Renal Artery Embolization

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ABSTRACT

Renal artery embolization (RAE) is an effective minimally invasive alternative procedure for the treatment of a variety of conditions. Since the 1970s when RAE was first developed, technical advances and growing experience have expanded the indications to not only include treatment of conditions such as symptomatic hematuria and palliation for metastatic renal cancer, but also preoperative infarction of renal tumors, treatment of angiomyolipomas, vascular malformations, medical renal disease, and complications following renal transplantation. With the drastically improved morbidity associated with this technique in part due to the introduction of more precise embolic agents and smaller delivery catheters, RAE continues to gain popularity for various urologic conditions. The indications and techniques for renal artery embolization are reviewed in the following sections.

KEYWORDS: Embolization, renal artery, kidney, hemorrhage, interventional radiology

Objectives: Upon completion of this article, the reader should be able to list the common indications for therapeutic renal arterial embolization.

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Renal artery embolization (RAE) is an effective minimally invasive alternative procedure for the treatment of a variety of conditions. Since the 1970s when RAE was first developed, technical advances and growing experience have expanded the indications to not only include treatment of conditions such as symptomatic hematuria and palliation for metastatic renal cancer, but also preoperative infarction of renal tumors, treatment of angiomyolipomas (AMLs), vascular malformations, medical renal disease, and complications following renal transplantation.^{1,2} With the drastically improved morbidity associated with this technique in part due to the introduction of more precise embolic agents and smaller delivery catheters, RAE continues to gain popularity for

various urologic conditions. The indications and techniques for renal artery embolization are reviewed in the following sections.

ANATOMY

Knowledge of the classic anatomy and variations of the renal vessels is important in the planning prior to renal artery embolization. We review here the classic and variant anatomy that may be encountered in patients undergoing RAE. Careful evaluation for variant anatomy on preprocedural imaging on ultrasound, computed tomography (CT), or magnetic resonance imaging (MRI) would be helpful prior to RAE.

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Classic Anatomy

The renal arteries arise from the abdominal aorta, below the origin of the superior mesenteric artery, typically at the level between the superior endplate of L1 and the inferior endplate of L2. Both renal arteries originate at the anterolateral aspect of the abdominal aorta. Near the hilum of the kidney, each renal artery divides into an anterior and a posterior branch, which in turn, divide into upper, middle, and lower pole segmental arteries (Fig. 1). These segmental vessels bifurcate into lobar arteries, which then penetrate the renal parenchyma and divide into the interlobar arteries. The interlobar arteries extend between each of the seven anterior and seven posterior pyramids of each kidney, and give rise to the arcuate arteries, which run parallel to the kidney surface. The arcuate arteries in turn give rise to the interlobular arteries, which become the afferent arterioles that enter the glomeruli. The efferent arterioles and vasa recta cannot be distinguished on angiography.

Variant Anatomy

Variations in the renal arteries are crucial issues to consider prior to renal artery embolization to achieve the intended goals for various indications.

There are two types of variant renal arteries. Branching of the main renal arteries into segmental branches more proximally than the hilum is called early division. The second type, known as the extra renal arteries, can be further divided into two groups: accessory (hilar) and aberrant (polar) arteries. Accessory arteries enter the kidneys from the hilum along with the main renal artery, and the aberrant arteries enter the kidneys directly from the capsule, outside of the hilum.

Accessory renal arteries constitute the most common, clinically important vascular variants, seen in up to 30% of patients. Multiple renal arteries are unilateral in ~30% of patients and bilateral in ~10%. These accessory renal arteries usually arise from the aorta or iliac arteries

anywhere from the level of T11 to the level of the L4 vertebra. In rare cases, these arteries can arise from the common iliac arteries, superior and inferior mesenteric arteries, lumbar arteries, middle sacral arteries, celiac artery, and middle colic artery. There have been reported cases of renal arteries also arising from a common trunk and the contralateral renal artery. This wide variety can be explained by the incomplete involution of the mesonephric arteries, which form a network of arteries during development, also known as the urogenital rete arteriosum, which arise from the aorta.

If present, the accessory artery enters the renal hilum to perfuse the upper or lower renal poles (Fig. 2). The most common type of accessory artery perfuses the lower pole. This is of clinical importance as this may pass the anterior side of the ureteropelvic junction and cause an obstruction. The next most common variant is a superior pole artery arising from the aorta to supply a minor part of the upper renal pole. Often, this artery is small enough that it cannot be seen angiographically, but seen on CT dissection protocols.

TECHNICAL CONSIDERATIONS

Preprocedure Planning

Before the procedure, patients are given prophylactic antibiotic coverage. Moderate sedation and administration of local anesthetic to the access site is usually adequate, although general anesthesia may be helpful in cases in which absolute alcohol is intended on being used as a sclerosing agent, particularly if large volumes (>10 mL) are planned for use because of the pain related to the procedure and the possibility of cardiopulmonary collapse if large volumes escape into the systemic circulation.

