Imaging in renal transplantation: from donor assessment to evaluation of the kidney transplant recipient

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Learning objectives

To describe the role of imaging in kidney transplantation, from the assessment of the donor's anatomy to the evaluation of early and late complications in transplant recipient.

Background

Renal transplantation from a living donor or cadaver represents currently the treatment of choice for patients with chronic renal failure in terminal uremic stage; despite the recent progress obtained in terms of survival with hemodialysis and peritoneal dialysis, transplantation is the best treatment not only to restore a normal kidney function, but also to propose a good quality of life in most cases. Careful donor selection and an accurate study of recipients are crucial for the transplantation.

In addition, it is easy to understand the importance of monitoring the post-transplant course, in order to identify early any post-operative problems [1].

Renal transplantation techniques

We illustrate the different surgical techniques of renal transplantation:

1. Monolateral single kidney transplantation;
2. Bilateral dual kidney transplantation / monolateral dual kidney transplantation;

The knowledge of these surgical techniques allows radiologists to easily identify the renal complications.

1. Monolateral single kidney transplantation.
Fig. 1: Monolateral single kidney transplantation: vascular anastomoses are performed using the right external iliac artery and the right external iliac vein.

References: Radiodiagnostic and Oncological Radiotherapy Unit, University Hospital "Policlinico-Vittorio Emanuele" - Catania/IT

There are 3 possibilities of placement for renal graft: extra-peritoneal, trans-peritoneal and intra-peritoneal.

In heterotopic renal transplantation, the renal graft is implanted in the right iliac fossa; the right iliac fossa is preferred because exposure of the iliac vessels is greater than in the left iliac fossa.

Extra-peritoneal placement of the renal graft into iliac fossa provides the following advantages:

- Wide adaptability of renal graft;
- Availability of iliac vessels for the anastomoses (iliac vessels are similar in size to the renal arteries and veins)
- Low infection potential;
• Short distance to the bladder (allowing to mobilize the distal end of the ureter for the anastomosis with the bladder);
• Evaluation of renal graft dysfunction.

In most cases, the vascular anastomoses are performed using the right external iliac artery and the right external iliac vein [2,3].

The most common technique is the end-to-side anastomosis between the renal artery of the neo-kidney and the external iliac artery. The venous anastomosis is performed between the renal graft vein and the right external iliac vein (end-to-side anastomosis); the left kidney is preferred for donation because the vein is longer; if renal veins are excessively short, it is possible to use a vein patch [4].

The most common surgical procedure for ureteral implantation is the "Politano-Ledbetter reformatting technique", also called intra-bladder anastomosis: in this surgical procedure, a short sub-mucosal tunnel in the trigonal region is performed, in order to create an anti-reflux mechanism.

2 Bilateral dual kidney transplantation / Monolateral dual kidney transplantation

In recent years criteria for organ procurement have been changed, and a significant role has been attributed to older donors and dual kidney transplantation.

Due to the disparity between organ supply and demand, the use of "expanded donor criteria" has been accepted: kidneys of elderly subjects, with limited potential, are transplanted in a single receiver in order to increase the nephronic mass and improve the long-term survival of these "marginal" transplants [5].

The choice of surgical technique is critical since the potential disadvantages of DKT, due to the longer operative times and percentage of risks increased when compared to "standard" monolateral single kidney transplant.

The kidneys could be implanted with two Gibson incisions (less frequently using a single medial incision); alternatively, a single Gibson incision has been used to place both renal grafts in an extra-peritoneal location (unilateral dual kidney transplantation, UDKT) [5].

The most commonly used technique for bilateral dual kidney transplantation has been introduced by Masson and Hefty; the right kidney is implanted performing venous anastomosis to the vena cava and arterial anastomosis to the right external iliac artery; the left kidney is anastomosed to the right external iliac vein and to the common iliac artery.

In the monolateral dual kidney transplantation, the arteries and veins of the two monolateral kidneys are anastomosed into the external iliac vessels.

