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The Role of Arterial Embolization in Urology*

Learning Objective: At the conclusion of this continuing medical education activity, the participant will be able to describe the techniques of arterial embolization and its role in treating urological disease.

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INTRODUCTION

Since transcatheter arterial embolization was first introduced, it has progressed to being used in the treatment of urological disease, often complementing other surgical techniques. Given their minimally invasive nature, many of these procedures can be done in patients who are otherwise not optimal surgical candidates. In this Update we review arterial embolization techniques to familiarize the urologist with the current state of the art in urology. We provide an overview of the methods involved, address application of renal embolization (eg for trauma, renal masses including renal cell carcinoma and angiomyolipoma, renal artery aneurysms and renal vascular malformations), discuss cavernous artery fistula embolization for non-ischemic priapism and describe pelvic embolization (eg for benign prostatic hyperplasia, refractory hematuria and arterioureteral fistula). Our aim is to help the urologist understand how to better counsel patients and when referral to an interventionist is appropriate.

The first documented successful transcatheter arterial embolization was performed in 1970 at the University of Oregon Medical School.[1] In that case the technique was applied to control upper gastrointestinal bleeding in a patient in whom surgery was contraindicated due to hemorrhagic shock and severe coagulopathy secondary to advanced liver cirrhosis. Subsequently, in 1973 at the University of Michigan, transcatheter embolization was successfully used to control a post-biopsy renal arteriovenous fistula.[2] These early applications revolved around the control of traumatic bleeding, although transcatheter arterial embolization has progressed from a last resort to control hemorrhage to first line therapy in many clinical scenarios.

Transcatheter embolization is a sterile procedure and, as such, involves the same precautions and sterile technique as any other surgical procedure, including use of preoperative antibiotic prophylaxis.[3] Continuous cardiac monitoring is required during the procedure, as well as intravenous access for infusion of fluids and medication. Conscious sedation, monitored anesthesia care, or general anesthesia can be used based on the degree of invasiveness, duration of the procedure and overall health of the patient.

The technique used in the earliest descriptions remains the foundation for current approaches to transcatheter arterial embolization. The first step in arterial embolization is to gain vascular access via the Seldinger technique.[4] **Due to its large caliber and superficial location, the femoral artery is often chosen as an access point, although other arteries such as the radial artery are increasingly being used.**[5] Currently, it is recommended that initial arterial access be obtained under ultrasound guidance. After access has been achieved, digital subtraction angiography, a form of fluoroscopy, is performed both to confirm correct placement and to identify target arterial anatomy, anatomical variants, or sites of vascular injury.[4] Once placement has been confirmed, a guidewire is used to reach the embolization target. The chosen embolic agent can then be delivered to the target via various proprietary devices depending on the agent selected.

Choice of embolic agent is an important point of consideration. A number of factors determine which agent is most appropriate, including target vessel caliber, preference for permanent vs temporary agent and desire for target tissue death vs continued viability.[6] Temporary agents include gelatin foam, collagen and thrombin.[7] Permanent agents include drug eluting particles, embolic spheres, polyvinyl alcohol, coils, plugs, detachable balloons and liquid agents (ie glue, absolute ethanol and ethylene vinyl alcohol copolymer dissolved in dimethyl sulfoxide). In general, the smaller the agent particles are, the more distally they embolize (and cause tissue ischemia) relative to where they are delivered.[6] Particle or device size must be chosen appropriately to embolize the vessel, which provides clinical improvement while minimizing unnecessary tissue ischemia. Preoperative images should be viewed prior to the case. Images should be obtained and saved throughout the procedure, with particular emphasis on documenting the preoperative and postoperative states as well as any interventions.

Once successful embolization has been performed and vascular access has been removed, it is important to apply manual pressure or a vascular closure device to the access site to allow for hemostasis. This step is followed by a period of bed rest, during which the puncture site is monitored for hematoma formation, in addition to standard postoperative monitoring of intake and output, pain and cardiac symptoms.[3] **Vascular examinations of extremities distal to the access site should also be performed to confirm adequate perfusion.**

Policy at our institution generally consists of the patient receiving nothing by mouth for 8 hours prior to the procedure. **Anticoagulation is generally stopped, although in select cases it may be continued if a closure device can be used**. Conscious sedation is provided by nursing staff and the interventional radiologist, although anesthesiologists are sometimes employed depending on the patient's health status. After the procedure the patient is monitored by nursing staff during recovery. Admission is patient specific but most procedures performed electively will be done on an outpatient basis.

Transcatheter arterial embolization can be administered for a number of disease entities, including aneurysm, pseudoaneurysm, arteriovenous fistula, arteriovenous malformation, hemangioma and acute/recurrent hemorrhage.[8] Embolization may also be used to provide controlled tissue ischemia to treat non-neoplastic conditions such as hypersplenism. **Within the field of urology transcatheter arterial embolization may be used to perform renal artery, penile and prostatic artery embolization, and pelvic embolization for bleeding.**

RENAL TRAUMA

Background. Renal injury is a relatively common consequence of trauma (1%-5%).[9] Blunt renal trauma is more common than

ABBREVIATIONS: ACF (arteriocavernous fistula), AML (angiomyolipoma), AUA (American Urological Association), BPH (benign prostatic hyperplasia), CT (computerized tomography), DSA (digital subtraction angiogram), HFP (high flow priapism), IPSS (International Prostate Symptom Score), MRI (magnetic resonance imaging), PAE (prostatic artery embolization), QOL (quality of life), RCT (randomized controlled trial), SSAE (subselective arterial embolization), TURP (transurethral prostatectomy)

penetrating renal trauma (65% vs 35%). Clinicians should be suspicious of renal trauma if a patient presents with an appropriate mechanism of injury, hemodynamic instability or hematuria. In stable patients, renal injury can be diagnosed by cross-sectional imaging. For unstable trauma cases requiring immediate laparotomy, diagnosis of a renal injury is performed intraoperatively via direct exploration in the presence of an expanding retroperitoneal hematoma or via one-shot excretory urography. Renal trauma is graded according to the American Association for the Surgery of Trauma grading system. Management is typically supportive in the hemodynamically stable patient. **For unstable patients, treatment is surgical exploration**.

Indications. **Selective embolization is indicated for renal injury or laceration when there is demonstrated persistent bleeding after initial injury confirmed by angiography.** Surgery may be indicated for renal injury if a patient is unstable and undergoing laparotomy for other abdominal injuries, or in the presence of injury to the collecting system that requires repair or complete renal pedicle avulsion.

Treatment. Most cases of renal injury are managed non-operatively. **Angiography is indicated to assess for continued bleeding in hemodynamically stable patients who require repeated resuscitation or transfusion.** Intravascular contrast extravasation (positive predictive value 58%) and perirenal hematoma rim distance have been associated with the need for embolization at the time of angiography. In a retrospective study evaluating CT after renal trauma, a perirenal rim distance ≥15 mm had a positive predictive value for requiring renal embolization of 33%, compared to 100% if perirenal rim distance was ≥35 mm.[10] Bleeding identified during angiography should be selectively embolized. Permanent embolic agents such as coils and glue are commonly used in this scenario.

