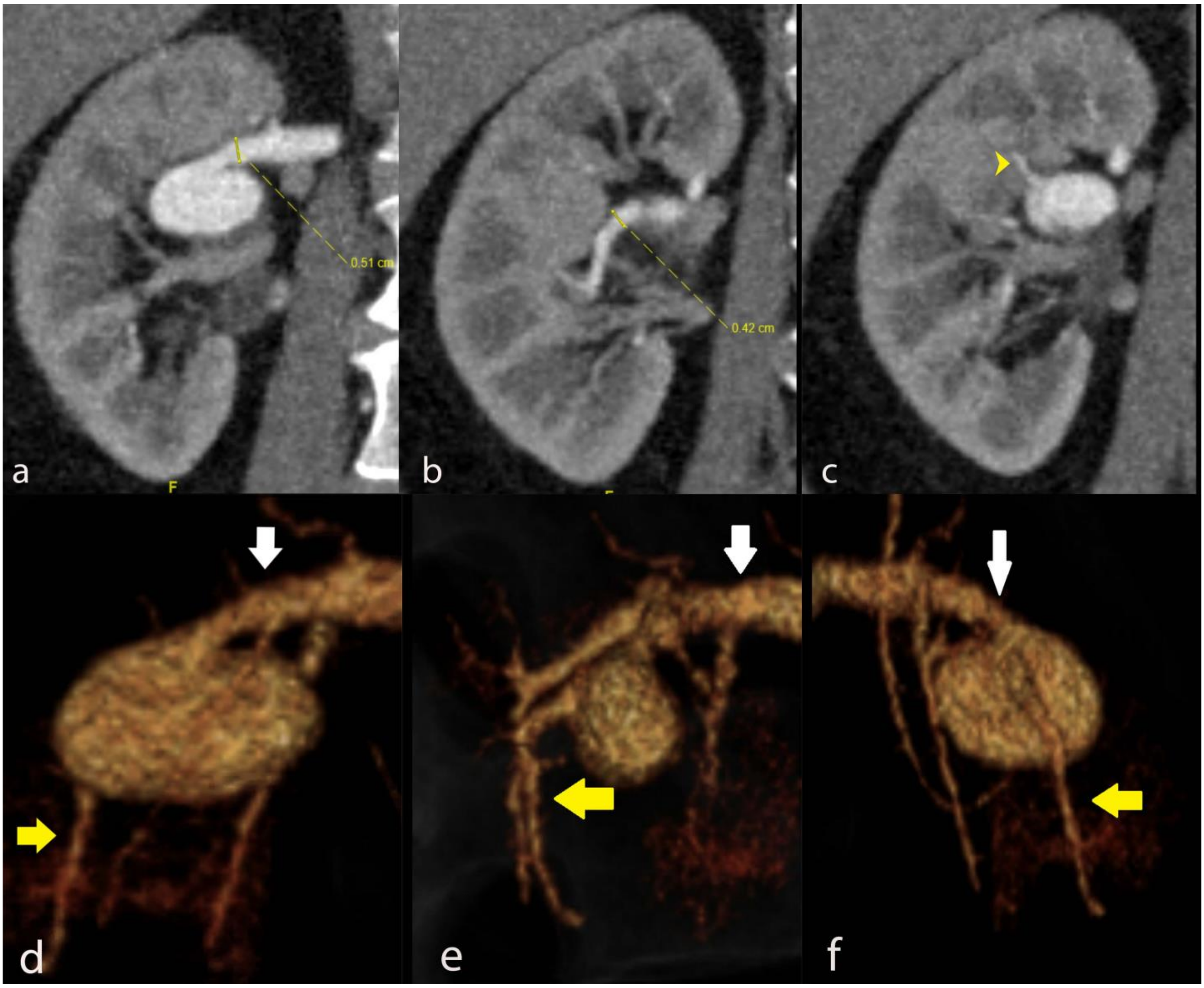

Figure 1: 62-year old female with right renal artery aneurysm. coronal CT angiography and volume-rendered 3D reconstruction.

