Sonographic Evaluation of Renal Allograft

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Abstract
Sonography has become an integral part of the care of renal allograft recipients. It is a simple, inexpensive and readily available non-invasive imaging modality. It is indicated as the initial investigation in patients presenting with decreased urine output, pain, infection and hematuria and for doing a percutaneous allograft biopsy. While sonography confirms the diagnosis of obstructive nephropathy and perinephric fluid collections, Doppler is an effective screening modality for the detection of post-transplant vascular complications. ©

INTRODUCTION
Renal transplantation is widely accepted as the treatment of choice for patients with end-stage renal disease (ESRD). As compared to dialysis, renal transplantation gives better long-term survival rate, better quality of life and superior degree of rehabilitation.1 Ultrasonography is ideally suited for imaging kidneys. The kidneys, especially allograft, are easily visualized. The renal cortex, medulla and collecting system have different acoustic properties and are easily discernible. In addition, the safety, simplicity and low cost of ultrasonography have made it an integral part of management of transplantation.2-4

Anatomy of the normal renal transplant
The preferred site of renal allograft is in the right iliac fossa outside the peritoneum. The transplanted kidney is often placed in the contra-lateral iliac fossa to keep the ureteral and collecting system medial and thus accessible to repair. The renal artery of the donor is anastomosed end-to-side to the external iliac (or internal iliac) artery of the recipient and the renal vein end-to-side with the external iliac vein. Unusual locations include left iliac fossa, intra-peritoneal in very young children or in a combined kidney - pancreas transplant. Technical complications after renal transplantation are uncommon but can result in graft loss and significant morbidity.5,6

Imaging technique
The superficial location of the renal allograft usually permits sonographic evaluation using 3.5 to 5.0 MHz probes. The initial gray scale examination of renal transplantation includes longitudinal and transverse images of the allograft and urinary bladder. Color Doppler imaging and then duplex Doppler is required to assess any vascular complications (Figs. 1a,b).

Anatomic relationships are readily apparent on sonography. The psoas muscle and iliac vessels lie posteriorly, the ureter courses medially. The peritoneum is superior and occasionally anterior to the graft and is identified easily by peristalsis in the bowel loops.

The ureter and renal vessels often are visible even when not dilated because of the superficial placement of the allograft.7,8

Indications for sonography
* Diagnosis of fluid collection in patients with graft pain or ipsi-lateral leg edema.
* All cases of allograft dysfunction or urinary tract abnormalities
* Ultrasound guided graft biopsy
* Measurement of residual bladder volume.
* Identification of ureteral stents

Perinephric Fluid Collections
Perinephric fluid collections have been reported in up to 50% of renal transplantation,9 and virtually all clinically important collections can be detected by sonography. Their size, location and internal echoes largely determine the clinical significance of these collections. These may present as pain, swelling around the allograft, drainage from surgical site, occult blood loss and ipsilateral lower extremity swelling. However, many collections are incidental findings without any clinical symptoms (Fig. 2).

The most common fluid collection is lymphoceles with an incidence of 2% to 18%. Lymph may collect in the retroperitoneal space if lymphatic vessels are not carefully ligated during surgery and form a lymphocele. About 50% of these lymphoceles occur within the first year post-
transplantation but may occur as late as four years. On ultrasound, the lymphocele appears as a well-defined cystic area, that may be an-echoic to hypo-echoic, that is situated medial and/or inferior to the lower pole where they may obstruct the ureter and cause graft dysfunction and require surgery. Lymphoceles are generally asymptomatic and resolve spontaneously.  

Urine leaks, reported with a 3% incidence in past, are now rarely encountered. Urine leaks should be considered when collections are seen soon after surgery. Most urinomas occur within weeks of transplantation and are due to trauma to ureter or its blood supply during surgery or rarely due to rejection within the ureter. Classic signs of pain and tenderness occur in 50%, and fever in 25% of patients. Anuria with elevation of serum creatinine is a rare clinical presentation. The sonographic appearance of urinoma is variable. It is a variable sized anechoic collection, usually around the ureter or dissecting along tissue planes. It’s appearance is similar to a lymphocele, and may be distinguished by the irregular and indistinct margins owing to the lack of true wall and inflammatory reaction, and the common findings of dilatation of the collecting system proximal to the leak. The creatinine in lymph and serum are identical, whereas that in urine is substantially high and the aspiration of fluid and measuring its creatinine concentration will further help to differentiate between the two.  