In patients with indwelling percutaneous nephrostomy tubes, flushing the nephrostomy tube with saline and instilling gentamicin through the tube after

Figure 1 Classic renal artery anatomy.

Figure 2 (A) Computed tomography in a patient with nonresectable renal cell carcinoma presenting with intractable hematuria. (B) Initial renal arteriogram shows a vascular mass occupying much of the kidney and a focus of what was felt to be either active bleeding or a small intratumoral aneurysm. (C) Postembolization shows successful devascularization of part of the kidney; to reduce the risk of severe postembolization syndrome, it was elected to treat only part of the tumor on the initial presentation.

the procedure is recommended to decrease the risk of infection.³

Vascular Access and Catheters

Vascular access is generally obtained via the common femoral artery with an 18- or 19-gauge puncture needle via a modified Seldinger puncture technique. If the femoral arteries are occluded, an alternative access site such as the axillary or brachial artery can be used. While a 5-French sheath is generally used, a larger caliber sheath may be needed for more complex procedures that involve balloon catheters.

For nonselective aortorenal arteriography, a conventional flush (straight or pigtail configuration) catheter is ideally positioned slightly superior to the origin

of the renal arteries. For catheterization of the main renal artery and its large branches, a Cobra configured (C2) may be used. Other catheters such as the RC-2 shaped catheter, SOS-shaped catheter, Levi (Lev-1), or Simmons shaped catheters may also be used. Factors to consider that may make it difficult to catheterize the renal artery include atherosclerosis, abdominal aortic aneurysm, narrowed or tortuous iliac arteries, renal artery stenosis, or mass effect from retroperitoneal tumors. Therefore, choosing a catheter that would conform to the vessel anatomy is recommended. This may involve catheter exchanges and the use of coaxial systems to cannulate smaller arteries. Superselective catheterization of renal artery branches involves the use of microcatheters either via coaxial or guidewire-controlled techniques.

Partial versus Total Embolization

When it is desirable to eliminate the vascular supply to a portion of the kidney while minimizing the extent of infarction of the functional portions of the kidney, partial renal artery embolization techniques are used. This is achieved with selective catheterization of segmental/lobar renal artery branches that perfuse a lesion. Superselective embolization can provide even more controlled occlusion of specific small renal artery branches that supply blood to a lesion, with very little effect on the surrounding normal renal parenchyma. One study reports less than 10% of nontarget renal parenchymal infarction using superselective renal artery embolization, which was not associated with a clinically significant reduction in renal function.⁴ In contrast, subselective embolization results in ~15 to 50% infarction of the surrounding renal parenchyma, which may compromise renal function.⁵ In any event, the patient should be made aware that there is always a risk for nontarget embolization and that some normal renal parenchyma may need to be sacrificed to accomplish the intended goal. This is because the vessels in the kidney are "end arteries" with no significant intrarenal collaterals.

When it is desirable to completely obliterate the renal function or blood supply to tumors that involve a large portion of the renal parenchyma, total renal artery embolization techniques are used. This is achieved by positioning the catheter within the main renal artery but distal to the ostium to minimize spinal, lower extremity, and bowel infarction.⁶⁻⁸ Embolization of small vessel branches with alcohol, polyvinyl alcohol (PVA) particles, microspheres, and/or Gelfoam is performed until there is contrast stasis in the targeted kidney. After flushing the guiding catheter, coils may be deployed in the main renal artery.

Renal Transplants

The most common indications for embolization in patients after renal transplantation are for the treatment of an arteriovenous fistula (AVF) or pseudoaneurysms. AVFs almost always occur as a result of percutaneous biopsies of the allograft, reported to occur in 1 to 18% of cases.^{9,10} To a lesser extent, percutaneous nephrostomy tube placements have also been reported as a cause for AVF formation. RAE is considered the first line of treatment for symptomatic AVF.¹¹ Pseudoaneurysms can occur in up to 30% of biopsied allografts and can also be treated with transcatheter coil embolization.

Embolization of lesions in renal allografts requires modification of the standard techniques for native kidneys. The nonselective arteriogram is performed with the injection catheter positioned above the aortic bifurcation to visualize the transplant main renal artery arising from the external iliac artery. Carbon dioxide (CO₂) can be utilized not only for its decreased neph-

rotoxicity compared with iodinated contrast, but also for its higher sensitivity in detecting small AVF secondary to its volatility.¹² After the aortic bifurcation is traversed with the guidewire, the catheter can be exchanged for a hydrophilic catheter and superselective methods with coaxial systems may be implemented to better access the lesion.