Findings: (A) Inflow vessel passing into the right renal aneurysm and (B) the main out-flow vessel passing out of the aneurysm and supplying the posterior right kidney parenchyma. At least one smaller outflow vessel arises from the aneurysm sac and supplies a small portion of the renal parenchyma (C). Volume-rendered 3D reconstruction in the anterior, lateral, and posterior views (D-F, respectively) demonstrates the main inflow (white arrow) and outflow (yellow arrow) vessels, and also demonstrates several more proximal arteries supplying renal parenchyma.

Technique: Coronal CT abdomen/pelvis with contrast (100mL of Optiray 300-399 IV contrast), (A-C) coronal, 2mm slice thickness, (D) 3D reconstruction. 178 mA, 120 kV.

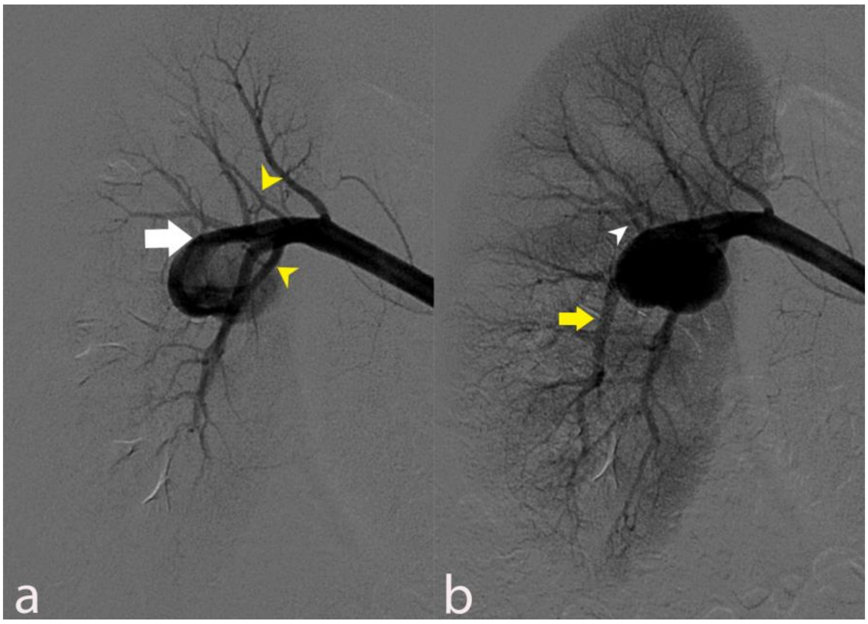

Figure 2: Right renal digital subtraction angiography. 62-year old female with right renal artery aneurysm.

Findings: (A) Main inflow vessel passing into the renal artery aneurysm (white arrow) and several proximal parenchymal branches (yellow arrowheads). (B) Later view from the same angiogram demonstrates the main outflow vessel (yellow arrow) passing to the renal parenchyma, and a smaller parenchymal vessel arising from the aneurysm sac (white arrowhead).

Technique: Digital subtraction angiography, contrast (100mL Visipaque 320), fluoro time 33.9 minutes, reference air kerma (mGy): 2397, kerma area product (mGy-cm2): 269321

