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The Changing Landscape of Urologic Practice, An Issue of Urologic IR: 2022

Md. Abdus Salam

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Abstract

Interventional Uroradiology or Urological IR covers various minimally invasive procedures to treat problems that affect the kidney, bladder and ureter (the tube connecting the kidney to the bladder), and testes.

Almost all patients in the UK with obstructed and/or infected kidneys are referred to interventional radiology for percutaneous nephrostomy and/or placement of an anterograde JJ stent. Although this 'tradition' is going strong in the UK, urologists worldwide have evolved their practice to encompass such interventional procedures in their remit.[1]

Advances in imaging technology, especially in the last two decades, have led to a paradigm shift in the field of image-guided interventions in urology. While the traditional biopsy and drainage techniques are firmly established, image-based stone management and endovascular management of hematuria have evolved further. Ablative techniques for renal and prostate cancer and prostate artery embolization for benign prostatic hypertrophy have evolved into viable alternative treatments. Many urologic diseases that were earlier treated surgically are now effectively managed using minimally invasive image-guided techniques, often on a daycare basis using only local anaesthesia or conscious sedation. This article presents an overview of the technique and status of various image-guided urological procedures, including recent emerging techniques.[2]

Keywords: Angiography, fluoroscopy, imaging, ultrasonography, urology

Introduction

Interventional radiology services frequently receive consults from urologists for various genitourinary conditions. These pathologic conditions lend many opportunities to the intervention list to provide unique and innovative patient-centred care to treat acute and chronic disease processes.

Percutaneous image-guided interventions have changed the management of various urologic diseases. Their applications are growing because of the minimally invasive nature, lower procedure-related morbidity and reduced hospital stay. These have evolved from a few traditional diagnostic procedures to current state-of-art therapeutic techniques, including a broad range of non-vascular and vascular applications. Today, they continue to play an important role in drainage procedures, the management of urolithiasis, tumour ablation and Renovascular diseases. Multiple imaging modalities are used for this purpose, with fluoroscopy, ultrasound and digital subtraction angiography (DSA) being the mainstay. A close multidisciplinary collaboration between urologists, nephrologists and interventional radiologists is important. This article reviews an outline of various aspects of interventional uroradiology.[2]

Correspondence : Professor Md. Abdus Salam, Former Professor of Uro oncology and Chairman Department of Urology Bangabandhu Sheikh Mujib Medical University

General principles

Uroradiological interventions may be broadly classified as non-vascular and vascular. Non-vascular procedures mainly include tissue sampling (fine needle aspiration or biopsy), percutaneous nephrostomy (PCN) and stone extraction. Vascular procedures include embolization of pseudo aneurysms, arterio-venous malformations and fistulas, most commonly presenting with hematuria. Others include prostate artery embolization (PAE), recanalization of renal artery stenosis (RAS), gonadal vein embolization (varicocele, pelvic congestion syndrome), etc. A few common principles apply to all interventional uroradiology procedures.

Image guidance

Anatomical location, use of iodinated contrast and real-time guidance are the most important factors in choosing a preferred imaging modality. *Fluoroscopy* helps to access the urinary collecting system using iodinated contrast material. Urinary drainage procedures and ureteric stenting are routinely performed under fluoroscopic guidance. *Digital subtraction angiography* (DSA) also involves the administration of an intra-arterial iodinated contrast medium and the use of radiation to obtain images for the treatment of vascular disorders. Intravascular carbon dioxide and gadolinium-based magnetic resonance imaging (MRI) contrast media are other less commonly used alternatives to conventional iodinated contrast media. Both fluoroscopy and DSA provide real-time guidance with a full view of catheters, wires and stents. Evaluation of vascular anatomy is now commonly performed by non-invasive techniques like computed tomography (CT) or magnetic resonance (MR) angiography.

*Ultrasonography (*USG) provides excellent radiation-free and real-time guidance and is routinely used in urinary drainage procedures, Cryotherapy or other ablative procedures and robotic surgery. *CT* guidance has the distinct advantage of providing 3D anatomical details without hindrance from gas or bony structures. It is commonly used for the drainage of perirenal collections and adrenal biopsies due to their strategic location and in radiofrequency ablation (RFA) of renal tumours. *Cone beam CT* uses the newest technology to acquire volumetric imaging data with one gantry rotation. It is a compact, low-cost and low-radiation equipment that can be mounted on a C-arm in interventional urology suites. The use of MRI in guiding interventional urologic procedures is evolving. The excellent image contrast that leads to improved lesion detection and the lack of ionizing radiation makes MRI an attractive modality for targeting pathologies for biopsy and treatment. However, its main limitations are the dependence on expensive MRI-compatible equipment and long procedure time. The chief role of interventional MRI is to perform an accurate biopsy and minimally invasive therapy of early prostate cancer and cryoablation of renal tumours.

Routes of access

While the urethra is the main portal of entry for Endourological procedures, the vascular route is employed by interventional radiologists. The percutaneous route is common to both. For percutaneous procedures, the target is reached by a needle following a straight and the shortest route, avoiding large bowel and vascular structures. The pancreas and spleen are other organs that must not be transgressed. For vascular procedures, the trans-femoral approach is most preferred.

Tools of trade

These include puncture needles, guide wires, dilators, various drainage catheters, stents, balloon catheters, embolizing materials, etc.; Balloon expandable stents are used for RAS. Embolic materials are used to treat leaking pseudoaneurysms, arterio-venous shunts and devascularization of tumours. Intravascular embolic agents are generally classified based on their duration of occlusion or physical state.[3]

The choice of an agent depends on the target vessel size, duration of occlusion required, tissue viability and clinical setting. Coils are used to occlude a bleeding artery identified on DSA. Metallic embolization coils occlude a feeding artery similar to a surgical ligature. Commercially available vascular plugs are more suitable for the occlusion of a larger vessel, like the main renal artery.[3]

Table I. *Embolic agents used in interventional urology.*[3]

Duration of action	Agents
Temporary	Gelfoam, autologous blood clot
Permanent	Mechanical agents – Coils, vascular plugs Microparticles-Polyvinyl alcohol particles Liquid polymers-Cynoacrylate glue, ethyl Vinyl alcohol (Onyx) Liquid sclerosants –Ethyl alcohol, sodium tetradecyl sulfate.

The choice of an agent depends on the target vessel size, duration of occlusion required, tissue viability and clinical setting. Coils are used to occlude a bleeding artery identified on DSA—metallic embolization coils act by occluding a feeding artery similar to a surgical ligature. Commercially available vascular plugs are more suitable for the occlusion of a larger vessel, like the main renal artery.

Most image-guided interventions are performed under local anaesthesia with conscious sedation and analgesia. Generally, the INR should be d"1.5 and platelets greater than 50,000/cu mm for most procedures.[3]

Non-vascular procedures

Tissue sampling

Image-guided urologic biopsies include non-focal and focal renal biopsies, renal cyst aspiration, adrenal biopsies and transrectal prostate biopsies.

Non-focal renal biopsy: Indicated for histological characterization of renal parenchymal diseases, renal grafts suspicious for a rejection or unexplained renal failure. After placing the patient in the appropriate position (supine for transplant and prone or prone oblique with target side dependent on native kidneys), the biopsy needle (15–18 G) is advanced obliquely into the renal cortex near the lower pole [Figure 1. The cortical sample ensures that the specimen contains a few glomeruli necessary to make a diagnosis. Puncture of the renal medulla or renal sinus must be avoided.

Biopsy of renal masses:

The purpose is to save these patients from unnecessary nephrectomies. Large enhancing renal masses are considered renal cell carcinoma (RCC) and are therefore operated without a biopsy. However, smaller, indeterminate masses are now often biopsied, as many of them are thought to be benign. Such indications are rising due to the increased detection of small renal masses due to the widespread use of cross-sectional imaging. A renal mass biopsy is also considered before a percutaneous thermal (radiofrequency/cryo) ablation when suspected to be infective in borderline surgical candidates or sometimes to differentiate a concurrent renal cancer from metastasis in known primary extra-renal malignancy. A renal mass biopsy may be performed under CT or USG guidance. If the mass is not visible on a non-contrast CT scan, it may be demonstrated following the administration of intravenous iodinated contrast [Figure 2].

