EFSUMB Course Book, 2nd Edition

Editor: Christoph F. Dietrich

Ultrasound after kidney transplantations

Francesco M Drudi[1], Flavia Angelini[1], Sarah Campagnano[1]

[1]University “la Sapienza”, Rome, Italy

Corresponding author:

Francesco M Drudi

University “la Sapienza”, Rome, Italy

Tel.: +390649978439

Fax: +390649978438

Email: francescom.drudi@uniroma1.it

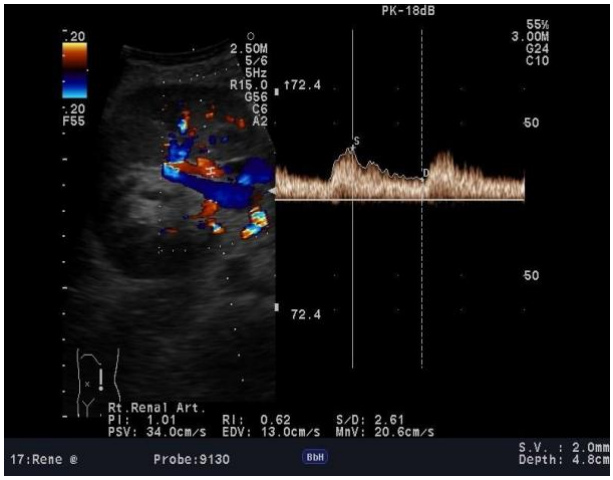
Introduction

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 the number of functioning grafts. Many causes of renal graft dysfunction are treatable, which makes prompt detection and diagnosis of complications mandatory. Acute tubular necrosis (ATN) [(2)] may cause immediate oliguria and follow an initial short period of graft function as well as acute rejection. Finally, there is a possibility of cyclosporine or tacrolimus toxicity [(3)].

Evaluation of kidney transplants using greyscale sonography and colour Doppler imaging

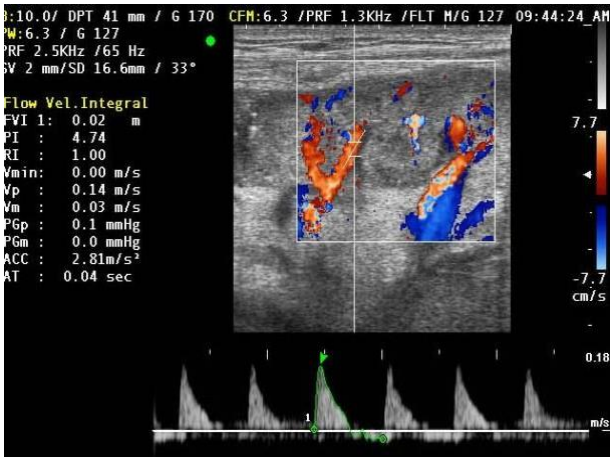
Renal graft measurements (length and width) and anatomical characteristics (corticomedullary differentiation, the existence of hydronephrosis affecting the graft, perinephric fluid collections or masses) [Video 1] as well as vascular flow [(4)] [Video 2, Figure 1] can be defined using greyscale sonography and colour Doppler imaging.

Figure 1 Colour Doppler imaging in a normal patient shows blood flow and vascular morphology (renal artery and renal vein are both visible)



During the first 24h after surgery the graft must be examined using greyscale and colour Doppler imaging as the first 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 [Figure 2] is a sign of complete allograft vein thrombosis or acute rejection. Incomplete vein thrombosis is more difficult to identify. When colour Doppler imaging cannot completely rule out arterial occlusion, stenosis or vein thrombosis, a CT scan or even arteriography is required [(5)].

Figure 2 Acute rejection. Typical colour Doppler aspect. The flow under the baseline indicates the retrograde arterial blood flow during diastole.



Infarctions can be diagnosed on Doppler ultrasound or power Doppler examination by demonstrating a lack of blood flow to the infarcted region of the parenchyma. Exploration using ultrasound contrast agent is the best option in these cases. Sonographic exploration cannot differentiate between ATN and acute rejection and therefore, ultrasound-guided allograft biopsy is required.

Renal artery stenosis usually occurs at the site of the surgical anastomosis, at a rate of 1−10%. Diagnosis is made by demonstrating a focal and segmental region of flow abnormality characterised by elevated peak systolic velocity (PSV) (normal value 250cm/s) with associated turbulence at an adequate insonation angle. The ratio of renal artery PSV compared with that of the iliac artery can be 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, MRI or CT angiography may be indicated to confirm the diagnosis before percutaneous transluminal angioplasty is performed.