Outcomes. A retrospective review of a large trauma database from 2002 to 2007 identified 165 patients who underwent diagnostic angiography after renal injury (78% grade III to IV).[11] Of 77 patients who underwent embolization at the time of angiography, 68 required a second therapy (diagnostic angiography, repeat embolization, percutaneous nephrostomy placement or nephrectomy) or evaluation (ureteroscopy or retrograde urography). Of 36 patients who underwent repeat embolization, the procedure was successful in 35. In this series, 78% and 83% of patients with grade IV and grade V renal lacerations, respectively, retained the kidneys. In another study of 79 patients who underwent angiography for a suspected renal laceration, 22 (27.8%) required embolization.[12] Patients with failed embolization (27.2%) required more blood transfusions than those in whom the procedure was successful. **Overall, 16.5% of patients in this cohort who were managed non-operatively via angiography, with or without embolization, ultimately required surgical intervention.**

Follow-up. Patients with renal injury treated with segmental or main renal artery embolization should be monitored in the hospital for continued signs of bleeding and resuscitated as needed. Renal function and blood pressure should be monitored and patients should be provided appropriate follow-up with a nephrologist if renal impairment or hypertension develops. Those with high grade renal injury should also be monitored for hypertension during hospitalization and in the years subsequent to discharge. **These patients also require repeat cross-sectional imaging such as contrast enhanced CT.**

RENAL CELL CARCINOMA

Background. Approximately 74,000 new cases of renal cell carcinoma are diagnosed in the United States yearly.[13] Performing radical nephrectomy for a large locally advanced tumor is challenging and often involves a difficult dissection with an increased risk of bleeding. Providers may elect to embolize the kidney before radical nephrectomy in order to reduce the risk of bleeding and to allow intraoperative ligation of the renal vein immediately on identification rather than after identification and control of the renal artery. Alternatively, for patients with large unresectable symptomatic tumors, palliative embolization of the renal artery may be elected to address symptoms such as hematuria and pain and to improve QOL.[14]

Indications. Pre-radical nephrectomy embolization may be performed based on provider preference. Currently, no prospective randomized trials have been conducted to evaluate its use. Reported studies are retrospective in nature and have yielded variable results regarding the benefit of embolization for preventing blood loss and complications in this setting.[15] Older studies have mixed outcomes in terms of survival.[16, 17] **In the largest comparative study, embolization was associated with increased blood loss and transfusion requirement.[18] However, this study was not controlled, and the cohort undergoing embolization had higher stage disease and greater anesthetic risk scores**. The current consensus is that the optimal timing of nephrectomy after embolization is 24-72 hours.[14]

Palliative renal artery embolization is indicated in patients with hematuria or flank pain who have large unresectable tumors. **Multiple studies have indicated that up to 75% of patients will experience improvement in cancer related symptoms (eg colicky pain, hematuria and palpable mass) following embolization in this setting and that this effect can be potentiated by adding doxorubicin.**[19, 20]

Treatment. Access may be achieved via the femoral, radial or brachial artery with a 5Fr or 6Fr sheath. The renal artery is identified via angiography. Embolization may be performed with various materials including permanent and temporary embolic agents. The proximal renal artery should be spared to allow surgical clamping during nephrectomy if it is subsequently required.

Complications. **Embolization prior to nephrectomy is well tolerated and the literature does not indicate significant complications other than post-embolization syndrome (i.e. pain, fever, nausea)**.[18] Complications common to all embolization procedures include those related to the access site (eg hematoma, vessel injury and site infection), those related to injection of contrast medium (eg contrast induced nephropathy or anaphylaxis) and those related to the embolization itself, including non-target embolization (with particular risk to the adrenal in this procedure) and post-embolization syndrome.[14]

Follow-up. Patients undergoing renal artery embolization prior to nephrectomy require follow-up as dictated by the underlying pathology (eg per normal nephrectomy guidelines if performed for renal cell carcinoma). Patients undergoing palliative embolization should be monitored for post-embolization syndrome postoperatively and subsequently followed closely by a provider for symptom management.

Emerging use in ablation. Ablation is considered first line therapy for small renal masses, with many studies showing durable long-term oncologic control. However, vascular supply surrounding the mass may create a heat sink, which can be

detrimental to the effectiveness of ablative techniques.[21] **Selective embolization prior to ablation has the potential to counteract this effect while also providing larger margins and decreasing the risk of preoperative or postoperative bleeding (fig. 1)**.[22]

ANGIOMYOLIPOMA

Background. Angiomyolipomas are rare, benign, highly vascular tumors, which can be sporadic or associated with tuberous sclerosis complex. Sporadic AMLs are twice as likely to be diagnosed in women and are associated with hemorrhage in 0.4% of cases.[23] AMLs are found in 61%-80% of tuberous sclerosis complex cases and are associated with renal impairment and hemorrhage in 40% and 25% of patients, respectively. AMLs may be diagnosed by ultrasound, CT or MRI. MRI is the study of choice for diagnosing lipid poor AMLs,[24] which may be associated with flank pain, hemorrhage, or gross hematuria.[25]

Classically, AMLs are observed until they reach 4 cm or larger. This approach is based on retrospective studies suggesting that the likelihood of hemorrhage is higher in lesions greater than 4 cm. In patients with an AML, 64%-74% of hemorrhages are larger than 6 cm, 17%-26% are 4-6 cm and 9% are <4 cm.[26] Sporadic AMLs may be followed with active surveillance, which may obviate the need for treatment in up to 65% of patients.[27] AMLs smaller than 4 cm may be observed unless symptomatic.[28] **AMLs greater than 5 cm are associated with hemorrhage and are therefore an indication for prophylactic embolization**.[29] However, level 1 data are lacking for prophylactic embolization for AMLs and treatment decisions related to sporadic AMLs are largely determined by patient and provider preference and judgment. AML growth in pregnancy may be accelerated, although the literature exploring AML management in pregnancy is limited to case reports with variable treatment strategies.[30] Therefore, it would be prudent to manage these cases conservatively if possible.

Treatment, outcomes and complications. The mainstay of treatment of sporadic AML in the prophylactic and acute hemorrhagic settings is selective embolization (fig. 2). Level 1 evidence exists that use of an mTOR inhibitor is efficacious in reducing the size of AMLs in patients with tuberous sclerosis complex and this management should be strongly considered in such cases.[31,32] Examples of mTOR inhibitors include sirolimus, everolimus and temsirolimus. The literature on various embolization materials for AML remains unclear. A meta-analysis published in 2015 revealed that at 5-year follow-up, 20.9% of patients required repeat treatment.[33]

Lin et al published a meta-analysis of 30 studies including 653 patients treated with selective embolization, of whom 32% were treated urgently for hemorrhage while the remaining cases were elective.[34] The authors found that there was no change in renal function after treatment based on creatinine and estimated glomerular filtration rate. Post-embolization syndrome was diagnosed in 54% of patients (range 12.2%-100%), however, there was a great deal of heterogeneity between studies regarding the criteria used to reach this diagnosis. Major complications occurred in 4.4% of patients, including renal abscesses, femoral artery pseudoaneurysms, urinary tract infections, renal insufficiency, acute respiratory distress and pleural effusion. One mortality was attributed to