**Fig. 2**: Joined monolateral dual kidney transplantation: the arteries and veins of the two monolateral kidneys are joined thorough a running suture (unilateral fusion of vessels), and the joined kidneys are anastomosed into the external iliac vessels. 

**References**: Radiodiagnostic and Oncological Radiotherapy Unit, University Hospital "Policlinico-Vittorio Emanuele" - Catania/IT

Dual Kidney Transplantation (DKT) might be considered a major surgical procedure and, in older recipients, has a potentially greater risk of surgical complications compared with the single kidney transplantation.

The monolateral dual kidney transplantation has been adopted to reduce these surgical complications.

Some Authors introduced a new technique called joined monolateral dual kidney transplantation [6]: the arteries and veins of the two monolateral kidneys are joined
thorough a running suture (unilateral fusion of vessels), and the joined kidneys are anastomosed into the external iliac vessels.

**Images for this section:**

**Fig. 1:** Monolateral single kidney transplantation: vascular anastomoses are performed using the right external iliac artery and the right external iliac vein.
**Fig. 2:** Joined monolateral dual kidney transplantation: the arteries and veins of the two monolateral kidneys are joined thorough a running suture (unilateral fusion of vessels), and the joined kidneys are anastomosed into the external iliac vessels.
Imaging findings OR Procedure details

Pre-transplant evaluation

The evaluation of the living donor kidney is very important to identify vascular and pieloureteral variations, whose presence affects the pre-transplant surgical planning. Recipient assessment is carried out during the pre-transplant and post-transplant, the latter in order to identify early and late complications.

Anatomical variations

Renal arteries and veins show numerous anatomical variations, characterized by one or more vessels with different morphologies and branch level; consequently, vascular anatomy plays a decisive role in the choice of the kidney for the transplantation, especially if a laparoscopic nephrectomy is carried out [7].

Since there are no intra-renal arterial anastomoses, each branch represents a terminal artery and their interruption causes ischemic damage; that's why the surgeon must reconstruct each branch of the renal vascular pedicle, including anatomic variants [7].

We describe the most common variations in renal arteries and renal veins (polar renal arteries, double renal arteries, tributaries to the left renal vein, retroaortic left renal vein and circumaortic left renal vein) identified with TCMD and/or RM in more than 50 renal transplant donors.

About 70% of the general population has a single artery to the kidney, while in the remaining 30% of cases anatomical variations may occur [8]. These vascular abnormalities depend on the persistence of fetal vessels, which usually regress when renal blood vessels are formed. In recent studies on living kidney donors investigated by MDCT and MRA, accessory arteries were found in 40-46% of cases.

Accessory arteries (usually 2 or 3) are twice as common as accessory veins; in addition, variants of number and position of renal arteries - without venous anomalies - are commonly encountered Fig. 3 on page 13.

The extra-hilar renal artery - commonly indicated as polar artery - is a variation type where the artery divides before reaching the renal parenchyma Fig. 4 on page 14, Fig. 5 on page 15.

The most common vein variations are: accessory veins Fig. 6 on page 16, tributaries to the left renal vein, retroaortic left renal vein Fig. 7 on page 17 and circumaortic left renal vein Fig. 8 on page 18.
About 85% of the population has a single right renal vein, often without other tributary vessels from other organs or structures; for this reason the right kidney is frequently chosen for laparoscopic nephrectomy procedures.

The anatomy of the left renal vein and its tributaries is often very complex; the most common variant of the left renal vein is the circum-aortic, which occurs in 5-7% of cases Fig. 8 on page 18. A single retroaortic left renal vein can be identified in 2-3% of individuals Fig. 7 on page 17.

In addition to vascular variants, pre-transplant evaluation must identify any alterations of morphology and course of the urinary tract; duplication of upper urinary tract - especially the duplication of the abdominal and pelvic ureter - is one of the most common variations; such anomalies result from the division of the ureteric bud. Ureteral duplication extension depends on the completeness of the diverticulum division [7].