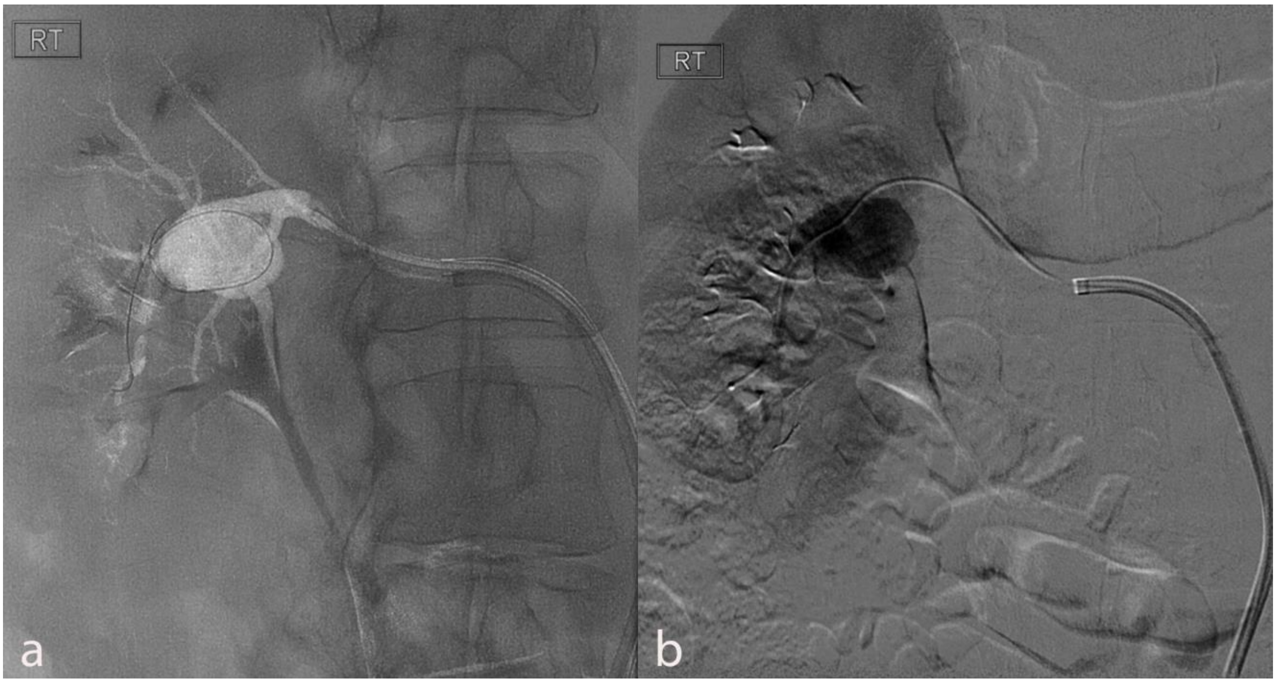

Figure 3: Right renal digital subtraction angiography. 62-year old female with right renal artery aneurysm.

Findings: Intra-procedural microcatheter loop technique. Cannulation of the main outflow vessel using the microcatheter and microwire was difficult. Therefore, the microcatheter was first looped in the aneurysm, allowing wire selection and cannulation (A) of the main outflow vessel. The tip of the microcatheter was wedged distally, and gentle traction was then used to straighten the microcatheter (B) in preparation for PED deployment.

Technique: Digital subtraction angiography, contrast (100mL Visipaque 320), fluoro time 33.9 minutes, reference air kerma (mGy): 2397, kerma area product (mGy-cm2): 269321

Figure 4: Right renal digital subtraction angiography. 62-year old female with right renal artery aneurysm.

Findings: Renal aneurysm embolization. (A) Digital subtraction image shows one micro-catheter passing into the distal outflow vessel in preparation for PED deployment, and a second microcatheter looped in the aneurysm sac in preparation for coil embolization. (B) The PED (white arrow) is first deployed distally before extending across the aneurysm (C), leaving the second microcatheter jailed in the aneurysm sac. (D) The aneurysm sac was embolized using soft detachable coils (white arrow marks the PED). Final angiogram shows cessation of flow into the aneurysm sac with excellent flow through the PED to the renal parenchyma (E). An atlas (F) labelling the position of the deployed stent, coiled aneurysm, and inflow/outflow tracts is provided.

Technique: Digital subtraction angiography, contrast (100mL Visipaque 320), fluoro time 33.9 minutes, reference air kerma (mGy): 2397, kerma area product (mGy-cm2): 269321