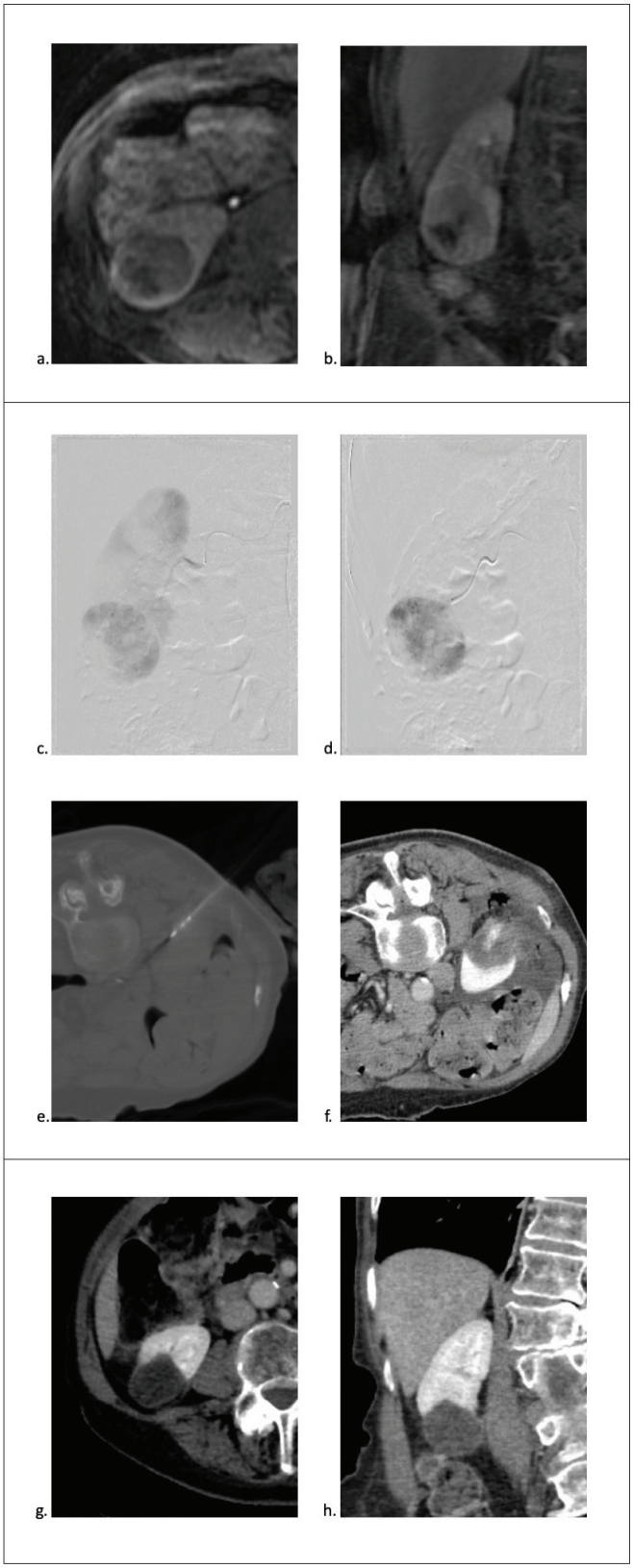

Figure 1. Imaging in 84-year-old female with dementia, leukemia, glaucoma, anxiety, depression, dysphagia and gastroesophageal reflux disease with 4.2-cm endophytic right lower pole renal mass. Contrast enhanced axial (*a*) and coronal CT (*b*) before embolization/ablation demonstrates mass. *c*, intraoperative DSA of right renal artery. *d*, DSA of segmental artery to lower pole mass during embolization. *e*, post-embolization placement of microwave ablation probe. *f*, post-ablation CT shows successful ablation of renal mass. At 12.5 months postoperatively, contrast enhanced axial (*g*) and coronal CT (*h*) reveal successful treatment of renal mass.

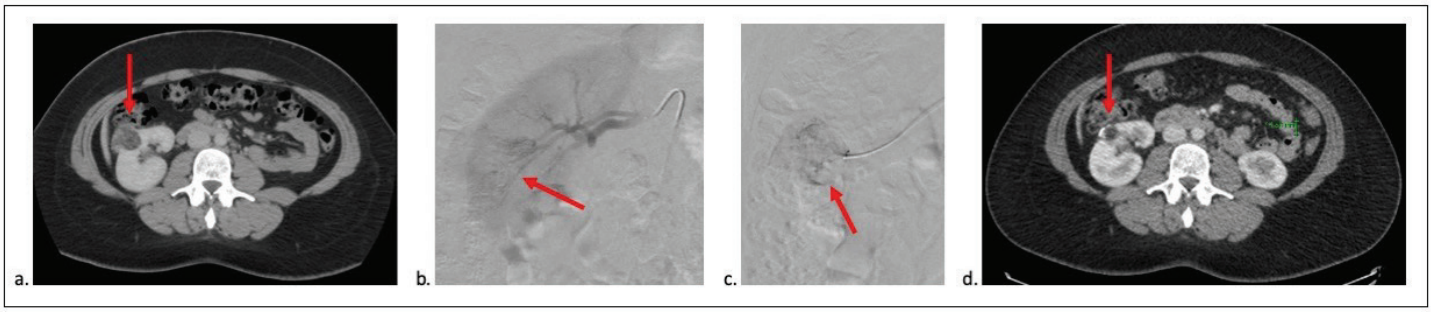

Figure 2. Imaging in 42-year-old female with hyperthyroidism status/post thyroidectomy and biopsy proven 3.9-cm AML. *a*, preoperative CT with intravenous contrast enhancement demonstrates right interpolar AML (arrow). *b*, DSA shows AML (arrow). *c*, DSA with selective catheterization of artery to AML (arrow). *d*, 4-month follow-up CT with intravenous contrast material without enhancement of now 2.2-cm AML (arrow).

treatment. **Average decrease in tumor size was 32%, although on follow-up, 11% of patients had no change or had an increase in tumor size.**

Urbano et al in 2017 published a series of 22 consecutive cases (37% urgent and 63% elective) involving symptomatic AMLs or AMLs larger than 4 cm managed by 6% ethylene vinyl alcohol.[35] At a median follow-up of 37.5 months, 18.5% of patients had experienced post-embolization syndrome and masses had shrunk by an average of 45.7%. Thulasidasan et al in 2016 published a series of 7 patients who underwent embolization of AML with ethylene vinyl alcohol copolymer dissolved in dimethyl sulfoxide with a mean follow-up of 431 days.[36] Embolization was associated with no change in serum creatinine, no hemorrhage events after treatment and a mean 22-mm reduction in tumor size. Recent reports suggest embolization of AMLs is possible using radial access.[37, 38] **Minor complications occurred in 7%-11% of patients and no major complications (including change in renal function or rebleeding) occurred in this setting**.[35]

Follow-up. There is no defined schedule for follow-up of patients with AML. However, patients with tuberous sclerosis complex undergo serial imaging to rule out development of brain involvement and some experts recommend following AMLs in these patients on the same schedule. AMLs should be monitored to ensure stability and can be followed with ultrasound, CT or MRI.

OTHER INDICATIONS FOR SELECTIVE RENAL ARTERIAL EMBOLIZATION

Renal artery pseudoaneurysm. Renal artery pseudoaneurysms typically occur after an intervention such as renal biopsy, partial nephrectomy, percutaneous nephrolithotomy (in approximately 0.3%-1.4% of interventions), or damage to the kidney from renal trauma.[39] Patients may present with hemorrhage (with or without shock), flank pain, or a pulsatile mass. Diagnosis is typically made on cross-sectional imaging. **First line management is selective embolization with coils rather than foam to avoid passage into the venous circulation (fig. 3)**.[22]

Renal arteriovenous fistula. Like pseudoaneurysms, renal arteriovenous fistulas typically result from operative interventions or trauma. Presenting signs include hematuria, renal failure, and high output heart failure and abdominal bruit. First line management is selective embolization with coils rather than foam, as with renal artery pseudoaneurysm, to avoid passage into the venous circulation.[22]

Renal artery aneurysm. Approximately 0.1% of the general population has a renal artery aneurysm with a higher percent-