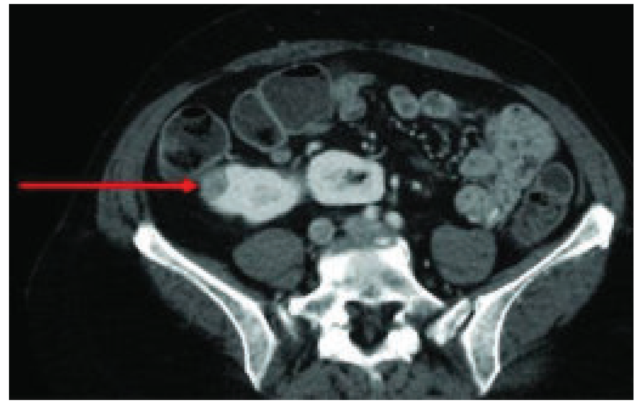

Figure 1. *A staging abdominal CT scan shows a 2 cm hypodense mass (red arrow) on the right lateral part of a horseshoe kidney*

The mass is first approached using a 17 G cannula, into which an 18 G co-axial biopsy needle or gun is introduced to obtain several cores. A co-axial system allows multiple samples to be taken by only one puncture of the renal capsule (Figure 1).

Core Renal biopsies

Core biopsies typically have a better diagnostic yield than fine-needle biopsies. The fine-needle aspiration (FNA) material is spread on slides and fixed in liquid preservatives, while the cores are sent to the pathologist in saline or formalin vials. In suspected lymphoma, the cores are additionally sent for flow cytometry. Renal biopsy/aspiration with either CT or USG guidance is safe and has a high success rate, with a sensitivity of 70–100% and specificity of 100%.[4]

Percutaneous core biopsy continues to provide an accurate and safe tool for pre-operative tissue diagnosis of indeterminate, incidentally detected, asymptomatic, small (d"4 cm) renal masses (SRM) and should be offered to patients before considering surgical intervention.[4] It is a safe and accurate technique for distinguishing malignant from benign tumours. The biopsy of SRMs is associated with a relatively high rate of technical failures.[5]

Renal biopsy may sometimes lead to complications like haemorrhage, pneumothorax, infection and adjacent visceral injury. Bleeding occurs due to injury to renal vessels or vascular tumours. Sometimes, arterio-venous fistulas or pseudoaneurysms may develop and present with persistent bleeding. Bleeding is common, but it is usually mild and self-limiting.[6,7] Patients should be instructed to report in case of frank hematuria or symptoms suggestive of hypotension. The risk of needle tract seeding is low (0.01%).[8]

Adrenal biopsy:

A biopsy of an adrenal mass is indicated when it cannot be characterized by standard imaging or laboratory tests. It can be easily performed using CT or sonographic guidance.[7-9] The transhepatic core route appears to be feasible and safe for the histologic diagnosis of right adrenal masses that are either invisible or inaccessible via the standard extrahepatic route.[10] Martinez *et al.* reported that endoscopic ultrasound (EUS)-FNA is a safe, minimally invasive and sensitive technique with a significant impact on the management of adrenal gland mass or enlargement.[11] CT-guided adrenal biopsy [Figure 3] has a high success rate (80–95%).[12-13] The overall sensitivity for diagnosis of malignancy is 94.6%, and the specificity is 95.3%.[14] Apart from the hemorrhage and infection, pneumothorax may be a complication due to its proximity to the pleural recess. When it is impossible to avoid lung/pleura, a transanal or transhepatic route may be taken to reach the target. Another rare but unique complication might be a hypertensive crisis.[15]

Prostate biopsy: Suspicion of prostate cancer based on abnormal digital rectal examination and elevated serum prostate-specific antigen (PSA) levels is currently the leading indication for prostate biopsy. It is most commonly performed using transrectal ultrasound (TRUS) guidance with the patient in the left lateral decubitus position. Hematuria and hematospermia are seen in up to 80% of patients in the first 2 weeks and are self-limiting.[16] Conventional TRUS-guided biopsy misses up to 20% of cancers. It frequently underestimates the grade of malignancy, but, despite its limitations, it is still used due to its universal availability, ease of use and real-time capability.

Percutaneous nephrostomy: A posterolateral subcostal approach targeting the lower (or middle) calyx prevents entering through the pleural recess and permits access through Brodel's avascular plane of the kidney [Figures44]. A soft tip wire is then inserted into the collecting system and is replaced with a stiff wire using a 6 F fascial dilator. The tract is serially dilated up to 8 or 10 F, and a pigtail catheter or Malecot nephrostomy tube is then placed into the renal pelvis [Figure 6]. The latter is a better choice if the collecting system is either small or filled with calculi. PCN has a high success rate, approaching 100%, in dilated systems and around 80% in undilated systems.[17] Complications include bleeding, infection and injury to adjacent organs.

Suprapubic catheter:

It may be inserted under ultrasound guidance or even fluoroscopy in a contrast-opacified urinary bladder. A 12 F Foley catheter loaded over a trocar is used to enter the bladder. Care must be taken to avoid injury to the sigmoid colon. It is a simple procedure with almost a 100% success rate.[18]

Stone management

Ureteric stent: An antegrade, percutaneous route may be required to place a ureteric stent [Figure 7]. The choice of approach (retrograde or antegrade) is based on the accessibility and the location of ureteric pathology. The procedure has a near 100% success rate with patency rates of 95% at 3 months.[19]

Percutaneous Urinary Diversion

Percutaneous urinary diversion is the most common reason for urologists to consult the interventional radiology service. One of the most urgent indications discussed in the online presentation is pyonephrosis, the so-called pus under pressure, which carries a high mortality risk. Emergent placement of a percutaneous nephrostomy is an essential skill for all interventionalists.

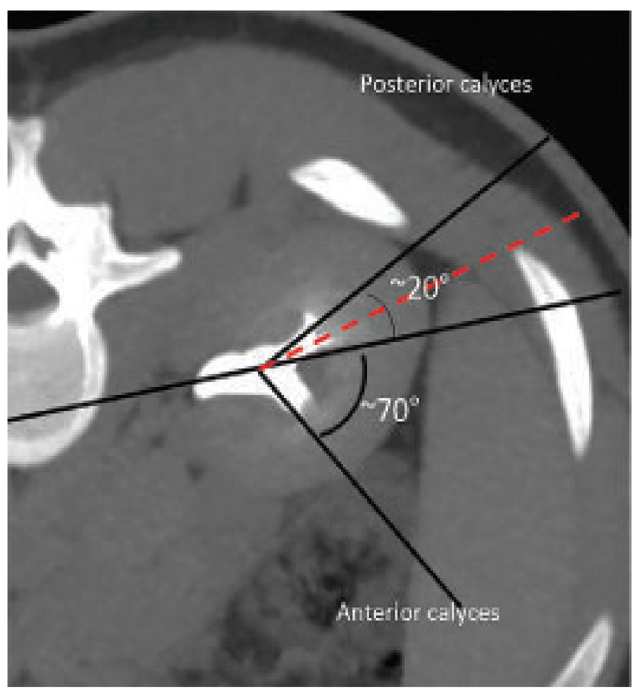

Figure 2. *Axial CT image with maximum intensity projection (MIP) reconstruction depicts optimal access into the renal collecting system through a posterior calyx (red dashed line).*

Efficient and timely pelvicalyceal access and subsequent management of nephrostomy drains are essential skills for an interventionalist [Figure 2]. In addition, urinary diversion therapies play a significant role in oncologic care, as outlined in case 3 in the presentation.