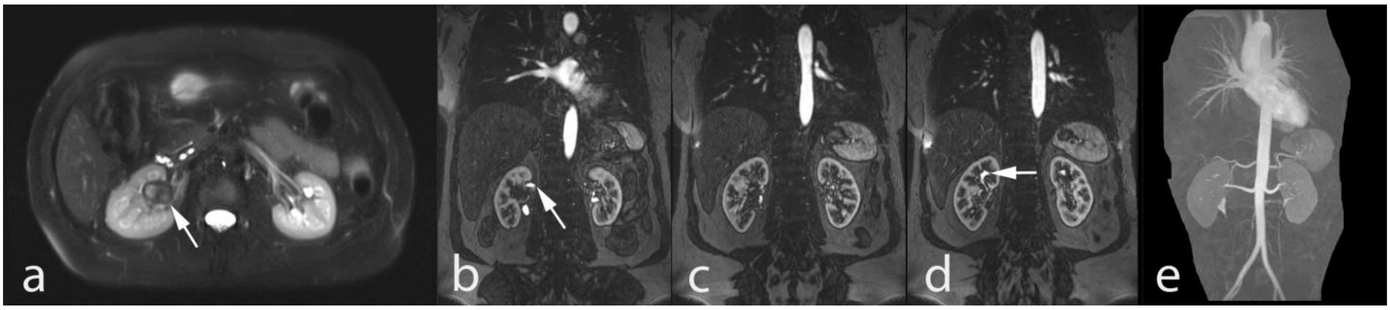

Figure 5: One-month follow-up Contrast-Enhanced MR Angiography. 62-year old female with right renal artery aneurysm.

Findings: T2-weighted MRI follow-up imaging demonstrates complete aneurysm occlusion (A, C) with patent inflow from the renal artery (B; white arrow shows inflow vessel), patent outflow (D; white arrow shows persistent perfusion in a vessel distal to the main outflow vessel) and no parenchymal loss (E).

Technique: 3.0 Tesla scanner (Siemens Magnetom), Contrast-enhance MR angiography (20mL Dotalem IV contrast), T2-weighted fat suppressed, arterial phase, TR 3.44, TE 1.42, 1.4mm slice thickness. A) axial view, B-E) coronal view

Etiology	Idiopathic, fibromuscular dysplasia, connective tissue disease (Ehlers-Danlos, Marfan syndrome)
Incidence	0.3-2.5% (Imaging), < 0.1% (autopsy)
Gender Ratio	More common in females than males (2-3:1 ratio)
Age predilection	Most common in 5th – 6th decade of life
Risk factors	Hypertension, fibromuscular dysplasia, hypercholesterolemia, smoking, connective tissue disease (i.e., Ehlers-Danlos, Marfan syndrome)
Treatment	Routine surveillance: preferred in patients with asymptomatic RAA < 2.0cm Intervention: indications include the following: -Asymptomatic RAA > 2.0cm (although a recent study suggests that RAA between 2-3cm rarely rupture) -RAA of any size in women of childbearing age -RAA of any size that are symptomatic (pain, hematuria, medically refractory HTN) -Acute sequelae such as thromboembolism, dissection, or rupture
Prognosis	0.3-3% of all aneurysms rupture; 18% rupture rate in aneurysms > 3.0cm, in a recent study. Reported post-intervention morbidity rates are variable, but long-term survival rates are > 90% at 10 years. No significant difference in morbidity and mortality for endovascular vs surgical repair, although the endovascular approach is associated with a shorter length of hospital stay.
Imaging findings	CT contrast: contrast-filled outpouching along course of renal artery

Table 1: Summary table of renal artery aneurysm.

	Ultrasonography	**CT**	**MR**
Aneurysm	Hypoechoic mass w/ turbulent flow seen on Doppler (although flow signal may not be seen in the presence of thrombosis)	Angiography: Contrast-filled outpouching along course of renal artery	Angiography: same as CT
Pseudoaneurysm	Hypoechoic mass w/ turbulent flow seen on Doppler (although flow signal may not be seen in the presence of thrombosis)	Angiography: Contrast-filled outpouching along course of renal artery. Distinguish from true aneurysm based on history and presenting symptoms (trauma, amphetamine use, vasculitis)	Angiography: same as CT
Perihilar cyst	Uncomplicated: anechoic lesion w/ thin walls, +/- thin septa. No flow signal on Doppler US.	Well-marginated, thin wall, non-enhancing.	Hypointense on T1 and hyperintense on T2; no enhancement
Renal Cell Carcinoma	Variable appearance. Hypoechoic halo (tumor pseudo-capsule) is a specific, but not sensitive finding.	Soft-tissue attenuation, +/- calcification, variable enhancement in corticomedullary phase.	T1: heterogenous appearance T2: clear cell (hyperintense); papillary (hypointense)

Table 2: Differential diagnosis table for renal artery aneurysm.

ABBREVIATIONS

AAA = Abdominal aortic aneurysm
HTN = Hypertension
PED = Pipeline embolization device
RAA = Renal artery aneurysm
RDC = Renal Double Curve

KEYWORDS

Renal artery aneurysm; visceral aneurysm; flow diverting stent; Pipeline; coil embolization

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