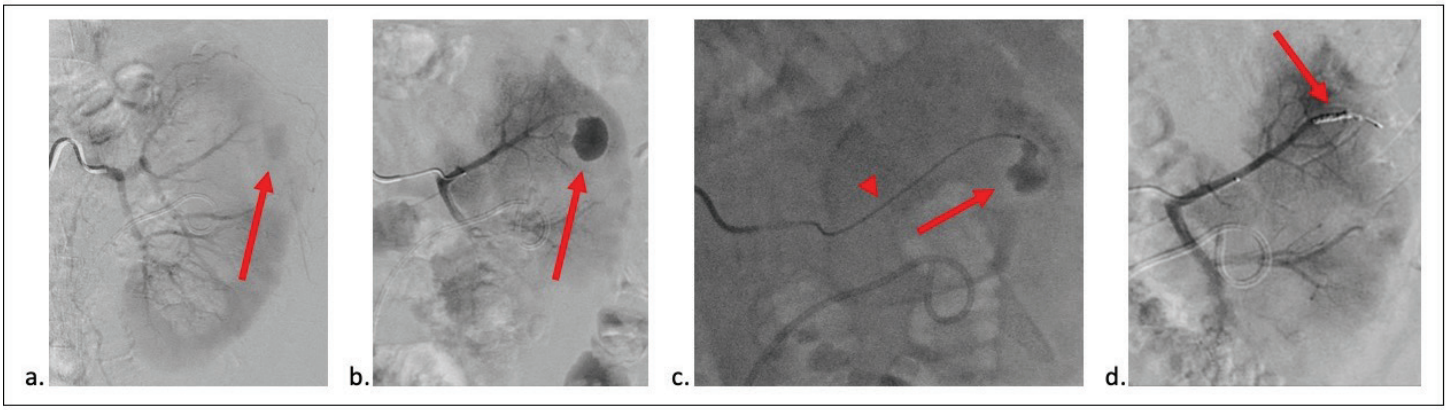

Figure 3. Imaging in 58-year-old male with hypertension, coronary artery disease, prior myocardial stents with cardiac stents, hyperlipidemia, hypercholesterolemia, aortic aneurysm and nephrolithiasis for which he underwent left percutaneous nephrolithotomy complicated by profuse bleeding from percutaneous nephrostomy tract and downward trending of hematocrit after removal. *a*, DSA of left kidney reveals pseudoaneurysm of upper segmental artery (arrow). *b*, selective catheterization and DSA of upper segmental artery demonstrate pseudoaneurysm (arrow). *c*, fluoroscopy of microcatheter (arrowhead) extended to pseudoaneurysm (arrow) for coil deployment. *d*, DSA shows successful coil deployment (arrow) with exclusion of previously seen pseudoaneurysm.

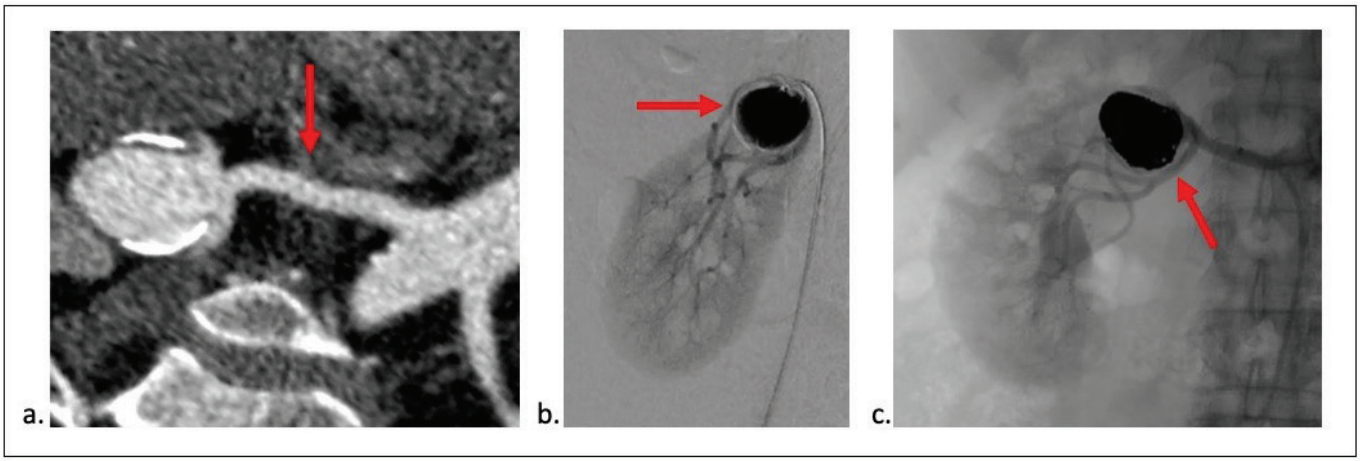

Figure 4. Imaging in 69-year-old female with hypertension and type-2 diabetes mellitus found to have 3.1×2.6×2.4 cm saccular right renal aneurysm after presenting with flank pain. *a*, computerized tomographic angiogram of right renal artery (arrow) in coronal view. *b*, DSA of right kidney prior to coiling reveals saccular collection of contrast material (arrow). *c*, final arteriography after successful coiling; arrow indicates coiled aneurysm excluded from arterial system.

age found in patients undergoing cross-sectional angiographic studies.[40] Patients typically present in the sixth decade of life with variable symptoms; most patients have hypertension but can also have renal insufficiency, renal bruit, abdominal/flank pain, or an abdominal mass. **Given the possibility of aneurysm rupture (approximately 0.3% over 10 years), indications for intervention are symptomatic aneurysm, aneurysm greater than 2 cm and aneurysm in a woman of childbearing age.**[40, 41] Repair can be either via an open approach or via transarterial intervention (ie coiling; fig. 4). In a recent meta-analysis, both methods had similar short-term and long-term mortality rates, however the open approach was associated with more cardiac (2.2% vs 0.6%, p=0.001) and peripheral vascular complications (0.6% vs 0.0%, p=0.01).[42] Reintervention rates were higher in the endovascular group, although the difference was not statistically significant. Endovascular repair was associated with a coil migration rate of 29% (95% CI 4-71) and a post-embolization syndrome rate of 9% (95% CI 9-52). **Discussion with the patient is imperative given the heterogeneity of outcomes and lack of guidelines directing care**.

PROSTATIC ARTERY EMBOLIZATION

Background. Transurethral prostatectomy is one of the most commonly performed urological procedures and has become the benchmark therapy for BPH due to durable results with long-term follow-up.[43] More recently, BPH treatment has come to include novel minimally invasive surgical therapies such as prostatic urethral lift (UroLift® System), convective water vapor energy (Rezūm™) and aquablation (AquaBeam® Robotic System).[44] New techniques also include PAE, which is performed by an interventional radiologist, often under local anesthesia and monitored anesthesia care, via common femoral artery access.

Indications. PAE, first reported for the treatment of BPH in 2010, has generated excitement within the interventional radiology community.[45] **In May 2019, the Society of Interventional Radiology officially released an updated position statement declaring that current evidence is adequate to support use of PAE for treatment of BPH in appropriately selected patients.[46] In addition, in the United Kingdom, NICE (National Institute for Health and Care Excellence) has stated that there is adequate evidence of safety and efficacy to support the use of PAE in BPH.[47] In contrast, in the 2019 amendment to the 2018 BPH guidelines, the AUA stated that due to the heterogeneity of outcomes in the available literature and concerns for procedural side effects, PAE should be performed only in the context of a clinical trial until more rigorously performed studies are available.[48]**

Treatment. **The goal of PAE is to induce a decrease in prostate size through the use of superselective embolization and thus reduce symptoms associated with BPH.** PAE is achieved by obtaining femoral artery access, performing selective catheterization of the bilateral prostatic arteries and embolizing via injection of microspheres (fig. 5). In general, the most commonly used microcatheters range in size from 2.0Fr to 2.4Fr. Currently, 2 embolization agents are approved by the U.S. Food and Drug Administration: Embosphere® and Embozene™ microspheres.[49, 50]

Of note, anatomical variants should be considered. Adjustments must be made depending on the location of the prostatic artery, which most commonly originates from the internal pudendal artery and the common gluteal-pudendal trunk but may vary in its origin. In 1 study, 2 separate vascular pedicles were found in approximately a fourth of pelvic sides.[51]

The entirety of the procedure can be performed under fluoroscopy with cone-beam CT for additional delineation of vascular anatomy. Specific preoperative and periprocedural practices differ between institutions. In general, perioperative antibiotics are administered and patients are discharged on a combination of steroids, nonsteroidal anti-inflammatory drugs and phenazopyridine to alleviate discomfort. Alpha blockers and 5alpha-reductase inhibitors can be discontinued postoperatively and patients are seen in the clinic to reevaluate symptoms and urinary parameters.

