Diagnostic and endovascular management of Renal Vascular Injuries after Nephron-Sparing Surgery.

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Learning objectives

To describe the role of imaging techniques and Renal Artery Embolization (RAE) in the management of Renal Vascular Injuries (RVI) after Nephron-Sparing Surgery (NSS), with a particular focus on the imaging features of RVI and both embolization technique and materials, in order to provide elements for procedural optimization, minimizing parenchymal loss and increasing procedure safety.
Background

NSS is a well-established treatment tool for patients with renal masses and it is growing up as treatment of choice for patients with small lesions and poor functional residual parenchyma. Active bleeding (AB), pseudoaneurysms (PA), arteriovenous fistulas (AVF), and arterio-caliceal fistulas (ACF) have been described as rare but potentially life-threatening RVI associated to NSS. In this scenario, rapid clinical evaluation and diagnosis of the underlying RVI are essential to obtain a good treatment outcome, avoiding fatal events in this subgroup of patients.

Ultrasonography (US) and Computed Tomography (CT) are the imaging tools commonly used to achieve the correct diagnosis and are generally sufficient to provide a proper lesion characterization (site, extension, vascular involvement) and, in association with the clinical evaluation, an adequate treatment planning (surgical vs endovascular; material choice).

US is generally the first imaging screening tool, in patients with suspected RVI, because of its clear advantages such as rapidity, availability, absence of radiation exposure, possibility to be performed at bedside, while the patient is being evaluated and managed in an emergency room and absent contrast medium administration. It has a high sensitivity for detecting intra-abdominal fluid but is relatively insensitive for parenchymal injuries and retroperitoneal haemorrhage.

CT angiography is often necessary to confirm the diagnostic suspect. CT easily detects signs of active bleeding in the peri-renal space or in the urinary tract, suggesting if bleeding has an arterial or venous origin, defines peri-renal hematoma and the possible discontinuity of Gerota’s fascia and clearly identifies other RVI such as PA and AVF.

Surgery (nephrectomy) remains the treatment of choice in patients presenting with unstable hemodynamic conditions. RAE refers to the intentional occlusion of the renal artery, or its branches, by the delivery of one or more embolic agents through an endovascular catheter, with the intent of permanently/temporary exclude the underlying RVI from the renal vascular bed.

Recently, as the consequence of the advances in interventional techniques, such as an improved image quality, the introduction of micro-catheters and more controllable embolic agents, super-selective RAE has emerged as a mini-invasive and effective approach for RVI management in haemodynamically stable patients, ensuring a good parenchymal preservation. However, the wide availability of materials prevents a univocal consensus on the technique and embolizing agent(s) to be used in the various possible situations.
Findings and procedure details

RVI and their imaging features

RVI after NSS include a variety of lesions that are generally isolated but which, in some cases, can be associated, resulting in complex vascular lesions.

· **Active arterial bleeding** is the consequence of a direct vascular injury determining blood extravasation in the peri-renal space. US usually shows an echoic collection close to the kidney but the direct demonstration of the vascular lesion is rare. CT shows an area of contrast medium extravasation with irregular and variable morphology that is evident in the arterial phase and shows spread and expansion in the surrounding tissue on the delayed scan phases; a peri-renal hematoma is a typical finding and may be evident within or outside the Gerota fascia. Direct bleeding may resolve spontaneously as suggested by the "incidental" asymptomatic and stable perirenal haematomas detected at follow-up investigations after NSS. Nevertheless, prolonged high output bleeding can lead to adverse consequences, including vascular shock, acute renal failure and death. In these subgroup of patients, treatment is mandatory and clinical status is conclusive on the indication to treatment: patients hemodynamically unstable will be treated surgically, those that are hemodynamically stable will receive endovascular treatment. (Fig.1)

· **Pseudoaneurysm** is a focal rounded and well defined lesion, within the renal parenchyma or in the surgical shear; US offers good sensitivity but poor specificity showing a hypoechoic lesion with the possible evidence of doppler signals inside. CT is more accurate showing intense enhancement of the lesion, that decreases (wash-out) similarly to that of the arterial blood pool; there is no incremental enhancement on delayed scan phases. Pseudoaneurysms are defined as unstable lesions with a high risk of rupture, especially if they show larger diameter > 2 cm or are symptomatic, therefore require rapid intervention. (Fig.2)