Hematomas are commonly the result of surgery, percutaneous biopsy or extremely rarely, the graft fracture due to rejection. Typical ultrasound findings would be liquid (anechoic) and solid (echogenic) components. When fully organized, completely echogenic hematomas need to be differentiated from psosas muscle by flexing the leg which leads to psosas muscle contraction.  

Hematomas and serous fluid collections (seromas) usually resolve spontaneously and have little clinical significance. The major differential diagnosis of seromas is abscess which is rarely encountered and ultrasound-guided aspiration can be performed to differentiate when clinically required.  

During sonography, fluid collections need to be differentiated from urinary bladder or bladder diverticuli. Similarly care must be taken not to confuse ascites with a lymphocele or urinoma. Ascitic collections, especially in the patients on CAPD, are generally large and extend superiority and are not immediately adjacent to the allograft or ureter. Ovarian cysts may also mimic lymphoceles.  

PARENCHYMAL DISEASE  

For sonographic interpretation of parenchymal renal disease, the size and echogenicity are two important parameters. Although, the superficial location of renal allograft is helpful in its easy identification, it often hinders in exact measurements of renal size as it extends beyond the scanning sector. Additionally, significant increase in kidney size up to 40% in volume occurs after transplantation with final size attained at approximately 6 months.  

Secondly, the lack of an adjacent reference organ, such as liver or spleen, renders allograft echogenicity difficult to evaluate. Because graft biopsy is a benign, easy and safe procedure, the renal size and echogenicity usually are not considered in clinical decisions. However, as in native kidneys, small echogenic allografts indicate advanced irreversible disease.  

The most common causes of allograft failure are acute tubular necrosis (ATN), acute rejection, drug toxicity and chronic allograft nephropathy. Sonographic findings of acute rejection lack sensitivity and specificity. Allografts often appear normal in mild and even moderate cases of rejection. Although, resistive indices of blood flow using Doppler (calculated as the difference between peak systolic and end-diastolic velocity divided by the peak systolic velocity) are commonly used, these are also non-specific (Fig. 3). When present, findings may be cortical swelling and increased echogenicity, which can be quite marked in severe rejection. Allograft enlargement is fairly specific for acute rejection but has low sensitivity. Preliminary work suggests that ultrasound contrast agents (UCAs) may allow small cortical vasculature to be analyzed, and that this may be superior to resistive index determinations for diagnosing rejection.  

Two basic types of UCAs available for clinical and investigational use are the non-encapsulated and the encapsulated micro-bubbles. The potential use of intravenous UCAs include evaluating normal, increased, and decreased vascularity; detecting vascular stenosis and occlusions; improving neoplasm detection; analyzing and characterizing tumor neovascularity.  

Acute tubular necrosis is the principle cause of delayed graft function. The diagnosis of ATN can not be made or excluded by ultrasonography because of non-specific findings.  

Chronic allograft nephropathy (chronic rejection) is frequently associated with increased cortical echogenicity. Reduced size and cortical thinning are observed in late stages only.  

Glomerular disease recurrence may occur in renal allograft and the ultrasound is not of much help for diagnosing these except for ultrasound-assisted graft biopsy.  

COLLECTING SYSTEM  

Urinary obstruction typically results in hydronephrosis, a dilation of the collecting system. Grading systems have been developed to indicate the severity of hydronephrosis but are of limited clinical use.  

Obstructive nephropathy as a cause of acute allograft failure is observed in 8% of the cases. In the immediate post-operative period, obstruction may be due to blood clots, kinking or external compression of ureter by edema or hematomas. At a later stage, lymphocele and ureteral stricture are observed in most obstructive nephropathies. Rarely acute rejection within the ureter may be the cause.  