Vascular interventions

Endovascular embolization

It is a minimally invasive procedure where the lumen of the intrarenal vessel is occluded by embolizing material. Indications include persistent hematuria as a result of pseudoaneurysm or arteriovenous fistula following a biopsy, surgical or accidental trauma. Super selective embolization of the feeding artery saves more functioning nephrons than conventional surgery. It is also employed to reduce the vascularity of renal tumours, e.g. angiomyolipoma or renal carcinoma, before surgery. Gel foam and vascular coils are the usual materials used for this purpose. This procedure has a success rate of around 90%. Complications include bleeding, infection, renal arterial injury, infarction and allergic reaction.[20]

Trans jugular renal biopsy

The procedure is carried out in patients with contraindicated percutaneous biopsy, usually due to a deranged coagulation profile. A special biopsy needle is wedged into the peripheral renal vein branch via the transjugular route(Figure 3). It provides diagnostic yield and safety similar to percutaneous. Renal biopsy. It has an added advantage in allowing multi-organ biopsy during the same procedure, e.g. simultaneous liver and renal biopsy.[21]

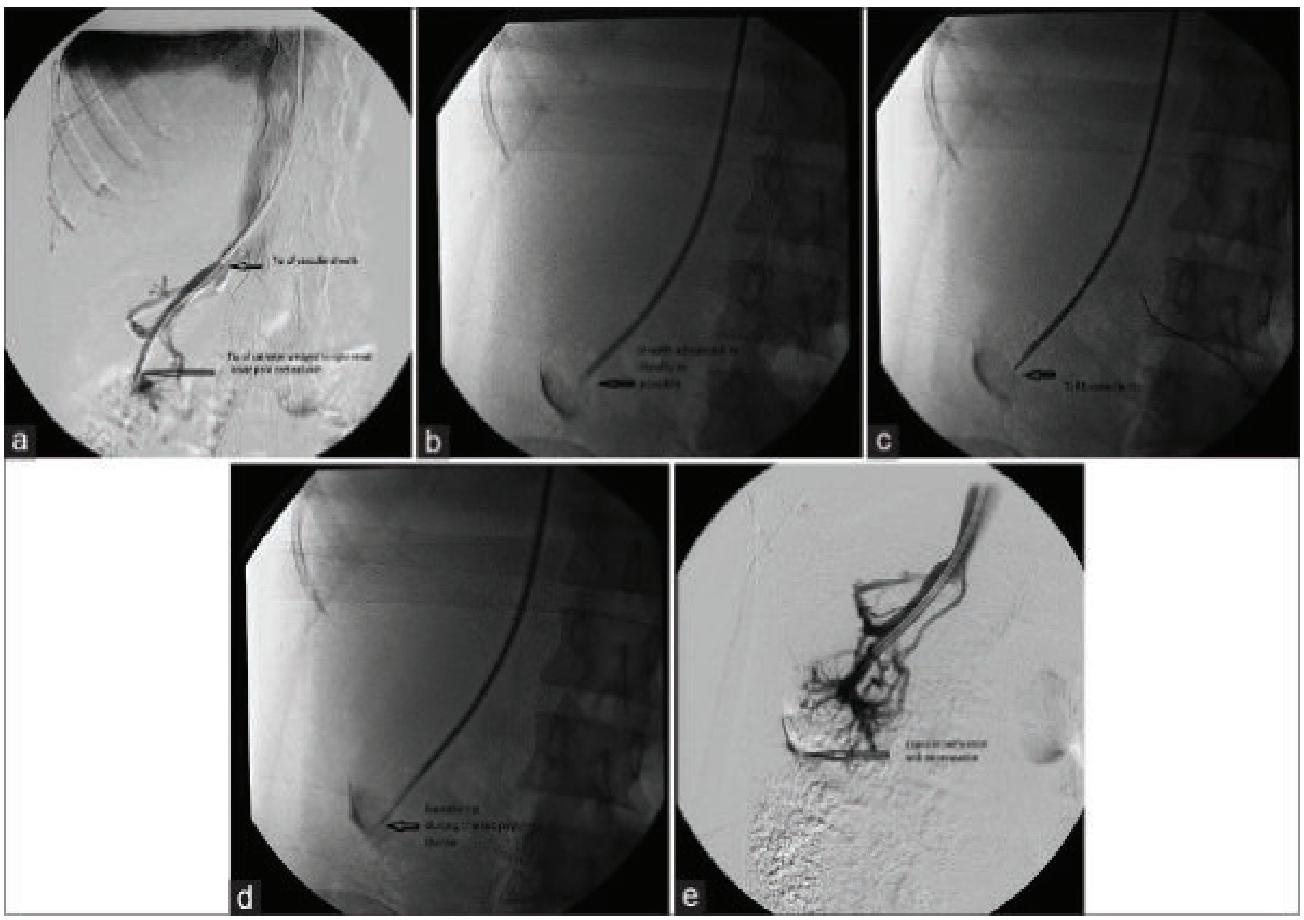

Figure 3 *Sequential images in a patient undergoing transjugular renal biopsy. Right renal venogram (a) with the tip of the vascular sheath in the proximal right renal vein through which the catheter is wedged distally into the right lower pole renal cortical vein. Following the venogram, the sheath is advanced as distally as possible into the cortical vein to allow the introduction of a transjugular renal biopsy needle (b). Renal access and biopsy set needle was advanced through the sheath and placed distally into the peripheral cortical vein (c), and the biopsy was performed (d) post-biopsy check run (e) shows capsular extravasation*

Management of renal arteriovenous malformations:

Arteriovenous malformations (AVMs) are communications between an artery and a vein. This pathologic communication may be either a fistula, a simple communication between a single artery and a dilated vein, or a more complex communication, a nidus of tortuous channels between one or more arteries/arterioles and draining veins. The latter type of lesion is most frequently seen in the extremities; they tend to appear more rarely in the kidney.

The most common clinical presentation of renal arteriovenous malformations (RAVMs) is hematuria. Compared to the more invasive surgical approaches, percutaneous treatment with selective endovascular techniques offers a minimally invasive, nephron-sparing option. This pictorial review aims to highlight the general lines of management and show the range of imaging findings of the percutaneous treatment of RAVMs.

The gold standard for the diagnosis/characterization of RAVMs is DSA, which offers the possibility to evaluate the lesion dynamically, delineate the feeder branches anatomically and plan the treatment. Retrograde puncture of the right common femoral artery is usually performed; a 4- or 5-F sheath is inserted, followed by selective renal artery catheterization. Automated pump injection (3–4 cc/s and 12 cc in total) of contrast medium is usually done via a 4- or a 5-F catheter located at the ostium of the renal artery and a 2-3 frames/s angiogram is performed. DSA will demonstrate the feeding arteries, and super-selective catheterization with a microcatheter may follow if necessary. Angiography of both kidneys is advisable since rarely bilateral RAVMs may be present.

Management

When haematuria is clinically manifested and the diagnosis of a RAVM has been established, urgent treatment planning is required. Especially if haematuria is life-threatening, an emergency approach is necessary. Surgical options include total or partial nephrectomy.[21] However, surgical options are invasive, require several days of hospitalization and are related to high morbidity because of the risk of complete loss of renal function and the risk of herniation of the lateral abdominal wall.[22] Therefore, percutaneous embolization techniques have been developed to manage such complex lesions.[23-25] Such procedures are performed under local anaesthesia in the majority of the cases.

Embolization techniques aim at permanent occlusion of the multiple small channels between arteries and veins that form the nidus of the AVM and all the arterial feeders. The outcome of the procedure depends on the technique and the type of embolic material used. Usually, several feeding arteries are involved at the segmental and interlobar level. Every feeding artery needs to be examined angiographically.

The embolic material used for the treatment of RAVMs may be Gelfoam, absolute alcohol, polyvinyl alcohol (PVA), coils and liquid embolic materials such as *n*-butyl 2-cyanoacrylate (NBCA) glue and ethylene vinyl alcohol copolymer (Onyx, Covidien, USA).[22,23]

Percutaneous antegrade ureteral stent placement:

Percutaneous antegrade ureteral stent placement is a safe and effective method for managing ureteral injuries and obstructions due to malignant and benign causes when the retrograde approach fails. After patient preparation, the procedure was performed in two stages: first, PN was performed, and then the ureteral stent was placed in an antegrade fashion. In patients who had nephrostomy catheters, the second stage of the procedure was performed directly. Generally, both procedures were not performed on the same day. In some cases, the indication for stent placement was determined after PN by urologists depending on whether the kidney is functional or not.