Vascular complications

Several studies have shown the significant role of vascular complications in terms of morbidity and mortality: they occur in 4-8% of patients [1]. These complications are represented by the renal artery stenosis of the transplanted kidney (TRAS), the renal vein thrombosis (TVR) and the arteriovenous fistula.

• **Renal artery stenosis:**

Renal artery stenosis ranges from 1% to 23%, and represents an important cause of hypertension and/or deterioration of the function of the transplanted kidney Fig. 9 on page 19. Stenosis generally occurs in the first year after transplantation.

The definition of hemodynamic significant TRAS is not standardized and the referee value ranges from >50% to >80%. In addition, the introduction of cyclosporine, a drug agent responsible for vascular damage, seems to increase the prevalence of TRAS. The stenosis is classified on the basis of its location:

- proximal stenosis: the stenosis is located before the anastomosis (due to atherosclerosis (donor vessel disease);
- anastomotic stenosis (due to altered vascular perfusion, faulty suture technique or reaction to suture material)
- post-anastomotic or distal stenosis (caused by rejection or turbulent flow due to malposition of the kidney)

Doppler criteria for significant hemodynamic stenosis have been formulated by Akbar et al1:
a) a peak rate greater than 7.5 KHz (with 3 MHz probes) or a systolic peak velocity higher than 2 m/sec;

b) a velocity gradient between stenotic vessel segment and pre-stenotic tract > 2: 1;

c) and the presence of turbulence flow phenomena.

Downstream of stenosis vessels of the renal parenchyma show characteristic flow paths "tardus and parvus" [1].

• **Thrombosis of the renal vein:**

It is a rare complication (5% of patients or renal transplant recipients) usually encountered in the first week after transplantation (acute post-transplantation phase).

The increased prevalence of renal vein thrombosis in the lower left abdominal quadrant has been attributed to the compression of the left common iliac vein between the sacred and the common iliac artery ("silent iliac artery compression syndrome") [1,2].

According to Sebastià et al [9], it is most frequently caused by "acute" or "hyperacute" rejection, but it may be caused by inadequate surgical technique, hypotension, hypercoagulability, cyclosporine therapy, emboli. Renal infarction is the consequence of vascular thrombosis, and it appears as hypoechoic area bounded by a hyperechoic rim, with variable enhancement [9].

• **Acute renal failure:**

Renal infarction is caused by the disparity between vascular supply and demand. We distinguish an early infarction - due to damage of the renal artery of the donor or resulting from surgical complications - and a late infarction, caused by embolic phenomena.

Patients show renal function impairment, often with oligo-anuria; frequently they report pain due to the local inflammatory response Fig. 10 on page 20

• **Hematoma:**

Frequently found during the early post-operative phase, occurring spontaneously or following procedures (biopsy) or trauma.

Hematoma usually resolves spontaneously, but if it increases in size it can lead to hydronephrosis and therefore require surgery. Patients complain severe pain at the site of transplantation, decreased haemoglobin or haematocrit, and increases in serum creatinine Fig. 11 on page 21, Fig. 12 on page 22
Hematomas should be differentiated from organized urinomi [1].

• **Fistulas and arteriovenous pseudoaneurysms:**

Among complications after biopsy, fistulas and arteriovenous pseudoaneurysms have an incidence ranging from 6.3% to 10%, depending on the techniques used for the biopsy and post-operative controls performed Fig. 13 on page 23. According to a recent study by Furness et al [10], the incidence of arteriovenous fistula after 2127 biopsies of kidney transplant is 2.4%. It should be noted that up to 95% of post-bioptic fistulas resolve spontaneously [10].

Pseudoaneurysm is frequently reported as complication after biopsy in 1 to 18% of cases. It is generally asymptomatic, but sometimes can occur with hypertension, hematuria and deterioration of renal function.

**Non-vascular complications**

Perirenal transplant fluid collections can be associated with renal transplant in up to 50% of patients, including urinomi, hematomas, lymphoceles, and abscesses. The clinical significance depends on their size, location and the eventual growth.