Several studies report minor infarcts (< 30% of allograft) occurring in up to 100% of cases involving coil embolization of lesions, but no data on the long-term consequences with regard to allograft survival have yet been reported in the literature.¹³ In one series, in 28.6% of patients, 30 to 50% infarction of the allograft was reported to occur.¹⁴

Unlike in native kidneys, to maximize the function of the renal allograft, complete obliteration of the AVF or pseudoaneurysm is not necessary unless symptoms persist, in which case repeat microcoil embolization is warranted. If the feeding vessel of a pseudoaneurysm cannot be accessed through the transplant renal artery, transcapsular embolization of the pseudoaneurysm can be considered.¹⁵

INDICATIONS

Malignant Renal Tumors

The most common indication for renal artery embolization is preoperative infarction of renal tumors prior to nephrectomy or radiofrequency ablation (RFA).^{4,16} RAE can be used for palliation by reducing the tumor bulk and providing symptomatic (hematuria, flank pain) relief in patients with unresectable renal cell carcinoma or in patients who are poor surgical candidates (Fig. 2). By decreasing the size and vascularity of the tumor, RAE also allows for a less-extensive surgical resection and decreased intraoperative blood loss.^{17,18} Several studies have also demonstrated that RAE-induced tumor necrosis may stimulate a tumor specific response, further decreasing its size preoperatively. RAE increases the edema within the tissue planes between the tumor and kidney, which makes dissection easier in patients who undergo nephrectomy.^{18,19} This added benefit is most pronounced at 72 hours.⁴ In cases where there is a large burden of tumor thrombus, there might be a beneficial effect of decreasing the size of tumor thrombus prior to surgery. The time it takes to maximize this benefit may be longer than 72 hours; however, this benefit must be weighed against the increased chance of collateral vessel formation. Therefore, it has been recommended that the ideal time between RAE and surgery is less than 24 hours to 2 days.¹⁷ One pilot study also reports preprocedural infarction of renal tumors prior to cryoablation reduces the size of the postcryoablation hematoma.²⁰

Technical success can be achieved using a variety of embolization agents. After selection or superselection

of the artery or arteries feeding the tumor, ethanol mixed with lipiodol, PVA particles, synthetic microspheres, or Gelfoam in the form of a slurry can be used to occlude the capillaries of the tumor for patients planned for a partial or total nephrectomy. If a total nephrectomy is planned, coil embolization of the main renal artery and any extrarenal feeding vessels can also be performed. However, a residual stump of the proximal renal artery should be spared to allow surgical clamping and ligation during the total nephrectomy without the problem of metallic coils hindering resection of the main renal artery or migrating back into the aorta and embolizing distally. If there is a large amount of shunting within the tumor, coils or Gelfoam torpedoes can be used to block them. Gelfoam when coupled with sealing coils has been reported to achieve stasis for 24 to 72 hours, which is the usual time lapse between embolization and subsequent nephrectomy.²¹ After embolization, a completion aortogram is then performed to evaluate for accessory or parasitized arteries that may be supplying the tumor. Repeat embolization may be performed as necessary.

Superselection of the feeding arteries for a renal tumor is preferred in patients planned for RFA and cryoablation.²²⁻²⁴ Preoperative RAE may be advantageous in patients with stage 1 renal cell carcinoma planned for RFA, possibly due to the devascularized region having a reduced heat sink effect, thus rendering RFA more effective.²³

Although its long-term effects are controversial, one study reports an increased overall 5-year survival benefit for patients that undergo prenephrectomy RAE compared with patients who undergo nephrectomy alone (62% vs. 35%; $P = .01$).²⁵ An older study did not find a statistically significant difference in overall 5-year survival in prenephrectomy RAE patients, but did find an increase in survival in patients if minimal pulmonary metastases were present.²⁶ Patients with mediastinal or hilar lymphadenopathy, pleural effusion, or nonpulmonary metastases showed no increased survival whether or not prenephrectomy RAE was performed. To date, there is no prospective data reported to demonstrate a survival benefit to adjuvant RAE prior to nephrectomy.

Renal Angiomyolipomas

Renal angiomyolipomas are benign vascular tumors that contain fat and smooth muscle elements. Tumors larger than 4 cm in diameter are at greater than 50% risk of rupture and hemorrhage.²⁷ Transcatheter renal artery embolization is now the treatment of choice for acute hemorrhage from angiomyolipomas and may eliminate the need for blood transfusion and surgery in technically successful cases (Fig. 3).²⁸ A decrease in tumor size can also be seen in nonhemorrhagic angiomyolipomas that undergo RAE.²⁹

Technical success can be achieved with several embolic agents. Embolic agents commonly used are microcoils, nonresorbable particles, absolute dehydrated ethanol (typically mixed with an oily contrast agent such as Ethiodol), Sotradecol, and *N*-butyl-2-cyanoacrylate. Given that angiomyolipomas are quite vascular, liquid embolic agents/sclerosants such as absolute dehydrated alcohol mixed with an oily contrast agent such as Ethiodol, Sotradecol, and glue have been recommended over particulate embolic agents and coils according to some sources.²¹ There is virtually no loss of renal function in the reported cases of treated AMLs with RAE.^{30,31} Although technical success has been reported to be in 80 to 90% of cases using superselective methods, long-term follow-up has shown tumor recurrence in over 30% of patients, with a higher recurrence rate of 43% in tuberous sclerosis patients.³² For this reason, these patients should undergo continued surveillance and proper counseling for potential future recurrences after RAE. One study reports angiomyolipomas undergo sterile liquefaction after RAE, sometimes requiring percutaneous drainage catheter placement.³³