Outcomes and complications. **The position statement published by the Society of Interventional Radiology in 2019 is based on a systematic review of 6 comparative studies (3 RCTs, 2 prospective comparative trials and 1 retrospective comparative study), 17 cohort studies, 6 meta-analyses and 19 review articles.**[46] In general, the RCTs included patients experiencing lower urinary tract symptoms with prostate size no larger than 100 cm^3 and evidence of obstruction (eg peak flow rate <15 mL per second).

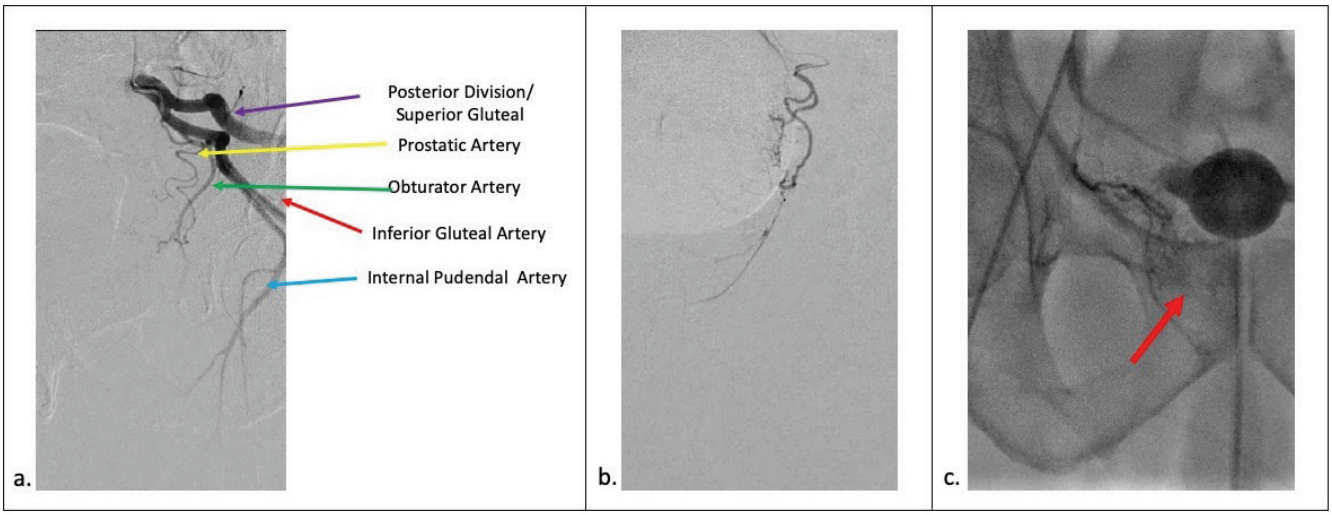

Figure 5. Imaging in 65-year-old male with depression, hyperlipidemia and hypercholesterolemia with 74-cc prostate, pre-PAE IPSS of 19 and QOL score of 2, and 1-year post-PAE IPSS of 3 and QOL score of 1. *a*, DSA of left internal iliac artery demonstrates branches. *b*, selective DSA after catheterization of left prostatic artery. *c*, angiogram of right prostatic artery; arrow indicates opacification of right hemiprostate.

A randomized controlled trial comparing PAE (57 cases) and TURP (57) indicated that TURP resulted in better functional outcomes at 1 and 3 months but was equivalent to PAE at 12 and 24 months as measured by IPSS, quality of life, peak flow rate and post-void residual.[52] Another prospective randomized controlled trial comparing PAE (15 cases) and TURP (15) demonstrated that TURP resulted in greater improvement in terms of IPSS, quality of life and peak flow rates compared to PAE at 1 year.[53] In that series, 15 non-randomized patients underwent a specialized proximal and distal embolization technique, and at 1 year, had IPSS improvement equivalent to that in 15 patients randomized to TURP. Finally, a third randomized controlled trial comparing PAE (51 cases) to TURP (48) indicated that at 3 months, symptomatic scores (IPSS, quality of life), frequency and nocturia were similar, although peak flow rate and post-void residual had significantly improved in the TURP group.[54]

When evaluating sexual function using International Index of Erectile Function score, the reviewed randomized controlled trials and meta-analyses showed no significant change from baseline.[46] Cases of reduced ejaculate volume, but not retrograde ejaculation, were reported. In the first 2 RCTs, no major complications were experienced within the PAE groups, and in the third trial TURP was associated with twice as many adverse events as PAE, including greater blood loss, longer hospital stay and higher rate of bladder catheterization. In the literature, PAE has been associated with post-embolization syndrome (pelvic pain, dysuria, transient worsening of lower urinary tract symptoms), which often lasts approximately 1 week and requires only symptom management.[55] More severe adverse events such as bladder necrosis, rectal ulcers and ischemic balanitis have been reported and are believed to be secondary to technical error/aberrant embolization.

Limitations. **PAE is a minimally invasive option for treating BPH that may be a reasonable alternative for patients who are poor surgical candidates or want to avoid general anesthesia and/or a transurethral approach.** The AUA advises caution when interpreting data from the 3 RCTs, the highest level data presented, as these series have substantial heterogeneity between patient groups (I^2 90%) as well as significantly different duration of follow-up (12 weeks to 12 months to 2 years).[48] However, considering the improvement in symptom scores and limited incidence of major complications, additional long-term RCTs using standard inclusion/exclusion criteria are needed.

REFRACTORY HEMATURIA

Transcatheter arterial embolization of bladder or prostate for intractable hematuria secondary to hemorrhagic cystitis, TURP, cancer and/or coagulopathy has been reported in patients who do not experience improvement with continuous bladder irrigation, fulguration, fluid resuscitation, or transfusions. The limited data available suggest success rates of 80% to 100% in this setting.[56–59] This strategy appears feasible and may be considered for addition to the repertoire of urological procedures for management of hematuria.

ARTERIOURETERAL FISTULAS

While incredibly rare, arterioureteral fistulas can be devastating with a reported acute mortality rate of 2.1%-7.7% in the current literature.[60,61] **While the data are limited to case reports, small series and a few meta-analyses, common predisposing factors are pelvic radiation, prior pelvic or vascular surgery, chemotherapy and chronic indwelling ureteral stent**.[60–62] All patients have presented with gross hematuria, with many also experiencing flank pain, abdominal pain, or acute urinary retention. As many of these patients have indwelling ureteral stents, this bleeding is often seen on stent manipulation during exchange, presenting as bleeding from the ureteral orifice. In such an incidence, the stent should be replaced and interventional radiology contacted on an emergent basis. CT is not indicated as it has low sensitivity for arterioureteral fistulas (39.1% in 1 series), which are often observed at the time of angiography with provocative maneuvers.[61] **Treatment involves placement of a stent graft, embolization of the fistula or aneurysm if present, or both, with a technical success rate of 91.3%. At**

a median follow-up of 8 months only 7.5% of patients treated endovascularly had a rebleed.[60,61] While rare (15%-17%), complications have included retroperitoneal abscess, stent thrombosis, urosepsis and native artery thrombosis.