Fluid collections can be distinguished by their clinical onset. The urinomi and haematomas develop early after transplantation, while the lymphoceles occur 4-8 weeks after surgery [1].

• **Urine Extravasation and Urinomi:**

These represent relatively rare complications in the post-operative period. The urine extravasation arises from the renal pelvis, the ureters and the ureteroneocistotomy. Other causes of extraureterale extravasation include inadequate surgical technique and rejection [9]. Urinomi generally occur in the second or third week after transplantation, and require surgery or percutaneous interventional approach.

The urinomi are usually located between the transplanted kidney and bladder Fig. 14 on page 24; less frequently they are encountered in the scrotum and thighs. Clinical features of these complications are: poor urine emission, sense of weight in iliac fossa and scrotal edema [2]. The small leaks can be treated by percutaneous nefrostomia or stent placement; alternatively, a new ureter reimplantation is recommended. The leak’s location suggests the causes of urinoma: when located near ureteopelvic-vescical anastomosis, it is most frequently due to ischemia or inappropriate surgical procedure; on the other hand, diffused urinomi along the ureteral course is more suggestive of ischemic alteration [2].
• **Abscesses:**

Abscesses represent a rare complication that occurs usually in the first week after transplantation. They may be caused by pyelonephritis, and bacterial infection of a lymphocele, hematoma or urinoma.

Clinically, the patient may have symptoms of infection due to the state of immunosuppression: fever of unknown origin, pain or symptoms related to the compression (in cases of large abscesses). US or CT guided drainage is generally recommended for their treatment.

• **Urinary obstruction:**

This, Fig. 15 on page 25, occurs in 2% of transplants, and almost always in the first 6 months after surgery. The most common site of obstruction is the site of implantation of the ureter into the bladder. More than 90% of stenosis regards the distal end of the ureter. In 50% of cases the obstruction is caused by kinking, technical errors during the ureteral anastomosis, or by post-ischemic fibrosis; rarely they are caused by pelvic fibrosis, lithiasis or papillary necrosis. The obstruction may be also due to compression by a large peri-renal mass of fluid collection.

There are early or late obstructions: early forms are related to kinking, clots, edema or inflammation; late obstructions are caused by fibrosis, ischemia and periureteral masses [9]. The patient does not report the typical pain (due to the denervation), but there is an increase of creatinine levels. The therapeutic approach - in cases of significant hydronephrosis - involves surgical reconstruction; in case of narrowing of the distal end of the ureter, therapeutic options include balloon dilatation and/or stent placement.

• **Infections:**

More than 80% of transplant recipients have at least one episode of infection during the first year after transplantation.

In the first week after transplantation, most infections are usually pneumonia, surgical wound infections and urinary infections. From 1 to 6 months after transplantation it is possible to find infections caused by opportunistic agents and CMV; 6 months after the transplant, transplant recipients are commonly prone to catching the same kinds of infections that target the general population [1].

Infection is the most feared complication of transplantation, and it should be recognized early and treated. Pulmonary infections may be transmitted from an infected donor or blood transfusions; more often, they are caused by the persistence of the infectious foci - existing in the recipient before transplantation. The underlying disease, the uremic state
and the established immunosuppressive therapy after transplantation, contribute to the decline of the immune system in the recipient.

• **Lymphocele:**

Represents the most frequent fluid collections responsible for hydronephrosis of the transplanted kidney, with a prevalence ranging from 0.5% to 20%. It may occur at any time, from weeks to years after transplantation, but in most cases they are encountered 1-2 months after transplantation.

The lymphoceles, Fig. 16 on page 26, Fig. 17 on page 27, Fig. 18 on page 28, are caused by extravasation of lymph from lymphatic vessels or iliac nodes - surgically destroyed in the transplantation. Risk factors include: inadequate ligation of lymphatic vessels at the level of the iliac vessels and administration of heparin.