Traumatic Renal Hemorrhage

Renal injuries in the setting of abdominal trauma are not uncommon. The most frequent presenting sign is hematuria or perinephric hematoma, but the amount of bleeding is usually a poor indicator of the severity of the trauma. The majority of renal artery injuries are minor (75–80%), representing contusions or superficial lacerations that can be managed conservatively, with only 5% grade V (completely shattered kidney or an avulsed renal hilum that devascularizes the kidney). The remaining 10% are generally serious injuries that are amenable to renal artery embolization.³⁴ Early diagnosis and treatment is necessary to preserve the maximum amount of normal renal tissue, as renal ischemia persisting for 3 hours or more may result in severe tubular necrosis and renal dysfunction. Additionally, a delay in diagnosis may result in an increased deformity of the kidney due to a large hematoma, which can prevent superselective catheter placement, therefore necessitating a more proximal embolization resulting in more parenchymal loss due to infarction.³⁴

Wide impact injuries that result in a broad volume of parenchymal injury should be evaluated first with CT for grading purposes, if the patient is stable. These injuries include stab and gunshot wounds, blunt trauma, and deceleration injuries, which can avulse the main renal arteries due to the relatively mobile kidneys that stretch the renal vessels. Higher-grade renal injuries or unstable patients may need to be operated on emergently. Interventional procedures may be indicated in more stable patients as well as in postoperative patients with persistent or recurrent hematuria.^{34,35}

Figure 3 Angiomyolipoma, with the patient presenting with hematuria. (A) Computed tomography shows an angiomyolipoma (AML) in the upper pole; note the bilateral masses typical of a patient with tuberous sclerosis. The patient has had embolization of other renal tumors in the past. (B) initial diagnostic arteriogram (early phase); (C) initial diagnostic arteriogram (later phase). (D) Postrenal artery embolization arteriogram shows successful devascularization of the AML. The agent used was a mixture of alcohol and Ethiodol.

Narrow tract injuries from street assaults, biopsies, and nephrostomy tube placements leave more sharply defined residual wound tracts. Not only can arterial injury occur in these settings, but also false aneurysms with or without arteriovenous fistulas. The exact location of vessel damage can be assessed with CT, but direct angiography is more likely to be definitive in these cases. Although most cases of arterial injuries after biopsy or nephrostomy tube placement heal spontaneously, if hematuria persists for longer than 3 days, angiographic investigation and possible embolization is warranted.^{36,37} Patients who become hemodynamically unstable following biopsies and nephrostomy should

undergo immediate angiography and treatment.³⁸ Most cases of vessel rupture due to angioplasty are treated surgically; however, there is one report of successful management using a balloon occlusion device to tamponade the site of rupture.³⁹ Most injuries resulting from biopsy or nephrostomy tube placements have been treated primarily with embolization, therefore avoiding surgery.³⁶

Agents used include Gelfoam because of its utility and absorbability in small vessel injuries, PVA particles, or microcoils for larger vessel injuries. A success rate of 93% has been reported in the literature for emergent hemorrhage cases.⁴⁰ Precise subselection

and embolization of peripheral lesions with the use of coaxial catheter systems is preferred to preserve as much kidney function as possible.

Arteriovenous Fistulas

Arteriovenous fistulas are rare lesions, often seen as a result of biopsies of native and transplanted kidneys, partial nephrectomy, percutaneous nephrostomy tube placement, and penetrating trauma. Although 70% of AVFs in renal allografts spontaneously resolve within 2 years, embolization is the treatment of choice for symptomatic AVFs.^{13,14} Patients usually present with hematuria, abdominal bruit, renal insufficiency, hypertension, and high output cardiac failure. Endovascular management is preferred over surgery to optimize preservation of renal function. Large, high-flow renal AVFs have been successfully treated with RAE as well.⁴¹

Technical success can be achieved with superselective catheters with coaxial systems to embolize the fistula tract with microcoils. Particles are not utilized as they pose a risk of passing through the connection between the artery and vein, which could lead to embolization in the pulmonary arteries. On diagnostic angiography, there is early opacification of the vein, nearly simultaneous with the adjacent artery. If the fistula is chronic, the artery and vein may be dilated because of increased flow. There may be extravasation of contrast into the renal collecting system if there is an arteriocalyceal fistula. Complete obliteration of the fistula tract is the technical goal; however, in cases of renal allografts, control of patient symptoms should be the desired goal to preserve as much functional renal parenchyma as possible. To achieve this, crossing through the fistula from the arterial side to the venous side is ideal to deposit the coil through the fistula. In cases where there is high arterial blood flow, a balloon can be used to temporarily occlude the draining vein and prevent coils from entering the systemic circulation.⁴²

Renal Artery Pseudoaneurysm

Renal artery pseudoaneurysms are also uncommon, typically seen in patients after a renal biopsy, partial nephrectomy, or trauma. Most of the time, they are asymptomatic when small and spontaneously thrombose.⁴³ However, when they are symptomatic, a patient can present with a pulsatile mass in the pelvis, flank pain, renal dysfunction secondary to compression of artery branches or shunting of blood, or hemorrhage from rupture. Although these lesions can be managed surgically, RAE is preferred if they are amenable to embolization to minimize the loss of normal functioning renal parenchyma (Fig. 4).