The usefulness of the resistive index

It is standard practice to determine the resistive index (RI) in clinical monitoring. The RI value is dependent on the graft vessels; however, 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 non-specific. In the days following the operation, an elevated RI values (0.9) [Figure 3] can be found in several types of graft dysfunction, such as acute rejection, calcineurin inhibitor toxicity, severe ATN [Figure 4], renal vein obstruction, uretheral obstruction and pyelonephritis [(6)]. Periodic RI measurement is useful in patients affected by these complications to help monitor graft function [(7)] [Figure 5].

Figure 3 Resistive index results are 0.90; this is a value that might indicate acute pathology

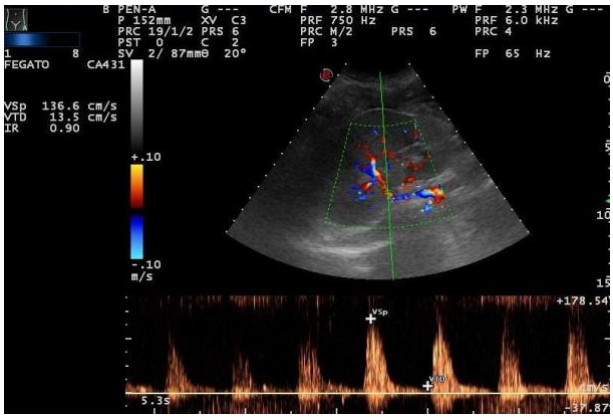


Figure 4 Sample volume used to calculate resistive index is positioned at the level of the interlobar artery.

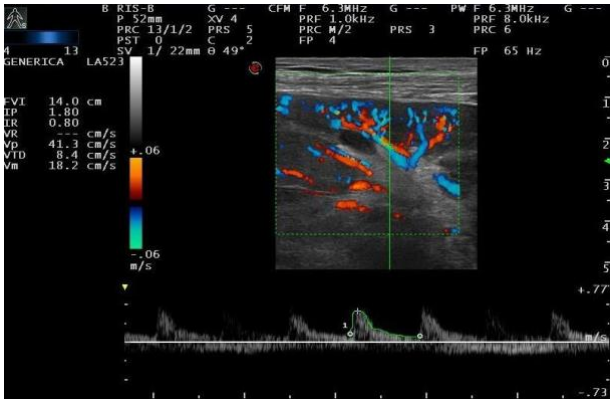
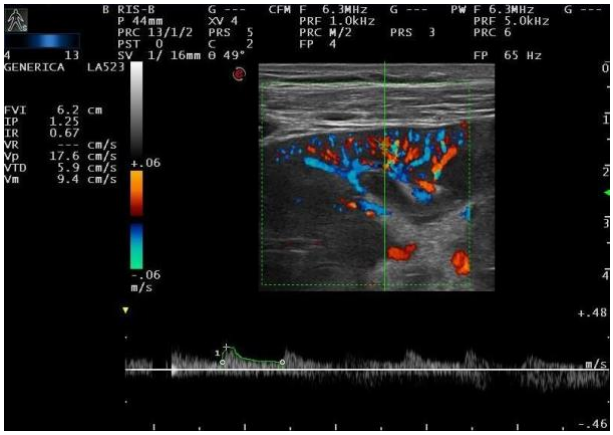


Figure 5 Sample volume used to calculate resistive index is positioned at the level of the arcuate artery.



RI has a limited value in the assessment of chronic allograft function 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 post-operatively is a predictor of subsequent poor graft function and/or death [(8)].

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 localised area of disorganised colour that extends outside the confines of the normal vessel caused by perifistula aliasing [(9)]. Waveform analysis demonstrates a high-velocity, low-resistance flow in the supplying artery and a high pulsatility flow in the draining vein (arterialisation).

Ultrasound contrast agents

Recently, the introduction of second-generation contrast agents has provided new possibilities and perspectives to ultrasound imaging and quantification of renal blood flow as well as microvascular tissue perfusion [Video 3]. Contrast-enhanced ultrasound (CEUS) has overcome the limitations of colour Doppler ultrasonography by depicting parenchymal blood perfusion.

CEUS provides the best visualisation of perfusion deficit. It indicates extension and allows the characterisation of indeterminate renal lesions, atypical cystic lesions and the identification of acute pyelonephritis [(10)] [Video 4, Figure 6a, b].