ARTERIOCAVERNOUS FISTULAS

Background. **Priapism is a persistent penile erection lasting 4 hours or greater that is unrelated to sexual stimulation and is not desired**. The majority of cases (>95%) involve low flow priapism (ie ischemic, venoocclusive) and a small number involve high-flow priapism (non-ischemic). While the scope of this Update does not include management of low-flow priapism, this condition remains a urological emergency. Treatment of low-flow priapism progresses through a graduated approach involving corporal irrigations, corporal injections of sympathomimetic agents and, if needed, surgically created shunts or insertion of a penile prosthesis.[49,50]

Arterial embolization is the intervention of choice in the treatment of HFP.[50,51] To understand the role of arterial embolization, one must focus on the pathophysiology of the disease. Parasympathetic innervation to the penis causes physiological erection, during which the lacunar smooth muscle is relaxed, allowing for increased blood flow to the corpora cavernosa, the engorgement of which compresses the emissary venules, creating a steady state of inflow and outflow with resultant penile tumescence.[52] **In essence, HFP is due to pathologically increased influx of arterial blood to the corpora cavernosa, which escapes the aforementioned venoocclusive mechanism and results in incomplete tumescence of the corpora cavernosa in the absence of spongiosal tumescence**.[49,53] Often, HFP is caused by blunt trauma to the perineum and/or penis and subsequent development of an ACF.[50,54] HFP is diagnosed based on history and physical examination and can be supported by cavernous blood gas.[50,51]

Indications. Initial management of HFP is observation as up to 62% of cases will resolve spontaneously.[63] **However, after expectant management, and if the patient chooses intervention, selective cavernous artery embolization is the treatment of choice**.[50,51] Prior to embolization, the penile vasculature is imaged to aid in planning. While penile Doppler ultrasonography can be used to confirm the presence of an ACF (near 100% sensitivity), computerized tomographic angiography can reveal a characteristic "blush" at the location of the ACF, and contrast enhanced magnetic resonance angiography may help in localization of the ACF (fig. 6).[54–57] Magnetic resonance angiography in particular can provide elevated detail of the segmental arteries. At the time of embolization, bilateral pudendal arteriography is performed to delineate the anatomy.[51] **The development of microcatheters has allowed interventional radiologists to perform SSAE of the exact feeder vessel to the ACF, affording access to the vessels from the internal pudendal artery down to the cavernous artery (site of embolization in >70% of published cases)**.[53,54]

Outcomes and complications. The first reported arterial embolization for HFP was performed by Wear et al in 1977, in which the internal pudendal artery was embolized with an autologous clot.[58] Since then, the gold standard has become SSAE employing permanent (eg microcoils, N-butylcyanoacrylate, miscrospheres, polyvinyl alcohol particles) and absorbable materials (eg autologous clot, gelatin foam).[49] Absorbable materials allow for recanalization after embolization with exclusion of the fistula and theoretically avoid long-term complications associated with permanent materials (eg erectile dysfunction), although direct comparisons have not been performed.[51,57] **Of note, autologous blood clot has been the material of choice in pediatric patients.**[59]

Success rates of SSAE for HFP are up to 89% in most series, and nearly all cases have been successfully treated with 3 or fewer embolization sessions.[51,53,57,60] **However, recurrence requiring reembolization ranges from 30%-40%**.[51,57,60] Severe complications (eg erectile dysfunction, gluteal ischemia, penile gangrene) are rare and mostly theoretical in the era of SSAE.

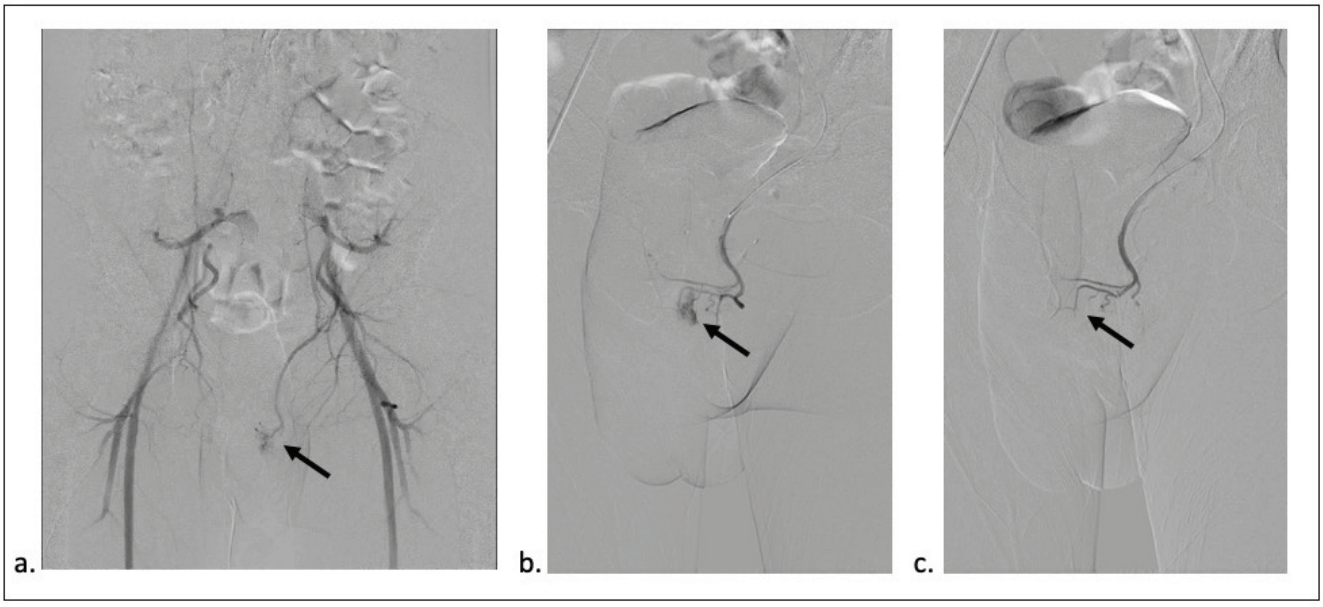

Figure 6. Imaging in 21-year-old male with high-flow priapism after bicycle accident. *a*, anteroposterior view of bilateral pelvic arteriogram; arrow indicates blush at arteriocavernous fistula. *b*, left anterior oblique view of internal pudendal artery before embolization; arrow indicates blush. *c*, left anterior oblique view of internal pudendal artery after embolization; arrow indicates resolution.

In 1 series, 27% of patients had bruising and slight pain at the needle insertion site, although none experienced leg numbness, bleeding, claudication, or embolic symptoms.[61] **Erectile dysfunction will manifest in 15%-20% of patients after SSAE, which is lower than the average rate of 50%-90% following surgical intervention, and many cases respond to oral phosphodiesterase type 5 inhibitors**.[54, 60, 61]

Follow-up. It is recommended that patients be followed for 1 to 2 weeks after embolization.[51] Patients with embolization failure may undergo repeat embolization or return to expectant management. While spontaneous resolution has been reported after an initial embolization failure, prolongation of intervention may be associated with distal corporal fibrosis.[57, 62] **In cases of post-embolization erectile dysfunction, it is reasonable to try an oral phosphodiesterase type 5 inhibitor**.

Limitations. The current literature is limited to small studies, with a lack of high quality, controlled trials, and the last AUA guideline on this subject was published in 2003. As such, questions remain regarding timing, preferred imaging modality prior to intervention and optimal material choice for embolization.

