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Nephrology, Transplantation and Shunts

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Introduction

Renal transplantation is an established cost-effective treatment in patients with end-stage renal disease [1]. However, after the first year, graft survival curves show an exponential decline in numbers of functioning grafts. Many causes of renal graft dysfunction are treatable, thus making prompt detection and diagnosis of complications mandatory. Acute tubular necrosis (ATN) may cause immediate oliguria and may follow an initial short period of graft function as well as acute rejection. Finally, there is a possibility of cyclosporine or tacrolimus toxicity.

Evaluation of kidney transplants using gray-scale sonography and color Doppler

Renal graft measurements (length, width) and anatomical characteristics (corticomedullary differentiation, the existence of hydronephrosis affecting the graft, perinephric fluid collections or masses) [Mov.1] as well as vascular flow [3,4] [Mov.2, Fig.1] can be defined using gray-scale sonography and color Doppler.
During the first 24 hours after surgery, the graft must therefore be explored using gray-scale and color Doppler as the first imaging technique according to the protocol or clinical indication. Absence of perfusion in the graft is a sign of renal artery occlusion. Reverse diastolic flow in the arteries due to retrograde blood flow during diastole [Fig.2] is a sign of complete allograft vein thrombosis or acute rejection. Incomplete vein thrombosis is more difficult to identify. When color Doppler cannot completely rule out arterial occlusion, stenosis or vein thrombosis, CT scans or even arteriography is required [7].

Figure 2 Acute rejection. Typical Color Doppler aspect. The flow under the baseline indicates the retrograde arterial blood flow during diastole.
Infarctions can be diagnosed at Doppler ultrasound or power Doppler examination by demonstrating a lack of blood flow to the infarcted region of the parenchyma. In these cases, exploration using ultrasound contrast agent is the best option.

Sonographic exploration cannot differentiate between ATN and acute rejection, so ultrasound guided allograft biopsy is required.

Renal artery stenosis occurs at a rate of 1% to 10%, usually at the site of the surgical anastomosis. Diagnosis is made by demonstration of a focal and segmental region of flow abnormality characterized by elevated peak systolic velocity (PSV; normal value 250 cm/s) with associated turbulence at an adequate insonation angle. The ratio of renal artery PSV compared to that of the iliac artery can be more useful, because PSV may be variable in the allograft artery. In addition to this, tardus-parvus waveform abnormalities can be observed in the renal parenchyma. After sonographic diagnosis of possible renal artery stenosis, magnetic resonance imaging or computed tomography angiography may be indicated to confirm the diagnosis before percutaneous transluminal angioplasty is performed.

The usefulness of the resistive index

Resistive index (RI) is usually determined as a standard practice in clinical monitoring. The RI value depends on the graft vessels, but it is possible that it is even more influenced by the recipient's vessels and their elasticity. An isolated elevated RI has limited value and is nonspecific. In the postoperative days, elevated RI values (0.9) [Fig. 3] can be found in several types of graft dysfunction such as acute rejection, calcineurin inhibitor toxicity, severe ATN [Fig. 4], renal vein obstruction, urethral obstruction and pyelonephritis. Periodic RI measurement is therefore useful in patients affected by these complications to help monitor the graft function [8] [Fig. 5].
Figure 3  RI results 0.90; this is a value which might indicate acute pathology

Figure 4  Sample volume used to calculate Resistive Index is positioned at the level of the interlobar artery.
In chronic allograft function, RI has limited value, because it is not a particularly sensitive marker of chronic graft pathology and cannot be used in clinical decision-making. However, it has been shown that an elevated RI value (0.8), measured 3 months postoperatively, is a predictor of subsequent poor graft function and/or death [9].

**Arteriovenous fistula as a complication of percutaneous graft biopsy**

Arteriovenous fistula is a possible complication after percutaneous graft biopsy. Doppler ultrasound depicts arteriovenous fistulae as a localized area of disorganized color that extends outside the confines of the normal vessel caused by perifistula aliasing [12]. Waveform analysis demonstrates a high-velocity, low-resistance flow in the supplying artery and a high pulsatility flow in the draining vein (arterialization).

**US contrast agents**

Recently, the introduction of second generation contrast agents has given new possibilities and perspectives to US imaging and quantification of renal blood flow as well as microvascular tissue perfusion [Mov.3]. CEUS has overcome the limitations of color Doppler ultrasonography and permits depiction of parenchymal blood perfusion. CEUS provides the best visualization of perfusion deficit indicating its extension and allowing the characterization of indeterminate renal lesions, atypical cystic lesions, and the identification of acute pyelonephritis [17] [Mov.4, Fig.6a, 6b].