Some authors have concluded that renal perfusion patterns of normal and abnormal tissue can be visualised 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 [(11)].

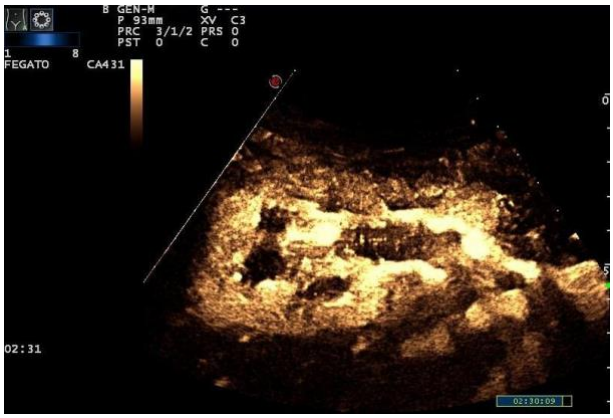
Magnetic resonance imaging

Magnetic resonance imaging (MRI) has emerged as an alternative imaging modality in renal transplant graft assessment [Figure 6c]. MRI is promising owing to its multiplanar capabilities and lack of ionising radiation, invasiveness and contrast medium-induced nephrotoxicity. Recent studies have shown the use of MRI in the evaluation of renal graft and the peritransplant region, but its role is not yet firmly established [(12)]. At MRI, loss of

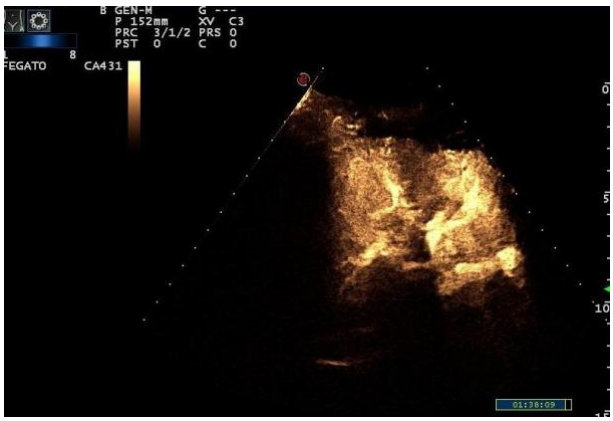
corticomedullary differentiation on T_1 weighted images is the most useful finding to indicate rejection [(13)].

Figure 6 **In the upper part of this image, (a) contrast-enhanced ultrasound (CEUS) clearly shows the parenchymal region with a perfusion deficit. Transplant patient with infarction in the central portion of the kidney. (b) CEUS shows a parenchymal perfusion defect. (c) MRI using contrast agent confirms the presence of a hypovascular area.**

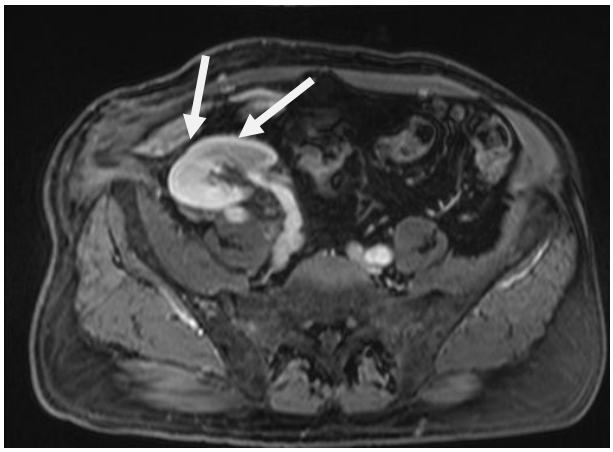
a



b



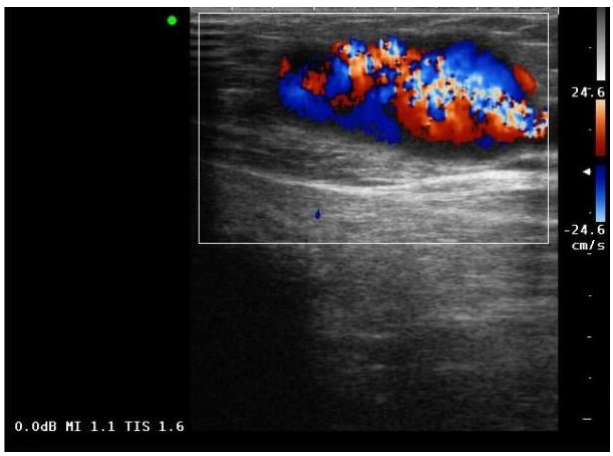
c



The use of ultrasound in the assessment of arteriovenous fistulae for haemodialysis access

Colour Doppler ultrasound has proved to be effective in the evaluation of arteriovenous fistulae for haemodialysis access both in the pre-operative phase for the assessment of anatomical vascular features and in the post-operative phase to detect clinically presumed arteriovenous fistula complications [Figure 7].