CONCLUSION

Since it was first described in 1970, arterial embolization has become a tool to treat urological disease. Arterial embolization can both complement and aid urological interventions (ie renal embolization prior to radical nephrectomy) or offer a minimally invasive alternative to surgery (eg PAE, embolization for HFP, traumatic renal bleed, refractory hematuria, arteriovenous fistula, renal mass as combined ablation/embolization, AML). While some techniques are currently only recommended by the AUA in the setting of a trial, many are well established. Increasing dissemination and efficacy of these interventions make it important for the practicing urologist to be aware of the indications to provide better patient counseling and undertake an interdisciplinary approach to care.

DID YOU KNOW?

- Arterial embolization by an interventional radiologist can complement the treatment of urological disease or offer a minimally invasive alternative to surgery; the urologist's familiarity with the indications and options is imperative for efficient multidisciplinary care.
- Embolization in the setting of renal trauma can control bleeding and obviate the need for nephrectomy.
- Renal embolization can be done 24-72 hours before nephrectomy in order to control intraoperative bleeding; however, well controlled supporting studies are lacking.
- Embolization of an arteriocavernous fistula is the treatment of choice in cases of high flow priapism refractory to conservative management.
- PAE is a promising procedure for benign prostatic hyperplasia in select patients.

REFERENCES

1. Rösch J, Dotter CT and Brown MJ: Selective arterial embolization. A new method for control of acute gastrointestinal bleeding. Radiology 1972; **102:** 303.
2. Bookstein JJ and Goldstein HM: Successful management of postbiopsy arteriovenous fistula with selective arterial embolization. Radiology 1973; **109:** 535.
3. Spies JB, Bakal CW, Burke DR et al: Standard for diagnostic arteriography in adults. J Vasc Interv Radiol 1993; **4:** 385.
4. Bauer JR and Ray CE: Transcatheter arterial embolization in the trauma patient: a review. Semin Intervent Radiol 2004; **21:** 11.
5. AIUM practice guideline for the use of ultrasound to guide vascular access procedures. J Ultrasound Med 2013; **32:** 191.
6. Lubarsky M, Ray CE and Funaki B: Embolization agents—which one should be used when? Part 1: large-vessel embolization. Semin Intervent Radiol 2009; **26:** 352.
7. Vaidya S, Tozer KR and Chen J: An overview of embolic agents. Semin Intervent Radiol 2008; **25:** 204.
8. Drooz AT, Lewis CA, Allen TE et al: Quality improvement guidelines for percutaneous transcatheter embolization. J Vasc Interv Radiol 2003; **14:** S237.
9. Lee YJ, Oh SN, Rha SE et al: Renal trauma. Radiol Clin North Am 2007; **45:** 581.
10. Charbit J, Manzanera J, Millet I et al: What are the specific computed tomography scan criteria that can predict or exclude the need for renal angioembolization after high-grade renal trauma in a conservative management strategy? J Trauma Acute Care Surg 2011; **70:** 1219.
11. Hotaling JM, Sorensen MD, Smith TG et al: Analysis of diagnostic angiography and angioembolization in the acute management of renal trauma using a national data set. J Urol 2011; **185:** 1316.
12. Menaker J, Joseph B, Stein DM et al: Angiointervention: high rates of failure following blunt renal injuries. World J Surg 2011; **35:** 520.
13. Siegel RL, Miller KD and Jemal A: Cancer statistics, 2019. CA Cancer J Clin 2019; **69:** 7.
14. Ramaswamy RS, Akinwande O and Tiwari T: Renal embolization: current recommendations and rationale for clinical practice. Curr Urol Rep 2018; **19:** 5.
15. Zargar H, Addison B, McCall J et al: Renal artery embolization prior to nephrectomy for locally advanced renal cell carcinoma. ANZ J Surg 2014; **84:** 564.
16. Zielinski H, Szmigielski S and Petrovich Z: Comparison of preoperative embolization followed by radical nephrectomy with radical nephrectomy alone for renal cell carcinoma. Am J Clin Oncol 2000; **23:** 6.
17. May M, Brookman-Amissah S, Pflanz S et al: Pre-operative renal arterial embolisation does not provide survival benefit in patients with radical nephrectomy for renal cell carcinoma. Br J Radiol 2009; **82:** 724.
18. Subramanian VS, Stephenson AJ, Goldfarb DA et al: Utility of preoperative renal artery embolization for management of renal tumors with inferior vena caval thrombi. Urology 2009; **74:** 154.
19. Onishi T, Oishi Y, Suzuki Y et al: Prognostic evaluation of transcatheter arterial embolization for unresectable renal cell carcinoma with distant metastasis. BJU Int 2001; **87:** 312.
20. Karalli A, Ghaffarpour R, Axelsson R et al: Transarterial chemoembolization of renal cell carcinoma: a prospective controlled trial. J Vasc Interv Radiol 2017; **28:** 1664.
21. Goldberg SN, Hahn PF, Tanabe KK et al: Percutaneous radiofrequency tissue ablation: does perfusion-mediated tissue cooling limit coagulation necrosis? J Vasc Interv