Technical success can be achieved with superselective catheters to embolize the pseudoaneurysm with microcoils or stents. On angiography, they will appear as

localized segments of arterial dilatation. If acute, they are smooth in contour; if chronic, they can be irregular in contour. To minimize the risk of disturbing the distal renal artery flow, a narrow pseudoaneurysm neck is ideal. In cases where the main renal artery is affected, to avoid devascularizing the entire kidney, one could consider the use of covered stents to exclude the pseudoaneurysm.⁴⁴ The success rates for transcatheter treatment of pseudoaneurysms range from 71% to 100% with alleviation of symptoms in 57% to 88% of cases.^{13,14,42}

Arteriovenous Malformation

Arteriovenous malformations (AVMs) of the kidney, which are rare, are typically described as moderate to high flow, and can be congenital or acquired. Congenital AVMs are usually small and asymptomatic, and close spontaneously. Acquired AVMs typically have an indolent, complex course. When they are symptomatic, patients usually present with gross hematuria, renal dysfunction, hypertension, and high-output cardiac failure. Because of their complexity, these lesions are almost never entirely cured and may recur. Patients with these lesions should be counseled that treatment may be lifelong and that currently there is no cure. Therefore, the endpoint is not to completely obliterate the vascular anomaly seen on angiography, but to reverse the clinical symptoms and repeat embolizations as needed.

The optimal method of improving patient symptoms is to ablate the nidus of the AVM, which is the epicenter of the abnormal vessels. For this reason, sclerosants are preferred over coils and detachable balloons that are not fine enough to negotiate the nidus. Because of the moderate to high flow in these AVMs, more-viscous sclerosants such as *N*-butyl-2-cyanoacrylate (glue), Onyx, and Sotradecol/CO₂ foam can be used as opposed to alcohol, which can be more difficult to control in this setting. Gelfoam is not desirable in the treatment for AVMs because of its temporary embolic effect and risk of recanalization of the nidus. A balloon-occlusion catheter can be placed proximal to the lesion to decrease the flow into the nidus, so that the sclerosant can dwell and not pass through a high-flow fistula, if necessary. Epinephrine injection before embolization may also make the procedure more effective by inducing vasoconstriction, thereby concentrating the injected material within the AVM. Coils can also be used in the emergent setting to rapidly reduce blood flow in patients who are actively bleeding, as well as to reduce symptoms and the risk of preoperative bleeding before partial or total nephrectomy.⁴

Renal Artery Aneurysm

Renal artery aneurysms are rare lesions, with a prevalence of 0.7% based on CT imaging of the general population.⁴⁵ Predisposing factors include atherosclerosis and

Figure 4 (A) Renal pseudoaneurysm seen by color Doppler ultrasound following a percutaneous biopsy; the patient presented with left flank pain but no hematuria. (B) A diagnostic left renal arteriogram shows a lobular pseudoaneurysm in the lower pole (C) following embolization; the aneurysm has been excluded from the circulation, leaving most of the remaining parenchyma intact.

connective tissue disease such as Marfan syndrome and Ehlers-Danlos syndrome, neurofibromatosis, fibromuscular dysplasia, polyarteritis nodosa, and tuberous sclerosis. Although there are no definite indications for aneurysm treatment, in general, aneurysms greater than 1.5 to 2.0 cm in diameter, or aneurysms presenting with flank pain, hematuria, found in women of child-bearing age or in patients with polyarteritis nodosa warrant intervention.

Overall, 100% technical success and resolution of symptoms in 88% of patients with extraparenchymal

renal artery aneurysms has been reported via embolization techniques.⁴⁶ The location and morphology of the aneurysms determines the particular technique. Main renal artery aneurysms are more amenable to stent grafting alone. However, the proximal-most aspect of the stent must be at least 1.5 mm away from the renal artery ostium and first bifurcation. Vessel tortuosity and angulations may limit the use of a stent graft despite the advent of more flexible devices. Distal renal artery branch aneurysms are more likely to be amenable to coil embolization with superselective catheterization.