· **Arteriovenous fistulas** are anomalous connections between the arterial and the venous systems without an intervening capillary network. At color doppler US renal AVF appears as a mosaic pattern with a speckling of perivascular soft tissue caused by tissue vibration, reacting to a rapid flow rate. At CT imaging, AVF appears as a tortuous and markedly dilated venous branches, with an early arterial enhancement in the post-contrast CT images. The majority of AVFs are asymptomatic and frequently resolve spontaneously within 24 months after diagnosis. AVFs are thus usually treated conservatively unless they are symptomatic or show persistent gross haematuria, haemodynamic instability or deterioration of renal function. Nevertheless, some investigators advocate aggressive early treatment, as AVFs can potentially enlarge...
over time and become high-flow lesions with potential consequences on cardiac function. (Fig.3)

Renal Artery Embolization technique

The majority of RAE procedures are performed through a common femoral approach, using 4-6F sized arterial sheaths. Catheterization of the renal arteries is performed using standard Cobra or Shepherd hookshaped 4-5F sized catheters. These catheters are sufficient to perform selective embolization in the majority of cases. Micro-catheters allow super-selective angiography and embolization and have been shown to reduce the morbidity and size of induced renal infarction; for these reasons, if RVI are distal an attempt of super-selective catheterization is suggested.

Types of embolization materials

The use of an appropriate technique and a safe and effective embolizing material is essential to obtain the best RAE outcome. The choice of the embolic agent depends mainly on technical aspects, lesion type, site of the lesion and primary goals. According to the type of occlusion induced, embolizing materials may be considered as temporary (re-absorbable) or permanent (not absorbable). The site of embolization may be both large (proximal embolization) or smaller (distal embolization) vessel. (Fig.4)

Temporary embolization (proximal and distal)

- **Absorbable Gelatine Sponges** are absorbed within certain amount of time leading to recanalization of the arteries that is beneficial in minimizing normal tissue damage. It is usually obtained in the form of a sheet that is manually cut into 1-3 mm pieces, depending on its requirement and induce a temporary vascular occlusion for 3-90 days.

- **Autologous clot**

Permanent distal occlusion

- **Inert Microparticles/Micropheres** provide distal occlusion with tissue necrosis; the majority of particles are available in a size range of 40 to 1200 micron and are supplied in apyrogenic sterile sodium solution. There are physical and mechanical difference between each type of particles that can significantly influence clinical outcomes. For any given embolization procedure, each type of microparticles differs in the size and angiographic end point. Usually, they are suspended in non-ionic contrast material that
serves as a carrier and provides radio-opacity for delivery speed and site control in order to avoid non-targeted embolization, thereby minimizing the risk of reflux.

There are different types of microparticles:

- **Non-spherical PVA particles (nPVA)** are the most commonly reported embolizing agents. The weak point of nPVA particles are the variation in size of the particles and the general tendency to aggregate with possible micro-catheter obstruction and/or proximal vessel occlusion due to the unpredictable level of occlusion. Moreover, nPVA particles cause moderate perivascular inflammatory change and recanalization can occur after several months or years at the site of occlusion.

- **Calibrated PVA microspheres (cPVA)** show the principal advantage of a more predictable level of occlusion and a less tendency to aggregate in the micro-catheter lumen. As nPVA, cPVA are not absorbable and not compressible.

- **Trisacryl-Gelatin Microspheres (TGMS) (Embosphere)** are a relatively new not-absorbable, hydrophilic, collagen-coated particulate embolic agent. They are compressible and therefore, easy to deliver through micro-catheters and are less prone to aggregate in both vessels and catheters as demonstrated by various experimental and clinical studies. Furthermore, it seems that they are able to cause a more distal embolization when compared to PVA particles of the same size, due to their compressibility.

- **Liquid Embolic Agents** have demonstrated high efficiency in generating permanent distal occlusion; however, due to their high vascular navigation capability, they must be used with caution to avoid reflux in non-targeted vessels.

There are different types of liquid agents:

- **Glues derived from N-butyl-2-cyanoacrylate (NBCA)**, are a fast and efficient not-absorbable, not-radiopaque embolizing material. Liquid monomeric cyanocrylate in converts to a solid long-chain polymer immediately after the contact with anionic substances such as plasma, blood cells or endothelium. The reaction proceeds so rapidly that the glue will solidify in a catheter unless a substance is added to extends the polymerization time. The most commonly used agent is the Ethiodized oil (lipiodol, Ethiodol), that has both the functions of carrier and visualization tool, due to its radiopacity; according to the different cyanoacrylate to oil ratios (usually from 1:0.5 to 1:5) a different time of polymerization and penetration capability is obtained. NBCA provokes
a more intense inflammatory reaction and involve the wall of the vessel and the adjacent interstitial areas. This inflammatory reaction ultimately leads to vessel necrosis, fibrous ingrowth, and permanent occlusion. Risks of using NBCA include rapid polymerization and reflux resulting in proximal embolization, with subsequent possible collateralization, or not targeted embolization; catheter entrapment is theoretical but possible. If the polymerization time is too long, the NBCA can pass into the venous circulation, resulting in venous embolism.