Radiol 1998; **9:** 101.
22. Ramaswamy RS and Darcy MD: Arterial embolization for the treatment of renal masses and traumatic renal injuries. Tech Vasc Interv Radiol 2016; **19:** 203.
23. Fittschen A, Wendlik I, Oeztuerk S et al: Prevalence of sporadic renal angiomyolipoma: a retrospective analysis of 61,389 in- and out-patients. Abdom Imaging 2014; **39:** 1009.
24. Krueger DA, Northrup H and International Tuberous Sclerosis Complex Consensus Group: Tuberous sclerosis complex surveillance and management: recommendations of the 2012 International Tuberous Sclerosis Complex Consensus Conference. Pediatr Neurol 2013; **49:** 255.
25. Bhatt JR, Richard PO, Kim NS et al: Natural history of renal angiomyolipoma (AML): most patients with large AMLs >4cm can be offered active surveillance as an initial management strategy. Eur Urol 2016; **70:** 85.
26. Kuusk T, Biancari F, Lane B et al: Treatment of renal angiomyolipoma: pooled analysis of individual patient data. BMC Urol 2015; **15:** 123.
27. Ouzaid I, Autorino R, Fatica R et al: Active surveillance for renal angiomyolipoma: outcomes and factors predictive of delayed intervention. BJU Int 2014; **114:** 412.
28. Ryan JW, Farrelly C and Geoghegan T: What are the indications for prophylactic embolization of renal angiomyolipomas? A review of the current evidence in the literature. Can Assoc Radiol J 2018; **69:** 236.
29. Yamakado K, Tanaka N, Nakagawa T et al: Renal angiomyolipoma: relationships between tumor size, aneurysm formation, and rupture. Radiology 2002; **225:** 78.
30. Zapardiel I, Delafuente-Valero J and Bajo-Arenas JM: Renal angiomyolipoma during pregnancy: review of the literature. Gynecol Obstet Invest 2011; **72:** 217.
31. Franz DN, Belousova E, Sparagana S et al: Long-term use of everolimus in patients with tuberous sclerosis complex: final results from the EXIST-1 study. PloS One 2016; **11:** e0158476.
32. Bissler JJ, Kingswood JC, Radzikowska E et al: Everolimus for angiomyolipoma associated with tuberous sclerosis complex or sporadic lymphangioleiomyomatosis (EXIST-2): a multicentre, randomised, double-blind, placebo-controlled trial. Lancet 2013; **381:** 817.
33. Murray TE, Doyle F and Lee M: Transarterial embolization of angiomyolipoma: a systematic review. J Urol 2015; **194:** 635.
34. Lin L, Li X, Guan H et al: Renal function, complications, and outcomes of a reduction in tumor size after transarterial embolization for renal angiomyolipomas: a meta-analysis. J Int Med Res 2019; **47:** 1417.
35. Urbano J, Paul L, Cabrera M et al: Elective and emergency renal angiomyolipoma embolization with ethylene vinyl alcohol copolymer: feasibility and initial experience. J Vasc Interv Radiol 2017; **28:** 832.
36. Thulasidasan N, Sriskandakumar S, Ilyas S et al: Renal angiomyolipoma: mid- to long-term results following embolization with Onyx. Cardiovasc Intervent Radiol 2016; **39:** 1759.
37. Scharf Z, Momah-Ukeh I and Kim AY: Trans-radial embolization of bleeding renal angiomyolipoma in pregnant 30-year-old female—a case report. J Radiol Case Rep 2019; **13:** 34.
38. Matsumoto T, Hasebe T, Kamei S et al: Snuff box radial access in transcatheter arterial embolization for unruptured renal angiomyolipoma. Minim Invasive Ther Allied Technol 2019; **19:** 1.
39. Inci K, Cil B, Yazici S et al: Renal artery pseudoaneurysm: complication of minimally invasive kidney surgery. J Endourol 2010; **24:** 149.
40. Coleman DM and Stanley JC: Renal artery aneurysms. J Vasc Surg 2015; **62:** 779.
41. Klausner JQ, Lawrence PF, Harlander-Locke MP et al: The contemporary management of renal artery aneurysms. J Vasc Surg 2015; **61:** 978.
42. Barrionuevo P, Malas MB, Nejim B et al: A systematic review and meta-analysis of the management of visceral artery aneurysms. J Vasc Surg 2019; **70:** 1694.
43. Reich O, Gratzke C and Stief CG: Techniques and long-term results of surgical procedures for BPH. Eur Urol 2006; **49:** 970.
44. Chung ASJ and Woo HH: Update on minimally invasive surgery and benign prostatic hyperplasia. Asian J Urol 2018; **5:** 22.
45. Carnevale FC, Antunes AA, da Motta Leal Filho JM et al: Prostatic artery embolization as a primary treatment for benign prostatic hyperplasia: preliminary results in two patients. Cardiovasc Intervent Radiol 2010; **33:** 355.
46. McWilliams JP, Bilhim TA, Carnevale FC et al: Society of Interventional Radiology multisociety consensus position statement on prostatic artery embolization for treatment of lower urinary tract symptoms attributed to benign prostatic hyperplasia: from the Society of Interventional Radiology, the Cardiovascular and Interventional Radiological Society of Europe, Société Française de Radiologie, and the British Society of Interventional Radiology: endorsed by the Asia Pacific Society of Cardiovascular and Interventional Radiology, Canadian Association for Interventional Radiology, Chinese College of Interventionalists, Interventional Radiology Society of Australasia, Japanese Society of Interventional Radiology, and Korean Society of Interventional Radiology. J Vasc Interv Radiol 2019; **30:** 627.
47. NICE guidance—prostate artery embolisation for lower urinary tract symptoms caused by benign prostatic hyperplasia. BJU Int 2018; **122:** 11.
48. Foster HE, Dahm P, Kohler TS et al: Surgical Management of Lower Urinary Tract Symptoms Attributed to Benign Prostatic Hyperplasia: AUA guideline amendment 2019. J Urol 2019; **202:** 592.
49. Food and Drug Administration: De Novo Classification Request for Embosphere Microspheres 2016. Available at https://www.accessdata.fda.gov/cdrh_docs/reviews/DEN160040.pdf.
50. Boston Scientific: Embozene PAE Letter for Customers. April 26, 2018. Available at https://www.bostonscientific.com/content/dam/bostonscientific/pi/portfolio-group/embolization/Microspheres/Embozene/Embozene-PAE-Indication-Letter-For-Customers-PI-546911-AA.pdf.
51. Bilhim T, Pisco JM, Furtado A et al: Prostatic arterial supply: demonstration by multirow detector angio CT and catheter angiography. Eur Radiol 2011; **21:** 1119.
52. Gao Y, Huang Y, Zhang R et al: Benign prostatic hyperplasia: prostatic arterial embolization versus transurethral resection of the prostate—a prospective, randomized, and controlled clinical trial. Radiology 2013; **270:** 920.
53. Carnevale FC, Iscaife A, Yoshinaga EM et al: Transure-

thral resection of the prostate (TURP) versus original and PErFecTED prostate artery embolization (PAE) due to benign prostatic hyperplasia (BPH): preliminary results of a single center, prospective, urodynamic-controlled analysis. Cardiovasc Intervent Radiol 2016; **39:** 44.
54. Abt D, Hechelhammer L, Müllhaupt G et al: Comparison of prostatic artery embolisation (PAE) versus transurethral resection of the prostate (TURP) for benign prostatic hyperplasia: randomised, open label, non-inferiority trial. BMJ 2018; **361:** k2338.
55. Moreira AM, de Assis AM, Carnevale FC et al: A review of adverse events related to prostatic artery embolization for treatment of bladder outlet obstruction due to BPH. Cardiovasc Intervent Radiol 2017; **40:** 1490.
56. Loffroy R, Pottecher P, Cherblanc V et al: Current role of transcatheter arterial embolization for bladder and prostate hemorrhage. Diagn Interv Imaging 2014; **95:** 1027.
57. Delgal A, Cercueil JP, Koutlidis N et al: Outcome of transcatheter arterial embolization for bladder and prostate hemorrhage. J Urol 2010; **183:** 1947.
58. Mohan S, Kumar S, Dubey D et al: Superselective vesical artery embolization in the management of intractable hematuria secondary to hemorrhagic cystitis. World J Urol 2019; **37:** 2175.
59. Liguori G, Amodeo A, Mucelli FP et al: Intractable haematuria: long-term results after selective embolization of the internal iliac arteries. BJU Int 2010; **106:** 500.
60. Subiela JD, Balla A, Bollo J et al: Endovascular management of ureteroarterial fistula: single institution experience and systematic literature review. Vasc Endovascular Surg 2018; **52:** 275.
61. Heers H, Netsch C, Wilhelm K et al: Diagnosis, treatment, and outcome of arterioureteral fistula: the urologist's perspective. J Endourol 2018; **32:** 245.
62. Bergqvist D, Pärsson H and Sherif A: Arterio-ureteral fistula—a systematic review. Eur J Vasc Endovasc Surg 2001; **22:** 191.
63. Ingram AR, Stillings SA and Jenkins LC: An update on non-ischemic priapism. Sex Med Rev 2020; **8:** 140.
1. While the Society of Interventional Radiology has offi-

cially supported the use of prostatic artery embolization in benign prostatic hyperplasia, the AUA has reservations due to
a. limited number of randomized controlled trials with significant interstudy heterogeneity
b. lack of clinical trials showing improvement in voiding parameters or symptoms
c. low availability of interventionalists outside academic centers
d. criticism from NICE

2. Randomized controlled trial data in the management of angiomyolipomas in patients with tuberous sclerosis complex support the use of
a. active surveillance
b. mTOR inhibitor therapy
c. renal artery embolization
d. partial nephrectomy

3. The most common artery embolized for high flow priapism is the
a. internal pudendal
b. common penile
c. bulbourethral
d. cavernous

4. Temporary vessel occlusion is best provided by the use of
a. coils
b. gelatin foam
c. microspheres
d. polyvinyl alcohol

5. The embolizing agent of choice in cases of renal pseudoaneurysm is
a. glue
b. gelatin foam
c. microspheres
d. coils

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