**Figure 5** Sample volume used to calculate Resistive Index is positioned at the level of the arcuate artery.
Some authors have concluded that renal perfusion patterns of normal and abnormal tissue can be visualized using contrast-enhanced phase-inversion ultrasound imaging. New diagnostic possibilities of CEUS include evaluation of both cortical and medullar vessels as well as functional evaluation of renal perfusion. Measuring the microbubble transit time is useful in the diagnosis of renal artery stenosis and in the differential diagnosis between ATN and acute rejection in transplanted kidneys [13].

**Magnetic resonance imaging**

Magnetic resonance imaging (MRI) has emerged as an alternative imaging modality in renal transplant graft assessment [Fig.6c]. MRI is promising due to its multiplanar capabilities and lack of ionizing radiation, invasiveness, and contrast medium-induced nephrotoxicity. Recent studies have shown the utility of MRI in the evaluation of the renal graft and peritransplant region, but its role is not yet firmly established [5]. At MRI, loss of corticomedullary differentiation on T1-weighted images is the most useful finding indicating rejection.

**Figure 6** In the upper part of this image, CEUS clearly shows the parenchymal region with a perfusion deficit (a). Transplanted patient with infarction in the central portion of the kidney; CEUS shows a parenchymal perfusion defect (b). MRI using contrast agent confirms the presence of a hypovascular area (c).
The use of ultrasound in the assessment of arteriovenous fistulae for hemodialysis access

Color Doppler ultrasonography has proved to be effective in the evaluation of arteriovenous fistulae for hemodialysis access both in the preoperative phase, for the assessment of anatomical vascular features, and in the postoperative phase, to detect clinically presumed arteriovenous fistula complications [Fig.7].
Color Doppler ultrasonographic vein mapping allows the identification of veins that are not clinically evident. The inability of clinical examination alone to predict adequacy of venous outflow causes the use of suboptimal veins and arteries, and this results in a high failure rate of arteriovenous fistulae and in an increasing use of arteriovenous grafts [11].

Selection criteria for arteriovenous fistula insertion should be the following [12, 13]:

1. Cephalic or basilic veins measuring at least 2 mm in diameter in continuity with the deep system.
2. An appropriate artery measuring at least 2 mm in diameter with peak systolic velocity of 50 cm/s or greater.

The arteriovenous fistula complications that occur most frequently are thrombosis-correlated stenosis and aneurysm [14, 15, 16].

Hemodynamical data with higher diagnostic significance are the mean flow volume (1204 ml/min), the mean maximum velocity in anastomosis (2.7 m/s), and the mean maximum velocity in the brachial artery (1.35 m/s) [15].

Turbulent blood flow causes extensive vessel wall and perivascular tissue vibration. This localized tissue vibration causes artifactual color assignment of the perivascular soft tissues, which precludes adequate visualization of the venous anastomosis [14] [Fig.8].
Figure 8  Tissue vibration due to turbulent blood flow causes artifactual color assignment to the perivascular soft tissues.

Diagnostic criteria indicating stenosis at color Doppler ultrasonography are visible narrowing of the lumen, increased velocity of flow greater than 100% compared with that of an adjacent normal segment in color Doppler study [17, 18].

Arteriovenous fistula waveform is arterial with systolic velocities of 100-400 cm/sec [19] but demonstrates high end-diastolic flow because of the low-resistance runoff in the draining veins [20].

An increase of mean maximum velocity in anastomosis (4.35 m/s) indicates narrowing of the vessels with the degree of stenosis related to the increase in velocity [20, 21]. On the contrary, both the mean flow volume and the mean maximum velocity in the brachial artery are found to be lower in fistulae with venous stenosis [15].

In more than 3% of hemodialysis vascular accesses a false aneurysm is present, and in more than 50% of cases there is an aneurysm (vein diameter >6 mm). Almost 100% of these alterations are located at the puncture site [15].

Available data indicate that the mean flow volume is significantly higher in the fistulae with aneurysms. A strong correlation has been found between aneurysm and calcifications and aneurysm and fistula age [15].

Increased flow rates, more than 1500 ml/min, are associated with steal syndrome or venous hypertension.

The Doppler finding noted in steal syndrome was marked reduction of flow in the distal artery, while high flow rates reaching 600 ml/min in the distal venous limb of the arteriovenous fistula are associated with venous hypertension [14].
References