- **Onyx™** is a non-adhesive liquid agent composed of ethylene vinyl alcohol (EVOH) copolymer dissolved in dimethyl sulphoxide and mixed with micronized tantalum powder for radio-opacity. Upon contact with blood, it precipitates to form a cast that remains flexible for some minutes. Consequently, use of Onyx™ provides predictable embolization, as compared with glue.

*Permanent proximal occlusion*

- **Metallic coils** exist in multiple combinations of shape (elical, 3D), length and release mechanism (controlled or not controlled) and can be inserted either via regular catheters or micro-catheters. They cause a proximal occlusion of the vessel, but if smaller in size can be useful also for a distal vessel occlusion. The correct choice of the coil is essential because larger coils can be unable to fit in small vessels and longer ones can retreat into not target vessels with the risk of an undesired occlusion.

- **Vascular plugs** comprise a detachable nitinol cage filled with thrombogenic polyester filaments. Vascular plugs provide rapid embolization of large vessels and are ideal for high-flow situations.

**Complications**

RAE is generally considered a safe procedure, with a relatively low complication rate compared to surgery, but nonspecific and specific complications are described in literature.

*Nonspecific complications*

Complications not directly associated with the embolization procedure can occur as a result of endovascular manoeuvres, such as groin haematoma/pseudoanerysm and arterial dissection or thrombosis. Additional complications might occur as a consequence
of exposure to radiographic contrast media, such as contrast-induced nephropathy or anaphylaxis. (Fig.5)

Specific complications

As already outlined inadvertent embolization of not targeted areas can result in extensive or minimal renal infarction, as well as infarction to sites different from kidney such as adrenal glands and lower limbs. The majority of these incidents were reported in the 1970s and 1980s, when non-selective RAE was performed, and are now considered rare due to the improvement of embolic agents and the increased awareness of the operators.

Due to their small size, microparticles are contraindicated among patients with AVF because of the risk of induce venous embolism.
Images for this section:

Fig. 1: Renal CT scan and angiography of active bleeding in 61-year-old patient with history of laparoscopic partial nephrectomy for a tumour of the left kidney. A) Images obtained from a systematic CT scan performed 10 days after surgery, showing a large left perirenal haematoma (arrow). B-C) Selective renal angiogram showing active bleeding from an interlobar artery of the left kidney (arrows). D) The bleeding was stopped by selective embolization.

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Fig. 2: Renal CT scan and angiography of a pseudoaneurysm in an 72-year-old patient with history of partial nephrectomy for a tumour of the right kidney. A Images obtained from a systematic CT scan performed 17 days after surgery, showing a large
pseudoaneurysm in the operative site, CT shows a parenchymal area of intense enhancement similar of the arterial pool with synchronous washout and without incrementation during portal and late venous phase (arrows). b) Selective renal angiogram shows pseudoaneurysm in lower branch of renal artery (arrow head). c) Persistent enhancement on delayed angiography phase scan (arrow head). d) Control angiogram showing complete exclusion of the pseudoaneurysm with minimal infarction.

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Fig. 3: Traumatic right renal AV fistula in a 59-year-old woman with a laparoscopic partial nephrectomy for a tumour of the right kidney. A) CT angiogram after wedge resection of the right kidney shows a pseudoaneurysm at the edge of the operative part (arrow) B) Right renal DSA image (early arterial phase) shows early filling of the renal vein (arrowheads) and inferior vena cava, suggesting an AV fistula with pseudoaneurysms (arrow head. C) Control angiogram showing complete exclusion of AVF.

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Fig. 4: Embolizing materials.

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Fig. 5: Renal CT scan and angiography of branch renal artery dissection in an 50-year-old patient with history of percutaneous shock wave lithotripsy resulting. A-B) Angiography shows lower branch renal before and after dissection, during the embolization of a pseudoaneurysm (arrow). C-D) Images obtained from a systematic CT scan performed one and 13 days after renal artery embolization, that shows lower branch renal dissection (arrows head).
Conclusion

Endovascular treatment provides good alternative to surgery in diverse RVI with shorter hospitalization and preserving the effect of a NSS on the residual renal parenchyma reducing morbidity.

The safety and effectiveness of these procedures depend on many variables such as the correct selection of patients and the proper pre-procedural imaging and clinical evaluation; nevertheless the experience of vascular interventional radiologist in the selection of embolic agents play a central role in achieving best results.
References