Generally they are located in the medial position between the transplanted kidney and bladder. Clinically, the patient may be asymptomatic or present edema of the lower extremities (due to ipsilateral compression of the femoral vein) or, rarely, swelling of the abdomen or scrotum [2].

**Images for this section:**
Fig. 3: Patient with bilateral double renal arteries: accessory arteries (usually 2 or 3) are twice as common as accessory veins; the knowledge of these arteries is a crucial point in planning kidney transplantation surgery.
**Fig. 4:** Patient with polar renal artery: the extra-hilar renal artery - commonly indicated as polar artery - is a variation type where the artery divides before reaching the renal parenchyma.
Fig. 5: Another example of patient with polar renal artery: the extra-hilar renal artery - commonly indicated as polar artery (arrow) - is a variation type where the artery (arrowhead) divides before reaching the renal parenchyma.
Fig. 6: Patient with accessory left renal vein (asterisks): about 85% of the population has a single right renal vein, often without other tributary vessels from other organs or structures; for this reason the right kidney is frequently chosen for laparoscopic nephrectomy procedures.
Fig. 7: An example of patient with retroaortic (asterisk into the aorta lumen) left renal vein (arrowhead): a single retroaortic left renal vein can be identified in 2-3% of individuals.
Fig. 8: An example of patient with left circum-aortic vein (curved arrow): the anatomy of the left renal vein (arrowhead) and its tributaries (arrowhead) is often very complex; the most common variant of the left renal vein is the circum-aortic, which occurs in 5-7% of cases. Retroaortic vein (white arrow) is also demonstrated.
Fig. 9: An example of patient with renal artery stenosis (arrowhead): a renal artery stenosis ranges from 1% to 23%, and represents an important cause of hypertension and/or deterioration of the function of the transplanted kidney. Stenosis generally occurs in the first year after transplantation.
Fig. 10: An example of patient with renal infarction: renal infarction is caused by the disparity between vascular supply and demand. We distinguish an early infarction - due to damage of the renal artery of the donor or resulting from surgical complications - and a late infarction, caused by embolic phenomena. Patients show renal function impairment, often with oligo-anuria; frequently they report pain due to the local inflammatory response.
Fig. 11: An example of patient with hematoma: frequently found during the early post-operative phase, occurring spontaneously or following procedures (biopsy) or trauma. Hematoma usually resolves spontaneously, but if it increases in size it can lead to hydronephrosis and therefore require surgery. Patients refer severe pain at the site of transplantation, decreased haemoglobin or haematocrit, and increases in serum creatinine. Hematomas should be differentiated from organized urinomi.
Fig. 12: Another example of patient with chronic hematoma (asterisk).
Fig. 13: An example of patient with fistulas and arteriovenous pseudoaneurysms: among complications after biopsy, fistulas and arteriovenous pseudoaneurysms have an incidence ranging from 6.3% to 10%, depending on the techniques used for the biopsy and post-operative controls performed.
Fig. 14: An example of patient with urinoma: these represent relatively rare complications in the post-operative period. Urinomi generally occur in the second or third week after transplantation, and require surgery or percutaneous interventional approach.
Fig. 15: An example of patient with urinary obstruction: this occurs in 2% of transplants, and almost always in the first 6 months after surgery. The most common site of obstruction is the site of implantation of the ureter into the bladder. More than 90% of stenosis regards the distal end of the ureter.
Fig. 16: An example of patient with lymphocele: represents the most frequent fluid collections responsible for hydronephrosis of the transplanted kidney, with a prevalence ranging from 0.5% to 20%. It may occur at any time, from weeks to years after transplantation, but in most cases they are encountered 1-2 months after transplantation.
Fig. 17: Another example of patient with lymphocele.
**Fig. 18:** Another example of patient with lymphocele.
Conclusion

US, TCMD and RM have a critical role to give an accurate pre- and post-operative assessment of the donor and of the recipient; interventional radiologic techniques allow nonsurgical treatment of vascular complications of renal transplantation.

References

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