Figure 7 An arteriovenous fistula for haemodialysis access assessed using colour Doppler ultrasound.



Colour Doppler ultrasonographic vein mapping allows the identification of veins that are not clinically evident. The inability of clinical examination alone to predict the adequacy of venous outflow causes the use of sub-optimal veins and arteries, and this results in a high failure rate of arteriovenous fistulae and in an increasing use of arteriovenous grafts [(14)].

The selection criteria for arteriovenous fistula insertion should be [(9, 11)]:

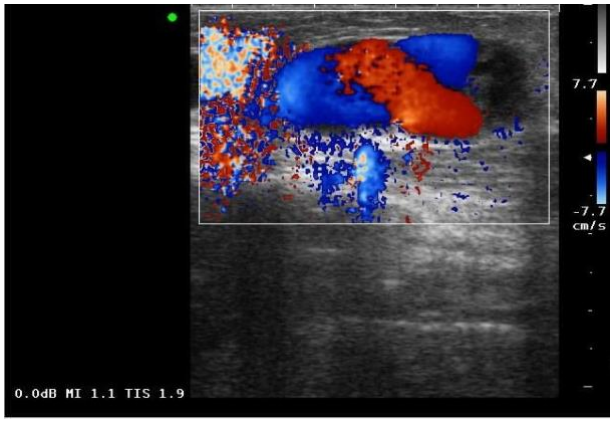
1. Cephalic or basilic veins measuring at least 2mm in diameter in continuity with the deep system.
2. An appropriate artery measuring at least 2mm in diameter with PSV of 50cm/s or greater.
3. Patent ipsilateral subclavian vein.

The most frequent arteriovenous fistula complications that occur are thrombosis-correlated stenosis and aneurysm [(15-17)].

The following haemodynamic data has a higher diagnostic significance: mean flow volume, 1204ml/min; mean maximum velocity in anastomosis, 2.7m/s; and mean maximum velocity in the brachial artery, 1.35m/s [(16)].

Turbulent blood flow causes extensive vessel wall and perivascular tissue vibration. This localised tissue vibration causes artefact colour assignment of the perivascular soft tissues, which precludes adequate visualisation of the venous anastomosis [(15)] **[**Figure 8].

Figure 8 Tissue vibration due to turbulent blood flow causes artefact colour assignment to the perivascular soft tissues.



Diagnostic criteria indicating stenosis on colour Doppler ultrasound are the visible narrowing of the lumen and increased velocity of flow greater than 100% compared with that of an adjacent normal segment in a colour Doppler study [(18)].

Arteriovenous fistula waveform is arterial with systolic velocities of 100–400cm/s [(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 (4.35m/s) indicates a narrowing of the vessels with the degree of stenosis, which is related to the increase in velocity [(20, 21)]. In comparison, 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 haemodialysis vascular cases a false aneurysm is present. In more than 50% of cases there is an aneurysm (vein diameter >6mm). 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 of more than 1500ml/min are associated with steal syndrome or venous hypertension.

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

References

1. Granata A, Di Nicolo P, Scarfia VR, Insalaco M, Lentini P, Veroux M, Fatuzzo P, et al. Renal transplantation parenchymal complications: what Doppler ultrasound can and cannot do. J Ultrasound 2015;18:109-116.

2. Rodriguez SA, Palacios VH, Mayayo ES, DosSantos VG, Nicolas VD. The Usefulness of Contrast-Enhanced Ultrasound in the Assessment of Early Kidney Transplant Function and Complications. Diagnostics 2017;53.

3. Egeland EJ, Reisaeter AV, Robertsen I, Midtvedt K, Strom EH, Holdaas H, Hartmann A, et al. High tacrolimus clearance - a risk factor for development of interstitial fibrosis and tubular atrophy in the transplanted kidney: a retrospective single-center cohort study. Transpl Int 2018.