Aneurysms with a wide neck, which can be defined as greater than 70% of the diameter of the aneurysm may require advanced techniques using a combination of a stent graft or balloon occlusion device with coils.⁴⁷

Chronic Renal Parenchymal Diseases

Chronic renal parenchymal disease such as end-stage renal disease, posttransplant patients with severe nephrotic syndrome, hypertension or hematuria, persistent urine leak from a ureterocutaneous fistula, severe and intractable hydronephrosis, autosomal dominant polycystic kidney disease, and irreversible transplant rejection have been reported indications for complete renal artery embolization in patients who may be poor surgical candidates for nephrectomy.^{3,48-51} The goal is to provide symptomatic relief by eliminating renal function while avoiding the morbidity and mortality of a nephrectomy.

Technical success can best be achieved using liquid or particulate agents to initially embolize small peripheral arteries, and coils to embolize large vessels. It is therefore crucial to know the number of renal arteries that supply the kidney as well as the presence of aberrant arteries that should be targeted as well. In chronically diseased transplant kidneys or in end-stage renal disease, the renal arteries may be small, which predisposes to reflux of embolization material into the aorta. It is for this reason that temporary balloon occlusion catheters can be positioned in the proximal main renal artery to avoid this problem. The technical endpoint is to observe stasis of contrast or slow to-and-fro flow in the main renal artery on completion angiography. Repeat embolization can be performed as needed.

COMPLICATIONS

Renal artery embolization is considered a safe procedure, with a relatively low complication rate. The most common occurrence is the postembolization syndrome that affects over 90% of patients.⁴ Patients usually present with mild flank pain, fever, nausea, vomiting, paralytic ileus, and/or leucocytosis for 1 to 3 days after RAE.¹⁶ Treatment is supportive, consisting of analgesics, antipyretics, and antiemetics as needed, until symptoms resolve, typically within several days. For this reason, it is recommended that patients be observed in a hospital overnight after RAE for monitoring and symptom control.

Coil migration is an unusual, but potentially serious, complication, occurring in less than 2% of cases.¹⁶ Typically, this is detected at the end of the embolization procedure and can be rectified using an endovascular grasping device (snare). Inadvertent non-target embolization can result in spine, lower extremity, and bowel infarction.⁶⁻⁸ Reflux of embolization materials can result in loss of renal function and subsequent

hypertension and inadvertent passage of PVA particles through an AVF can result in pulmonary embolism. Positioning the injection catheter properly and securely, possibly with the use of a temporary balloon occlusion device within the parent artery can reduce this risk. As with any percutaneous arterial intervention, there is a low risk of access site hematoma that can be reduced using proper manual compression technique or closure devices. Finally, contrast nephrotoxicity can occur, especially in those with limited renal function, and this should be considered when planning the procedure.

The incidence of infection related to RAE is very low. Follow-up imaging may demonstrate the presence of intrarenal gas, but this does not necessarily indicate infection. There have been only a few reported cases of post-RAE patients requiring a percutaneous drainage catheter.³³ Familiarity with the appearance of expected RAE changes of the kidney on cross-sectional imaging is important to avoid unnecessary interventions.

CONCLUSION

Renal artery embolization has become an effective, versatile therapeutic and adjuvant tool for many urologic conditions, both acute and chronic. It can be applied successfully in improving preoperative management of renal tumors prior to nephrectomy, achieving hemostasis in cases of hemorrhage from trauma or from tumors such as angiomyolipomas, treating complications of renal transplantation and biopsies such as arteriovenous fistulas and pseudoaneurysms, improving symptoms in patients with arteriovenous malformations and certain chronic renal parenchymal diseases, and for treating renal artery aneurysms. Depending on the indication and the character of the lesion, different embolic materials and catheters should be used to optimize outcomes. Preprocedural planning and careful attention in the event of complications during and after the procedure should be performed to optimally treat patients. With improving technology and techniques, the indications for RAE may expand, thus making it important to understand the variety of available techniques.

REFERENCES

1. Turini D, Nicita G, Fiorelli C, Selli C, Villari N. Selective transcatheter arterial embolization of renal carcinoma: an original technique. *J Urol* 1976;116(4):419-421
2. Kadir S, Marshall FF, White RI Jr, Kaufman SL, Barth KH. Therapeutic embolization of the kidney with detachable silicone balloons. *J Urol* 1983;129(1):11-13
3. Hom D, Eiley D, Lumerman JH, Siegel DN, Goldfischer ER, Smith AD. Complete renal embolization as an alternative to nephrectomy. *J Urol* 1999;161(1):24-27