Percutaneous nephrostomy was carried out with the patient in a 30° prone oblique position. After localization of the collecting system with the US, the lower pole collecting system was punctured with an 18-gauge Chiba needle (Cook Medical) by a dorsal approach with the Seldinger technique. If necessary, the middle or upper calyces were punctured, also. Then, the collecting system was opacified with nonionic contrast material (Iopromide, Ultra[redacted]® 370, Schering). Thereafter, a 0.035-inch guide[redacted] was advanced into the renal pelvis via the needl[redacted]d the needle was withdrawn. After tract dilatatio[redacted] 8 or 10 French (F) drainage catheter (Bioteque Co[redacted]ation) was placed into the renal pelvis.

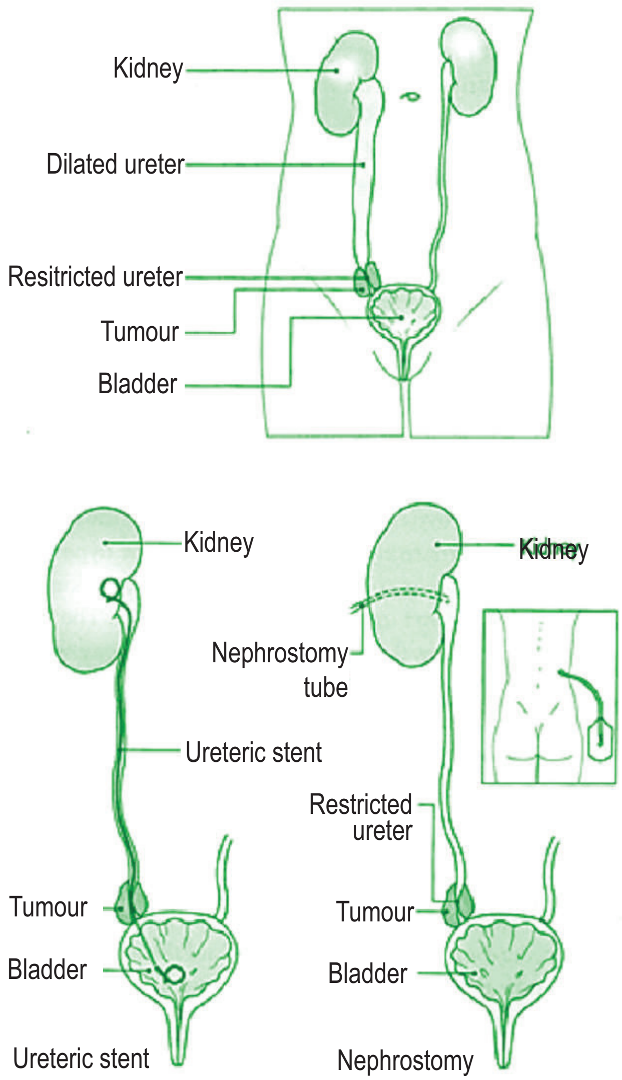

Fig.-4. *Illustration demonstrating the position of the DJ stent and associated covering nephrostomy.*

For ureteral stent placement procedure, ante-grade pyelography containing whole ureteric segments and the ureterovesical junction was performed by contrast material injection via the nephrostomy catheter, and pathology of the ureter such as stricture, occlusion, or leakage was demonstrated. After exchanging the nephrostomy catheter over the J-tipped guidewire, a 5 F multipurpose (45° tip) diagnostic vascular catheter (Cordis Corporation) was inserted. Once the pelvic ureteric junction was crossed and the ureter accessed, a straight hydrophilic guidewire (Roadrunner® PC Wire Guide, Cook Medical) and a catheter were used. Then, the catheter was advanced into the bladder over the wire; this guidewire was exchanged for an ultra-stiff guidewire (Back-up MeierTM steerable wire guide, Boston Scientific), an 8/10 F double-pigtail plastic ureteral stent (Flexima Ureteral Stent SystemTM, Boston Scientific) was placed over the guidewire. The safety kit of the stent was removed. A final fluoroscopic image was stored to correct the stent position.[19] An 8 F nephrostomy drainage catheter was placed, removed in 48 hours following a satisfactory nephrostogram. Stent length was 12 cm for transplant kidney patients, 22 cm, 24 cm, or 26 cm for other patients (figure 4). Stent length selection was based on personal experience. In our centre, the proper time for stent replacement is 3 months. However, due to complications in the process, stent revision was performed for some patients (n=15) before the suggested replacement time.[15]

Gonadal vein embolization

It is performed in males for scrotal varicocele, causing pain and infertility, and in women for pelvic congestion syndrome due to retrograde flow in incompetent ovarian veins, causing chronic pelvic pain. The veins are approached via a jugular or femoral route. After diagnostic angiography, the veins are embolized using steel coils. The clinical outcomes of technically successful percutaneous internal spermatic vein embolization are similar to surgical treatment.[24]

Recanalization of Renal artery Stenosis RAS

RAS is found in 2% and 40% of general and high cardiovascular-risk populations, respectively.[25] Recanalization involves balloon angioplasty and/or stenting of hemodynamically significant RAS defined by a trans stenotic pressure gradient of e” 20 mmHg. The renal artery is approached via the trans-femoral route. Preliminary diagnostic angiography defines the site of stenosis. The stenosis is crossed using a guide wire, and balloon angioplasty ± stenting is performed [Figure 11]. The technical success of renal angioplasty depends on the site of stenosis and the underlying aetiology. It ranges from 40% in ostial atherosclerosis to 90% in fibromuscular dysplasia. Stenting, coupled with angioplasty, has a higher success rate[26]. The procedure is associated with a significant risk of complications. Lately, there has been a marked decline in the number of these recanalization procedures conducted worldwide. This is a result of a few recently published trials that have not shown any benefit of renal revascularization over medical therapy for blood pressure control, preserving renal function or reducing cardiovascular events. However, it is agreed that selected high-risk patients, viz severe or refractory hypertension, heart failure or rapid loss of renal function may benefit from the revascularization procedure. Medical therapy remains the optimal choice for most patients.[27-28]

Thermal ablation for renal cancer

Of all such techniques, RFA and cryo-ablation have been best studied. These provide local treatment for renal carcinomas in patients unsuitable for surgery [Figure 12]. Patients having renal insufficiency at presentation and tumours requiring a more nephron-conserving approach (solitary kidney, multiple synchronous RCC, von Hippel Lindau/familial RCC) are also candidates for these minimally ablative therapies. In the short term, 90–95% local control rates and 6% significant complication rates are seen for tumours <3.0 cm for both techniques.[29-30] The major limitations of both these techniques are the lack of prospective randomized clinical trials or long-term follow-up data. A meta-analysis of 46 series (28 percutaneous, 18 surgical) by Hui *et al*. [30-31]. Compared the results of surgical and percutaneous treatment of renal tumours. The analysis showed a significantly lower primary effectiveness rate for the percutaneous group (87% vs 94%; $P < 0.05$) than the surgical group. There was no significant difference in the retreatment rates (92% vs. 95%; $P > 0.05$). The major complication rate was significantly lower in the percutaneous treatment group (3% vs 7%; $P < 0.05$) than in the surgical treatment group. Microwave ablation has the potential advantage of treating cystic renal tumours but has even lesser data available.[32]

MR-guided ablation of prostate cancer

Focal ablative therapy for prostate cancer is an emerging therapy being investigated for treating localized tumors. It is a minimally invasive therapeutic option with the favourable outcomes while preserving continence and sexual function. The technique is described in detail elsewhere in this issue.

Renal sympathetic denervation

The procedure is performed like renal angiography using the transfemoral route under local anaesthesia. A 6 F sheath is placed in the femoral artery through which an electrode-tipped catheter is advanced into the renal artery under real-time fluoroscopic guidance. Once the desired position is reached, the catheter is connected to a RF generator. Low-level radiofrequency energy is delivered through the renal artery wall to disrupt the surrounding renal nerves. Symplicity HTN-2 trial involving patients with uncontrolled hypertension showed that this procedure leads to notable and sustained reductions in blood pressure.[35]

Contrast-enhanced ultrasound (CEUS)-aided renal biopsy

CEUS uses stabilized microspheres filled with gas as a new ultrasound contrast (sulfur hexafluoride) medium. It enhances tumours and other vascular structures without potentially nephrotoxic iodinated contrast media. Ultrasound contrast is excreted via the lungs and has no serious side effects. Currently, there is a paucity of literature using CEUS-assisted renal biopsy. We sometimes use this technique in guiding renal biopsy by highlighting the solid portion of the necrotic renal tumour or accurately localizing small renal masses by their enhancement compared with the adjoining normal parenchyma.