4. Galgano SJ, Lockhart ME, Fananapazir G, Sanyal R. Optimizing renal transplant Doppler ultrasound. Abdom Radiol (NY) 2018;43:2564-2573.

5. Sun IO, Hong YA, Kim HG, Park HS, Choi SR, Chung BH, Chun HJ, et al. Clinical usefulness of 3-dimensional computerized tomographic renal angiography to detect transplant renal artery stenosis. Transplant Proc 2012;44:691-693.

6. Drudi FM, Pretagostini R, Padula S, Donnetti M, Giovagnorio F, Mendicino P, Marchetti F, et al. Color Doppler ultrasound in renal transplant: role of resistive index versus renal cortical ratio in the evaluation of renal transplant diseases. Nephron Clin Pract 2004;98:c67-72.

7. Schwenger V, Korosoglou G, Hinkel UP, Morath C, Hansen A, Sommerer C, Dikow R, et al. Real-time contrast-enhanced sonography of renal transplant recipients predicts chronic allograft nephropathy. Am J Transplant 2006;6:609-615.

8. Correas JM, Claudon M, Tranquart F, Helenon AO. The kidney: imaging with microbubble contrast agents. Ultrasound Q 2006;22:53-66.

9. Sedlacek M, Teodorescu V, Falk A, Vassalotti JA, Uribarri J. Hemodialysis access placement with preoperative noninvasive vascular mapping: comparison between patients with and without diabetes. Am J Kidney Dis 2001;38:560-564.

10. Mueller-Peltzer K, Rubenthaler J, Fischereder M, Habicht A, Reiser M, Clevert DA. The diagnostic value of contrast-enhanced ultrasound (CEUS) as a new technique for imaging of vascular complications in renal transplants compared to standard imaging modalities. Clin Hemorheol Microcirc 2017;67:407-413.

11. Vassalotti JA, Falk A, Cohl ED, Uribarri J, Teodorescu V. Obese and non-obese hemodialysis patients have a similar prevalence of functioning arteriovenous fistula using pre-operative vein mapping. Clin Nephrol 2002;58:211-214.

12. Radermacher J, Mengel M, Ellis S, Stuht S, Hiss M, Schwarz A, Eisenberger U, et al. The renal arterial resistance index and renal allograft survival. N Engl J Med 2003;349:115-124.

13. Marticorena Garcia SR, Guo J, Durr M, Denecke T, Hamm B, Sack I, Fischer T. Comparison of ultrasound shear wave elastography with magnetic resonance elastography

and renal microvascular flow in the assessment of chronic renal allograft dysfunction. Acta Radiol 2018;59:1139-1145.

14. Silva MB, Jr., Hobson RW, 2nd, Pappas PJ, Jamil Z, Araki CT, Goldberg MC, Gwertzman G, et al. A strategy for increasing use of autogenous hemodialysis access procedures: impact of preoperative noninvasive evaluation. J Vasc Surg 1998;27:302-307; discussion 307-308.

15. Moghazy KM. Value of color Doppler sonography in the assessment of hemodialysis access dysfunction. Saudi J Kidney Dis Transpl 2009;20:35-43.

16. Pietura R, Janczarek M, Zaluska W, Szymanska A, Janicka L, Skublewska-Bednarek A, Szczerbo-Trojanowska M. Colour Doppler ultrasound assessment of well-functioning mature arteriovenous fistulas for haemodialysis access. Eur J Radiol 2005;55:113-119.

17. Campos RP, Do Nascimento MM, Chula DC, Do Nascimento DE, Riella MC. Stenosis in hemodialysis arteriovenous fistula: evaluation and treatment. Hemodial Int 2006;10:152-161.

18. Dousset V, Grenier N, Douws C, Senuita P, Sassouste G, Ada L, Potaux L. Hemodialysis grafts: color Doppler flow imaging correlated with digital subtraction angiography and functional status. Radiology 1991;181:89-94.

19. Finlay DE, Longley DG, Foshager MC, Letourneau JG. Duplex and color Doppler sonography of hemodialysis arteriovenous fistulas and grafts. Radiographics 1993;13:983-989.

20. Elcheroth J, de Pauw L, Kinnaert P. Elbow arteriovenous fistulas for chronic haemodialysis. Br J Surg 1994;81:982-984.

21. Polak JF. Peripheral arterial disease. Evaluation with color flow and duplex sonography. Radiol Clin North Am 1995;33:71-90.