4. Ginat DT, Saad WE, Turba UC. Transcatheter renal artery embolization: clinical applications and techniques. *Tech Vasc Interv Radiol* 2009;12(4):224-239
5. Takebayashi S, Hosaka M, Kubota Y, Ishizuka E, Iwasaki A, Matsubara S. Transarterial embolization and ablation of renal arteriovenous malformations: efficacy and damages in 30 patients with long-term followup. *J Urol* 1998;159(3):696-701
6. Cox GG, Lee KR, Price HI, Gunter K, Noble MJ, Mebust WK. Colonic infarction following ethanol embolization of renal-cell carcinoma. *Radiology* 1982;145(2):343-345
7. Gang DL, Dole KB, Adelman LS. Spinal cord infarction following therapeutic renal artery embolization. *JAMA* 1977;237(26):2841-2842
8. Woodside J, Schwarz H, Bergreen P. Peripheral embolization complicating bilateral renal infarction with gelfoam. *AJR Am J Roentgenol* 1976;126(5):1033-1034
9. Diaz-Buxo JA, Kopen DF, Donadio JV Jr. Renal allograft arteriovenous fistula following percutaneous biopsy. *J Urol* 1974;112(5):577-580
10. Merkus JW, Zeebregts CJ, Hoitsma AJ, et al. High incidence of arteriovenous fistula after biopsy of kidney allografts. *Br J Surg* 1993;80(3):310-312
11. Loffroy R, Guiu B, Lambert A, et al. Management of post-biopsy renal allograft arteriovenous fistulas with selective arterial embolization: immediate and long-term outcomes. *Clin Radiol* 2008;63(6):657-665
12. Hedegard W, Saad WE, Davies MG. Management of vascular and nonvascular complications after renal transplantation. *Tech Vasc Interv Radiol* 2009;12(4):240-262
13. Maleux G, Messiaen T, Stockx L, Vanrenterghem Y, Wilms G. Transcatheter embolization of biopsy-related vascular injuries in renal allografts. Long-term technical, clinical and biochemical results. *Acta Radiol* 2003;44(1):13-17
14. Dorffner R, Thurnher S, Prokesch R, et al. Embolization of iatrogenic vascular injuries of renal transplants: immediate and follow-up results. *Cardiovasc Intervent Radiol* 1998;21(2):129-134
15. Sennett CA, Messersmith RN, Yousefzadeh DK, Thistlethwaite JR Jr. Percapsular and percutaneous embolization of renal transplant pseudoaneurysm and AV fistula: case report. *Cardiovasc Intervent Radiol* 1989;12(5):270-273
16. Schwartz MJ, Smith EB, Trost DW, Vaughan ED Jr. Renal artery embolization: clinical indications and experience from over 100 cases. *BJU Int* 2007;99(4):881-886
17. Kalman D, Varenhorst E. The role of arterial embolization in renal cell carcinoma. *Scand J Urol Nephrol* 1999;33(3):162-170
18. Bakal CW, Cynamon J, Lakritz PS, Sprayregen S. Value of preoperative renal artery embolization in reducing blood transfusion requirements during nephrectomy for renal cell carcinoma. *J Vasc Interv Radiol* 1993;4(6):727-731
19. Klimberg I, Hunter P, Hawkins IF, Drylie DM, Wajzman Z. Preoperative angioinfarction of localized renal cell carcinoma using absolute ethanol. *J Urol* 1985;133(1):21-24
20. Woodrum DA, Atwell TD, Farrell MA, Andrews JC, Charboneau JW, Callstrom MR. Role of intraarterial embolization before cryoablation of large renal tumors: a pilot study. *J Vasc Interv Radiol* 2010;21(6):930-936
21. Ginat DT, Saad WE, Turba UC. Transcatheter renal artery embolization for management of renal and adrenal tumors. *Tech Vasc Interv Radiol* 2010;13(2):75-88
22. Yamakado K, Nakatsuka A, Kobayashi S, et al. Radiofrequency ablation combined with renal arterial embolization for the treatment of unresectable renal cell carcinoma larger than 3.5 cm: initial experience. *Cardiovasc Intervent Radiol* 2006;29(3):389-394
23. Arima K, Yamakado K, Kinbara H, Nakatsuka A, Takeda K, Sugimura Y. Percutaneous radiofrequency ablation with transarterial embolization is useful for treatment of stage 1 renal cell carcinoma with surgical risk: results at 2-year mean follow up. *Int J Urol* 2007;14(7):585-590, discussion 590
24. Mondshine RT, Owens S, Mondschein JI, Cizman B, Stavropoulos SW, Clark TW. Combination embolization and radiofrequency ablation therapy for renal cell carcinoma in the setting of coexisting arterial disease. *J Vasc Interv Radiol* 2008;19(4):616-620
25. Zielinski H, Szmigielski S, Petrovich Z. Comparison of preoperative embolization followed by radical nephrectomy with radical nephrectomy alone for renal cell carcinoma. *Am J Clin Oncol* 2000;23(1):6-12
26. Swanson DA, Johnson DE, von Eschenbach AC, Chuang VP, Wallace S. Angioinfarction plus nephrectomy for metastatic renal cell carcinoma—an update. *J Urol* 1983;130(3):449-452
27. Rimon U, Duvdevani M, Garniek A, et al. Large renal angiomyolipomas: digital subtraction angiographic grading and presentation with bleeding. *Clin Radiol* 2006;61(6):520-526
28. Hamlin JA, Smith DC, Taylor FC, et al. Renal angiomyolipomas: long-term follow-up of embolization for acute hemorrhage. *Can Assoc Radiol J* 1997;48(3):191-198
29. Takebayashi S, Horikawa A, Arai M, Iso S, Noguchi K. Transarterial ethanol ablation for sporadic and non-hemorrhaging angiomyolipoma in the kidney. *Eur J Radiol* 2009;72(1):139-145
30. Dabbeche C, Chaker M, Chemali R, et al. [Role of embolization in renal angiomyolipomas]. *J Radiol* 2006;87(12 Pt 1):1859-1867
31. Ramon J, Rimon U, Garniek A, et al. Renal angiomyolipoma: long-term results following selective arterial embolization. *Eur Urol* 2009;55(5):1155-1161
32. Kothary N, Soulen MC, Clark TW, et al. Renal angiomyolipoma: long-term results after arterial embolization. *J Vasc Interv Radiol* 2005;16(1):45-50
33. Soulen MC, Faykus MH Jr, Shlansky-Goldberg RD, Wein AJ, Cope C. Elective embolization for prevention of hemorrhage from renal angiomyolipomas. *J Vasc Interv Radiol* 1994;5(4):587-591
34. Fisher RG, Ben-menachem Y. Angiography and embolization in renal trauma. In: Baum S, ed. *Abram's Angiography: Vascular and Interventional Radiology*. 4th ed. Boston: Little, Brown and Company; 1997:1230-1243
35. Teigen CL, Venbrux AC, Quinlan DM, Jeffs RD. Late massive hematuria as a complication of conservative management of blunt renal trauma in children. *J Urol* 1992;147(5):1333-1336
36. Fisher RG, Ben-Menachem Y, Whigham C. Stab wounds of the renal artery branches: angiographic diagnosis and treatment by embolization. *AJR Am J Roentgenol* 1989;152(6):1231-1235
37. Cope C, Zeit RM. Pseudoaneurysms after nephrostomy. *AJR Am J Roentgenol* 1982;139(2):255-261
38. Low RN, Jeffrey RB Jr. Intraperitoneal hemorrhage after renal biopsy: a grave prognostic sign. *AJR Am J Roentgenol* 1988;151(1):113-114
39. Ashenburg RJ, Blair RJ, Rivera FJ, Weigle JB. Renal arterial rupture complicating transluminal angioplasty: successful