Thermal Ablation for Renal Cell Carcinoma:

Incidental detection of renal cell carcinoma (RCC) has become more frequent in patients who undergo ultrasound (US), computed tomography (CT), and magnetic resonance imaging (MRI) for unrelated reasons. Since 2000, thermal ablation has become more widely available in clinical practice. Recently, radiofrequency ablation (RFA), cryoablation, and microwave ablation (MWA) have become the main thermal ablation modalities.

Despite the lack of strong evidence, the American and European Urologic Associations recommend thermal ablation as a primary treatment option for patients with RCC who cannot undergo surgery because of the high risk of postoperative morbidity.[36,-37] These conditions include poor cardiopulmonary function, chronic kidney disease, bleeding tendency, coagulopathy, and other severe comorbidities. Furthermore, thermal ablation can be a good alternative treatment option for hereditary[38-39], single kidney[40-42], central[43-45], and recurrent[46-48] RCCs following surgery or thermal ablation. Prior to thermal ablation, fever should be detected and controlled. The platelet count should be more than 50000/μL, and the internalized normalized ratio should be maintained at less than 1.5.[49]

Choosing Thermal Ablations

The size or location of the RCC influences the choice of thermal ablation due to different oncologic outcomes. If the RCC size is > 3 cm, cryoablation or MWA is useful because these techniques can create a larger ablation area than RFA using a single electrode. If an RCC is centrally located or protruding into the renal sinus, cryoablation is more useful for reducing urothelial damage than RFA or MWA. All thermal ablations provide acceptable oncologic outcomes if an RCC is less than 3 cm.[38]

Cryoablation

Cryoablation is a minimally invasive technique that causes cell death by freezing (Fig. 2). cryoablation causes direct cell injury based on two biophysical changes osmotic dehydration of cells and formation of intracellular ice.[49] A complete cryoablation session consists of a double freeze-thaw cycle with 10–15 minutes of freezing and 8–10 minutes of thawing. For RCCs < 4 cm (T1a), cryoablation offers excellent local control results with a 5-year recurrence-free survival rate of > 90%. For renal tumourse" 4 cm (T1b), cryoablation is also a valid treatment alternative to surgery, although the local recurrence rate is higher than that with surgery (Fig.5).

Fig 5. *Percutaneous cryoablation: Non-contrast axial CT image showing one (arrowhead) of two cryo-applicators in the right renal cell carcinoma. An ice ball (arrows) was created to ablate the tumour.*

The most common complication of cryoablation is bleeding, followed by frozen injury to adjacent vulnerable organs, including ureter stricture, colon perforation or fistula, and nerve injury.[50-51]

Cystic Renal Mass

Park et al. showed that RFA achieves a higher recurrence-free survival rate in patients with Bosniak III or IV cysts, most of which were not proven to be RCC. Cryoablation and MWA can potentially provide excellent treatment outcomes in treating these cysts.[54] The investigations dealing with long-term outcomes of treating cystic renal masses are scarce, and the evidence level of recommendation needs to be higher. Therefore, thermal ablation should be performed selectively in patients who cannot undergo surgery.

MWA

Micro Wave (MW) energy causes cell death due to the agitation of water molecules. MWA offers several advantages, including higher intratumoral temperatures, less ablation time, and less dependence on the electrical conductivity of tissue. In particular, MWA is useful for treating renal tumours because it has fewer heat sink effects. A single antenna was used for tumours d" 3.0 cm in diameter, and e" 2 antennas were used simultaneously for tumours> 3.0 cm in diameter. A recent meta-analysis showed no significant difference was observed in local recurrence and cancer-specific mortality between MWA and nephron-sparing surgery. MWA has a relatively low complication rate, similar to other techniques.[55]

Selective Arterial Embolization of Renal Angiomyolipomas

Selective arterial embolization (SAE) for renal angiomyolipoma (rAML) effectively treats or prevents bleeding. We report our experience using a cyanoacrylate–Lipiodol mixture. Angiomyolipoma (AML) is a benign hamartomatous tumour that accounts for 0.3 to 3% of all renal masses. It is composed of varying proportions of fat, dysmorphic vessels, and smooth muscle tissue. In AMLs with macroscopic fat, a density less than "20 HU by computed tomography (CT) or a signal drop on fat-saturated magnetic resonance imaging (MRI) sequences provides the diagnosis, obviating the need for invasive diagnostic investigations.

SAE of rAMLs using a mixture of NBCA and Lipiodol is feasible, safe, and effective for the emergency treatment of bleeding and for bleeding prophylaxis. In our patients, SAE had an excellent technical success rate with low complication and relapse rates and no rebleeding. Major complications were rare, and the only patient who died had a severe presentation and pre-existing risk factors. Greater volume reduction was associated with a smaller fat component, a larger initial tumour volume, and longer follow-up.[56]

The Role of Arterial Embolization in Renal Cell Carcinoma

Twenty-five years ago, arterial embolization was introduced to facilitate the surgical excision of the carcinomatous kidney or to palliate symptoms, such as haemorrhage from non-resectable tumours. The role of this technique in the therapeutic armamentarium has been a source of debate in the literature.

In view of multiple limitations in the efficacy and safety of RAE, the present indications for the application of this procedure include mostly

- Palliative RAE in advanced RC which results in relief of life-threatening haematuria and lumbar pains;
- Embolization of large, highly vascularized neoplasms prior to surgery (effective RAE results in contraction of vascular collaterals, facilitates dissection of the tumour, and allows to change the sequence of affixing renal vascular pedicle, ie first artery and the renal vein later);
- Embolization of highly vascularized RC metastases (e.g. vertebral metastasis.
- The role of renal artery embolization (RAE) in the strategy of treatment of renal carcinoma (RC) has a multiyear history in scientific literature and in personal experience. In view of personal experience, we have a strong feeling that RAE is beneficial both in operable and advanced RC, partially because of longer survival and stimulation of certain immune reactions.[57]

RAE was introduced to clinical practice in the 70s of the last century. At that time, arteriography was the basic diagnostic method, and the identification of renal tumours was made during the embolization. Today, vascular embolization procedures are becoming widely used to treat persistent bleeding, vascular defects and cancer.

In urology, RAE is well established in the treatment of bleeding observed after iatrogenic complications of NSS (nephron-sparing surgery), PCN (percutaneous nephrostomy), ESWL (extracorporeal shock wave lithotripsy), PCNL (percutaneous nephrolithotrypsy), closing arteriovenous fistulas

The basic form of treatment of locoregional RC is surgical resection of the kidney containing the tumour (optionally with the adrenal gland and extraperitoneal lymph nodules). Recently it has been advised to introduce new, less invasive surgical techniques (laparoscopy and use of robots), as well as NSS (nephron-sparing surgery).

At present different coils, haemostatic sponges, cyanoacrylic glues and alcohols are applied as materials for RAE .This leads to acute necrosis of tissues where blood flow has been blocked,

RAE has been applied in the treatment of RC for about 40 years. It may be evoked prior to surgery, considered as a technique securing the surgery, or used as palliative embolization in large, inoperable RC, mostly with intensive bleedings and/or pains. RAE, which precedes nephrectomy, provides better conditions for the surgery and shortens the intervention time. There exists information that RAE may lead to stabilization and regression of distal metastases. These effects may be due to the immunomodulating effects of RAE suggested by some authors. However, knowledge of the influence of RAE on immune status and the response of immunocompetent cells still needs to be more extensive and fragmentary. Systematic studies of this issue are needed.

Because of multiple limitations in the efficacy and safety of RAE, the present indications for the application of this procedure include mostly

- Palliative RAE in advanced RC, which results in relief of life-threatening haematuria and lumbar pains;
- Embolization of large, highly vascularized neoplasms prior to surgery (effective RAE results in contraction of vascular collaterals, facilitates dissection of the tumour, and allows to change the sequence of affixing renal vascular pedicle, ie first artery and the renal vein later);
- Embolization of highly vascularized RC metastases (e.g. vertebral metastases).