- conservative management. *Radiology* 1990;174(3 Pt 2):983–985
40. Somani BK, Nabi G, Thorpe P, McClinton S. Endovascular control of haemorrhagic urological emergencies: an observational study. *BMC Urol* 2006;6:27
 41. Sofocleous CT, Hinrichs C, Hubbi B, et al. Angiographic findings and embolotherapy in renal arterial trauma. *Cardiovasc Intervent Radiol* 2005;28(1):39–47
 42. Nakatani T, Uchida J, Han YS, et al. Renal allograft arteriovenous fistula and large pseudoaneurysm. *Clin Transplant* 2003;17(1):9–12
 43. Bach AM, Merton DA, Burke JF Jr, Halpern EJ. Sonographic diagnosis of arteriovenous fistula and pseudoaneurysm after biopsy of a transplanted kidney. *J Ultrasound Med* 1993;12(9):545–547
 44. Horwitz MD, Hanbury DC, King CM. Renal artery pseudoaneurysm following partial nephrectomy treated with stent-graft. *Br J Radiol* 2005;78(926):161–163
 45. Zhang LJ, Yang GF, Qi J, Shen W. Renal artery aneurysm: diagnosis and surveillance with multidetector-row computed tomography. *Acta Radiol* 2007;48(3):274–279
 46. Garg N, Pipinos II, Longo GM, Thorell WE, Lynch TG, Johanning JM. Detachable coils for repair of extraparenchymal renal artery aneurysms: an alternative to surgical therapy. *Ann Vasc Surg* 2007;21(1):97–110
 47. Abath C, Andrade G, Cavalcanti D, Brito N, Marques R. Complex renal artery aneurysms: liquids or coils?. *Tech Vasc Interv Radiol* 2007;10(4):299–307
 48. Millard FC, Hemingway AP, Cumberland DC, Brown CB. Renal embolization for ablation of function in renal failure and hypertension. *Postgrad Med J* 1989;65(768):729–734
 49. Keller FS, Coyle M, Rosch J, Dotter CT. Percutaneous renal ablation in patients with end-stage renal disease: alternative to surgical nephrectomy. *Radiology* 1986;159(2):447–451
 50. Hahn ST, Park SH, Lee JM, Kim CY, Chang YS. Renal artery embolization controls intractable pain in a patient with polycystic kidney disease. *Cardiovasc Intervent Radiol* 1999;22(5):422–424
 51. Harley JD, Shen FH, Carter SJ. Transcatheter infarction of a polycystic kidney for control of recurrent hemorrhage. *AJR Am J Roentgenol* 1980;134(4):818–820