Opinions on the role of pre-operative RAE in the management of patients with RC are controversial. Although many studies on RAE are reported in RC patients, there is no consensus on the benefits and morbidity associated with the procedure. Moreover, many large studies on using RAE both before nephrectomy and in advanced RC were conducted in the 1980s, before improved techniques and imaging were developed. Most proponents of pre-operative RAE report the facilitation of nephrectomy through decreased operative blood loss, ease of dissection secondary to the development of oedema in tissue planes, and decreased operative time.[57]

With technical advances and growing experience, the indications have broadened to include conditions such as vascular malformations, medical renal disease, AMLs, and pre-operative infarction. The introduction of smaller delivery catheters and more precise embolic agents has drastically improved the morbidity associated with this technique.[57] RAE has continued to gain popularity as a minimally invasive approach for various urological conditions.

Renal embolization has been established as a palliative treatment for unresectable renal carcinoma and in patients with less advanced disease who, for whatever reason, are unsuitable or unwilling to undergo surgery. In this group of patients, the technique reduces tumour bulk and relieves local symptoms such as pain or intractable haematuria. And the larger tumours can be managed by Partial Nephrectomy

However, opinions on pre-operative RAE's role in managing patients with RC are controversial. Although many studies on RAE are reported in these patients, there is no consensus on the benefits and morbidity associated with the procedure.[57].

Renal Arteriovenous Malformation Treatment & Management

The initial means of treating renal arteriovenous malformation (AVM) is usually arteriographically guided embolization. One indication for the treatment of these malformations is pain. The pain from renal AVMs results from either obstruction of the collecting system by clots or from the expansion of the renal capsule due to intrarenal haemorrhage. Persistent gross hematuria, especially in patients with anaemia, may prompt treatment.

Hypertension is an important indication for treatment. Attempts have been made at preoperatively determining whether the malformation is responsible for hypertension.

AVMs are uncommon but may give rise to massive and persistent hematuria, so computerized tomography scans, angiography, and DSA are the most important tools for diagnosing in an urgent setting. The therapeutic options must be selected in emergencies depending on the patient's general condition and symptoms. The only therapy considered in the past was total nephrectomy, but embolization by selective catheterization can be considered safe and effective. However, many studies need to be done to confirm the role of embolization.[58]

Renal Artery Aneurysm

A renal artery aneurysm (RAA) is a dilated segment of a renal artery with a diameter more than twice that of a normal renal artery.[1] Symptomatic RAAs can cause hypertension, pain, hematuria, and renal infarction.[2] Asymptomatic RAAs may seem benign, but the potential for rupture and fistulization increases with size. Asymptomatic patients can be referred for elective repair, but further investigation with possible surgical intervention should be considered if patients are symptomatic.

Figure 6. *Endovascular interventions Traditional endovascular therapies have utilized coil embolization for distal and parenchymal aneurysms and stent graft exclusion for main renal artery lesions. The indications for endovascular repair have broadened with the introduction of three-dimensional detachable coils, non-adhesive liquid embolic agents (i.e., Onyx), remodelling techniques (which include balloon- and stent-assisted coiling), and flow diverter stents (i.e., the Cardiatis multilayer stent).*

Technical success across larger series have been reported as 73% to 100%, with highly variable rates of morbidity (13%-60%) that include primarily radiographic evidence of end-organ malperfusion from thromboembolism and subsequent postembolization syndrome (Fig. 6). These reported series describe no incidence of access-related complications, arterial dissections, or renal compromise, along with low rates of recanalization requiring reintervention (4%-13%).

Comparisons of open surgical and endovascular procedures have reported no significant difference in mortality, perioperative morbidity, freedom from re-intervention, decline in renal function, or length of stay.[69]

Renal arteriovenous fistula

Renal arteriovenous fistulae (AVFs) are anomalous direct communications between arteries and veins in the kidney, which may be confused with a renal AVM. The incidence of renal AVF is variable, estimated at 0.3-19% in native kidneys and 6-8% in renal Transplants. Approximately 70% of cases are acquired or iatrogenic, while about 20% are congenital.

Figure 7. *Renal Arteriovenous shunts*

Renal arteriovenous fistulae are usually acquired lesions, unlike renal AVMs, which are frequently developmental abnormalities. Most cases are iatrogenic and occur as a complication of renal biopsy, nephrostomy, blunt or penetrating trauma inflammation, malignancy, or renal surgery. A few cases of congenital AVFs have been documented and are thought to be present at birth or to result from a congenital aneurysm that erodes into the adjacent vein (Figure 7).

Colour Doppler images depict a flash of colour, "visible thrill" or "soft tissue bruit", that results from the vibration of the soft tissue surrounding the renal AVF, producing a focal colour mosaic overlying the adjacent soft tissue. Adjusting the colour Doppler to higher velocities may show the feeding artery and the enlarged draining vein.

Spectral Doppler tracings show a high-velocity, low-resistance flow within the artery and turbulent, pulsatile, arterialized flow in the segmental draining vein. If large, the main renal vein has pulsatile flow.

CT angiography may demonstrate anomalous renal arteriovenous communication with associated aneurysms and early opacification of the renal vein on the arterial phase.

It may be treated whenever it is symptomatic, large or extra-renal. The therapeutic method of choice is endovascular intervention. Different technical methods of embolization are available.[60]

Prostatic Artery Embolization

Prostatic artery embolization (PAE) is a minimally invasive treatment that helps improve lower urinary tract symptoms caused by Benign Prostatic Hyperplasia (BPH). BPH is a noncancerous prostate gland enlargement and is the most common benign tumour found in men.

The PAE procedure is performed by an interventional radiologist (IR), a doctor who uses X-rays and other advanced imaging to see inside the body and treat conditions without surgery.

PAE is a non-surgical procedure that decreases the blood supply to the prostate, thus reducing its size and symptoms. An interventional radiologist, who uses X-rays and other imaging techniques to see inside the body and treat conditions without surgery, performs PAE. At Johns Hopkins, our interventional radiologists are expertly trained and experienced in performing this technically challenging procedure.

The PAE procedure is best for candidates who are either ineligible due to pre-existing health conditions or not interested in traditional surgery. An exam with an interventional radiologist can determine if you are a candidate for PAE. At this appointment, you may be asked how often you have urinary symptoms of BPH, how severe they are, and how much they affect your quality of life. Men with advanced heart diseases associated with smoking or diabetes may not be candidates for PAE.

PAE is a new and promising procedure. In a study published in 2016, 630 patients underwent a prostate artery embolization procedure. The study found that the procedure had a positive effect on urinary symptoms as well as overall quality of life. This positive effect lasted 1-3 years in 82% of the patients and 3-7 years in 76%. Additionally, there was no urinary incontinence or sexual dysfunction reported.

With the high success rate of PAE, men ineligible for surgery can improve their quality of life by eliminating or reducing uncomfortable BPH symptoms. Be sure to speak to your urologist to help determine your best approach.

Several different procedures may be used to treat BPH. PAE offers several key advantages that make it an excellent choice for men. These advantages include the following: The most minimally invasive BPH procedure can improve BPH symptoms with a lower risk of urinary leakage or sexual side effects compared to other procedures and no retrograde ejaculation.

Conclusion

Multimodal team-based image-guided interventional procedures are integral to contemporary urologic practice. These are minimally invasive treatment strategies, often with very little procedure-related morbidity. The domain is all set to expand further with the upcoming applications and novel imaging techniques. Thermal ablation for RCC is expected to become more popular in Asian countries as the necessity for minimally invasive treatments increases. Therefore, interventional oncologists should be familiar with the ACTA expert consensus to perform safe and precise renal tumour ablation in Asian patients.

References

1. Junaid Masood,[1,2] Mohamed Ismail,[2] Tamer El-Husseiny,[1] Konstantinos Moraitis,[1] Stephanos Albanis,[1] Athanasios Papatsoris,[1] and Noor Buchholz. 'An interventional urology list' – a novel concept for UK urological services, Ann R Coll Surg Engl. 2011 Jan; 93(1): 27–30. Published online 2010 Oct 25. doi: 10.1308/003588411X 12851639107115
2. Chandan J. Das, Vinit Baliyan, and Sanjay Sharma Image-guided urological interventions: What the urologists must know. Indian J Urol. 2015 Jul-Sep; 31(3): 202–208. doi: 10.4103/ 0970-1591.156919
3. Medsinge A, Zajko A, Orons P, Amesur N, Santos E. A case-based approach to common embolization agents used in vascular interventional radiology. *AJR Am J Roentgenol.* 2014;203:699–708. [PubMed] [Google Scholar]
4. Herts BR, Baker ME. The current role of percutaneous biopsy in the evaluation of renal masses. *Semin Urol Oncol.*1995;13:254–61. [PubMed] [Google Scholar]
5. Shannon BA, Cohen RJ, de Bruto H, Davies RJ. The value of pre-operative needle core biopsy for diagnosing benign lesions among small incidentally detected renal masses. *J Urol.* 2008;180:1257–61. [PubMed] [Google Scholar]
6. Lechevallier E, André M, Barriol D, Daniel L, Eghazarian C, De Fromont M, et al. Fine-needle percutaneous biopsy of renal masses with helical CT guidance. *Radiology.* 2000;216:506–10. [PubMed] [Google Scholar]
7. Gibbons RP, Bush WH, Jr, Burnett LL. Needle tract seeding following aspiration of renal cell carcinoma. *J Urol.*1977;118:865–7. [PubMed] [Google Scholar]
8. Kiser GC, Totonchy M, Barry JM. Needle tract seeding after percutaneous renal adenocarcinoma aspiration. *J Urol.*1986;136:1292–3. [PubMed] [Google Scholar]
9. König CW, Pereira PL, Trübenbach J, Fritz J, Duda SH, Schick F, et al. MR imaging-guided adrenal biopsy using an open low-field-strength scanner and MR fluoroscopy. *AJR Am J Roentgenol.* 2003;180:1567–70. [PubMed] [Google Scholar]
10. Park SY, Park BK, Kim CK. Sonographically guided transhepatic core biopsies of right renal and adrenal masses: Safety and short-term follow-up. *J Ultrasound Med.* 2013;32:2013–21. [PubMed] [Google Scholar]
11. Martinez M, LeBlanc J, Al-Haddad M, Sherman S, DeWitt J. Role of endoscopic ultrasound fine-needle aspiration evaluating adrenal gland enlargement or mass. *World J Nephrol.* 2014;3:92–100. [PMC free article] [PubMed][Google Scholar]
12. Saeger W, Fassnacht M, Chita R, Prager G, Nies C, Lorenz K, et al. High diagnostic accuracy of adrenal core biopsy: Results of the German and Austrian adrenal network multicenter trial in 220 consecutive patients. *Hum Pathol.*2003;34:180–6. [PubMed] [Google Scholar]
13. Silverman SG, Mueller PR, Pinkney LP, Koenker RM, Seltzer SE. Predictive value of image-guided adrenal biopsy: Analysis of results of 101 biopsies. *Radiology.* 1993;187:7158. [PubMed] [Google Scholar]

14. Moore TP, Moulton JS. Co-axial percutaneous biopsy technique with automated biopsy devices: Value in improving accuracy and negative predictive value. *Radiology.* 1993;186:515–22. [PubMed] [Google Scholar]

15. Güven Kahriman, Nevzat Özcan, Aytaç Doðan, Hakan Ýmamoðlu, and Abdullah Demirtaº Percutaneous antegrade ureteral stent placement: single centre experience Diagn Interv Radiol. 2019 Mar; 25(2): 127–133.Published online 2019 Mar1. doi: 10.5152/dir.2019.18252 PMCID: PMC6411265PMID

16. Ghani KR, Dundas D, Patel U. Bleeding after transrectal ultrasonography-guided prostate biopsy: A study of 7-day morbidity after a six-, eight- and 12-core biopsy protocol. *BJU Int.* 2004;94:1014–20. [PubMed] [Google Scholar]

17. Maher MM, Fotheringham T, Lee MJ. Percutaneous nephrostomy. *Semin Interv Radiol.* 2000;17:329–39. [Google Scholar]

18. Lee MJ, Papanicolaou N, Nocks BN, Valdez JA, Yoder IC. Fluoroscopically guided percutaneous suprapubic cystostomy for long-term bladder drainage: An alternative to surgical cystostomy. *Radiology.* 1993;188:787–9.[PubMed] [Google Scholar]

· 19. U. Raja, S. Valliani, K. Patatas Is a routine covering nephrostomy following antegrade ureteric stent insertion necessary?" Poster: "ECR 2015 / C-2301 / Corpus ID: 58273046

20. Jacobson AI, Amukele SA, Marcovich R, Shapiro O, Shetty R, Aldana JP, et al. Efficacy and morbidity of therapeutic renal embolization in the spectrum of urologic disease. *J Endourol.* 2003;17:385–91. [PubMed] [Google Scholar]

21. K. R. Rathod, B. A. Popat, A. Pandey, T. E. Jamale,[1] N. K. Hase,[1] and H. L. Deshmukh Safety and effectiveness of transjugular renal biopsy: A single-centre study Indian J Nephrol. 2017 Mar-Apr; 27(2): 118–123. doi: 10.4103/0971-4065.196932

22. Chatziioannou A, Mourikis D, Kalaboukas K, et al. Endovascular treatment of renal arteriovenous malformations.*UrolInt.* 2005;74:89–91. [PubMed] [Google Scholar]

23. Defreyne L, Govaere F, Vanlangenhove P, Derie A, Kunnen M. Cirsoid renal arteriovenous malformation treated by endovascular embolization with n-butyl 2-cyanoacrylate. *Eur Radiol.* 2000;10:772–775. doi: 10.1007/s003300051002. [PubMed] [CrossRef] [Google Scholar]

24. Gat Y, Bachar G, Everaert K, Levinger U, Gornish M. Induction of spermatogenesis in azoospermic men after internal spermatic vein embolization for the treatment of varicocele. *Hum Reprod.* 2005; 20:1013–7. [PubMed][Google Scholar]

25. Piecha G, Wiecek A, Januszewicz A. Epidemiology and optimal management in patients with renal artery stenosis. *J Nephrol.* 2012;25:872–8. [PubMed] [Google Scholar]

26. Lee MJ. Percutaneous genitourinary interventions. In: Kaufman JA, Lee MJ, editors. *The requisites: Vascular and interventional radiology.* 1st ed. St. Louis (MO): Mosby; 2004. [Google Scholar]

27. ASTRAL Investigators; Wheatley K, Ives N, Gray R, Kalra PA, Moss JG, et al. ASTRAL Investigators. Revascularization versus medical therapy for renal artery stenosis. *N Engl J Med.* 2009;361:1953–62. [PubMed][Google Scholar]

28. Liang P, Hurks R, Bensley RP, Hamdan A, Wyers M, Chaikof E, et al. The rise and fall of renal artery angioplasty and stenting in the United States, 1988-2009. *J Vasc Surg.* 2013;58:1331–8.e1. [PMC free article] [PubMed] [Google Scholar]

29. Gervais DA, McGovern FJ, Arellano RS, McDougal WS, Mueller PR. Radiofrequency ablation of renal cell carcinoma: Part 1, indications, results, and role in patient management over a 6-year period and ablation of 100 tumours. *AJR Am J Roentgenol.* 2005;185:64–71. [PubMed] [Google Scholar]

30. Littrup PJ, Ahmed A, Aoun HD, Noujaim DL, Harb T, Nakat S, et al. CT-guided percutaneous cryotherapy of renal masses. *J Vasc Interv Radiol.* 2007;18:383–92. [PubMed] [Google Scholar]

31. Hui GC, Tuncali K, Tatli S, Morrison PR, Silverman SG. Comparison of percutaneous and surgical approaches to renal tumour ablation: Meta-analysis of effectiveness and complication rates. *J Vasc Interv Radiol.* 2008;19:1311–20.[PubMed] [Google Scholar]

32. Clark PE, Woodruff RD, Zagoria RJ, Hall MC. Microwave ablation of renal parenchymal tumours before nephrectomy: Phase I study. *AJR Am J Roentgenol.* 2007;188:1212–4. [PubMed] [Google Scholar]

33. isco JM, Tinto HR, Pinheiro LC, Bilhim T, Duarte M, Fernandes L, et al. Embolization of prostatic arteries as treatment of moderate to severe lower urinary symptoms (LUTS) secondary to benign hyperplasia: Results of short- and mid-term follow-up. *Eur Radiol.* 2013;23:2561–72. [PubMed] [Google Scholar]

34. Carnevale FC, da Motta-Leal-Filho JM, Antunes AA, Baroni RH, Marcelino AS, Cerri LM, et al. Quality of life and clinical symptom improvement support prostatic artery embolization for patients with acute urinary retention caused by benign prostatic hyperplasia. *J Vasc Interv Radiol.* 2013;24:535 42. [PubMed] [Google Scholar]

35. Cao L, Fu Q, Wang B, Li Z. Renal denervation: A new therapeutic approach for resistant hypertension. *Chin Med J (Engl)* 2014;127:3302–8. [PubMed] [Google Scholar]

36. Campbell S, Uzzo RG, Allaf ME, Bass EB, Cadeddu JA, Chang A, et al. Renal mass and localized renal cancer: AUA guideline. *J Urol.* 2017;198:520–529. [PubMed] [Google Scholar]

37. Ljungberg B, Albiges L, Abu-Ghanem Y, Bensalah K, Dabestani S, Fernández-Pello S, et al. European Association of urology guidelines on renal cell carcinoma: the 2019 Update. *Eur Urol.* 2019;75:799–810. [PubMed] [Google Scholar]

38. Krokidis ME, Orsi F, Katsanos K, Helmberger T, Adam A. CIRSE guidelines on percutaneous ablation of small renal cell carcinoma. *Cardiovasc Intervent Radiol.* 2017;40:177–191. [PubMed] [Google Scholar]

39. Park BK, Kim CK, Park SY, Shen SH. Percutaneous radiofrequency ablation of renal cell carcinomas in patients with von Hippel Lindau disease: indications, techniques, complications, and outcomes. *Acta Radiol.* 2013;54:418–427. [PubMed] [Google Scholar]

40. Xiaobing W, Wentao G, Guangxiang L, Fan Z, Weidong G, Hongqian G, et al. Comparison of radiofrequency ablation and partial nephrectomy for a tumour in a solitary kidney. *BMC Urol.* 2017;17:79. [PMC free article] [PubMed] [Google Scholar]

41. Bhindi B, Mason RJ, Haddad MM, Boorjian SA, Leibovich BC, Atwell TD, et al. Outcomes after cryoablation versus partial nephrectomy for sporadic renal tumours in a solitary kidney: a propensity score analysis. *Eur Urol.*2018;73:254–259. [PubMed] [Google Scholar]

42. Lin Y, Liang P, Yu XL, Yu J, Cheng ZG, Han ZY, et al. Percutaneous microwave ablation of renal cell carcinoma is safe in patients with a solitary kidney. *Urology.* 2014;83:357–363. [PubMed] [Google Scholar]

43. Park BK, Gong IH, Kang MY, Sung HH, Jeon HG, Jeong BC, et al. RFA versus robotic partial nephrectomy for T1a renal cell carcinoma: a propensity score-matched comparison of mid-term outcome. *Eur Radiol.* 2018;28:2979–2985. [PubMed] [Google Scholar]

44. Rosenberg MD, Kim CY, Tsivian M, Suberlak MN, Sopko DR, Polascik TJ, et al. Percutaneous cryoablation of renal lesions with radiographic ice ball involvement of the renal sinus: analysis of hemorrhagic and collecting system complications. *AJR Am J Roentgenol.* 2011; 196:935–939. [PubMed] [Google Scholar]

45. Maciolek KA, Abel EJ, Posielski NM, Hinshaw JL, Lubner MG, Lee FT, Jr, et al. Tumor location does not impact oncologic outcomes for percutaneous microwave ablation of clinical T1a renal cell carcinoma. *Eur Radiol.*2019;29:6319–6329. [PubMed] [Google Scholar]

46. Hudspeth TN, Abdelsalam ME, Sabir SH, Kusin SB, Matin SF, Wood CG, et al. Minimally invasive image-guided thermal ablation for recurrent renal cell carcinoma (RCC) after ipsilateral partial nephrectomy. *J Clin Oncol.*2018;36:e16557 [Google Scholar]

47. Park SY, Park BK, Kim CK, Lee HM, Jeon SS, Seo SI, et al. Percutaneous radiofrequency ablation of renal cell carcinomas in patients with von Hippel Lindau disease previously undergoing a radical nephrectomy or repeated nephron-sparing surgery. *Acta Radiol.* 2011;52:680–685. [PubMed] [Google Scholar]

48. Okhunov Z, Chamberlin J, Moreira DM, George A, Babaian K, Shah P, et al. Salvage percutaneous cryoablation for locally recurrent renal-cell carcinoma after primary cryoablation. *J Endourol.* 2016;30:632–637. [PubMed] [Google Scholar]

49. Higgins LJ, Hong K. Renal ablation techniques: state of the art. *AJR Am J Roentgenol.* 2015;205:735–741.[PubMed] [Google Scholar]

50. Higgins LJ, Hong K. Renal ablation techniques: state of the art. *AJR Am J Roentgenol.* 2015;205:735–741.[PubMed] [Google Scholar]

51.. Krokidis ME, Orsi F, Katsanos K, Helmberger T, Adam A. CIRSE guidelines on percutaneous ablation of small renal cell carcinoma. *Cardiovasc Intervent Radiol.* 2017;40:177–191. [PubMed] [Google Scholar]

52.. Georgiades CS, Hong K, Bizzell C, Geschwind JF, Rodriguez R. Safety and efficacy of CT-guided percutaneous cryoablation for renal cell carcinoma. *J Vasc Interv Radiol.* 2008;19:1302–1310. [PubMed] [Google Scholar]

53. Park JJ, Park BK, Park SY, Kim CK. Percutaneous radiofrequency ablation of sporadic Bosniak III or IV lesions: treatment techniques and short-term outcomes. *J Vasc Interv Radiol.* 2015;26:46–54. [PubMed] [Google Scholar]

54. Park BK, Kim CK, Lee HM. Image-guided radiofrequency ablation of Bosniak category III or IV cystic renal tumours: initial clinical experience. *Eur Radiol.* 2008;18:1519–1525. [PubMed] [Google Scholar]

55. Yu J, Liang P, Yu X, Liu F, Chen L, Wang Y. A comparison of microwave ablation and bipolar radiofrequency ablation both with an internally cooled probe: results in ex vivo and in vivo porcine livers. *Eur J Radiol.*2011;79:124–130. [PubMed] [Google Scholar]

56. François-Victor Prigent etal. selective Arterial Embolization of Renal Angiomyolipomas with a N-Butyl Cyanoacrylate-Lipiodol Mixture: Efficacy, Safety, Short- and Mid-Term Outcomes . *Clin. Med.* 2021, *10*(18), 4062; https://doi.org/10.3390/jcm10184062

57. Zielinski H, Szmigielski S, Petrovich Z. Comparison of pre-operative embolization followed by radical nephrectomy with radical nephrectomy alone for renal cell carcinoma. Am J Clin Oncol 2000; 23: 612

58. E.A. AbdelGawad, A.M. Housseini, K.J. Cherry, H. Bonatti, I.M. Maged, P.T. Norton, *et al.* CT angiography of renal arteriovenous fistulae: a report of two cases Vasc Endovascular Surg, 43 (2009), pp. 416-420

59. Klausner J.Q. Lawrence P.F. Harlander-Locke M.P. Coleman D.M.Stanley J.C. Fujimura N. The contemporary management of renal artery aneurysms. *J Vasc Surg.* 2014; 61: 978-984

60. Guo H, Wang C, Yang M et al. Management of Iatrogenic Renal Arteriovenous Fistula and Renal Arterial Pseudoaneurysm by Transarterial Embolization. Medicine. 2017;96(40): e8187.doi: 10.1097/md.0000000000008187