Ultrasonography is an excellent screening modality for...
obstruction with near 100% sensitivity, though specificity is lower. Because of the superficial placement of renal allograft, small degrees of calyceal separation are commonly visualized by ultrasound as compared to native kidneys.14

It is important to emphasize that hydronephrosis is only an anatomic diagnosis and does not necessarily indicate urinary obstruction. Non-obstructive calyceal dilatation in renal allograft may occur due to vesicoureteric reflux, papillary necrosis, brisk diuresis and pregnancy. There are no strict criteria to differentiate obstructive from non-obstructive hydronephrosis, however, a useful clue to urinary obstruction is dilatation of the minor calyces.17

Sonography often indicates the duration and cause of obstruction. In acute obstruction, the cortex is intact whereas chronic obstruction can lead to marked thinning of the cortex. Dilated venous system can mimic hydronephrosis and the distinction is made readily by Doppler sonography. Stones are infrequent in allograft kidneys. Care must be taken not to confuse stones with ureteral stents, the latter gives the classic appearance of two parallel echogenic lines with varying degrees of acoustic shadowing. Sonography is useful in establishing that the stent is in position, with one end in the allograft and the other in the bladder.21

**Vascular Complications**

Vascular complications account for < 10% of all, but these are an important cause of graft dysfunction. Diagnosis of vascular complications can be made by color and pulsed wave Doppler which have excellent sensitivity and specificity.
though clues may also be provided by gray scale sonography.\textsuperscript{15,22}

**Transplantrenal artery stenosis (TRAS)**

It is the most common vascular complication with a reported incidence of up to 12\%. It has been reported as early as 2 months and as late as 2 years after the transplant but in general is thought to be a late complication. The clinical suspicion is made by a new onset hypertension or worsening of the existing hypertension, bruit over graft or azotemia to ACE-inhibitors or angiotensin II Receptor blockers. Surgical anastomotic site stricture is the commonest cause of TRAS, rarely may be endothelial injury due to surgical clamp or cannulation injury during cold perfusion.

On sonography, no significant disturbance in the echo pattern of the parenchyma is observed. There is however, lack of normal post-transplant hypertrophy. The vessel must be isonated in its entire length, and abnormally elevated peak velocities and turbulent flow indicative of stenosis must be sought (Fig. 4a). The criteria for TRAS include:

* Velocities in excess of 200 cm/s
* A velocity gradient of at least 2:1 between stenotic and pre-stenotic segments
* Spectral broadening (Fig. 4b)
* Parvus - tardus waveform (Fig. 4c)

An acknowledged difficulty that precludes widespread use of ultrasound to detect renal artery stenosis is the technically demanding nature of this examination. Color flow imaging after administration of ultrasound contrast agents (UCAs) provides more rapid and complete visualization of both intra-renal and extra-renal arterial anatomy. Sonographic contrast administration has been shown to increase the percentage of diagnostic main renal artery examinations.\textsuperscript{23}

Angiography should be used for confirmation and treatment of TRAS in patients with a positive sonogram or those with inadequate or unequivocal sonograms when clinical suspicion is strong.\textsuperscript{4,24,25}

**Renal artery thrombosis**

Complete renal artery occlusion is a rare but an ominous complication occurring very early in the postoperative period and invariably results in graft loss. This can be diagnosed by Doppler sonography with near 100\% sensitivity and specificity. Absence of flow within the entire kidney or within a portion of the parenchyma can be used as a criterion for renal and segmental artery thrombosis. Thrombosis of the accessory artery is more common than thrombosis of the main renal artery though this usually is of little functional consequence.\textsuperscript{12,15}

**Renal vein thrombosis (RVT)**

This is uncommon, though more frequent in pediatric kidneys transplanted into adults, occurring within the first week after transplantation and may lead to graft loss. Sudden decline in urine output, graft tenderness and enlargement may be the clinical clues. The causes of RVT include:

* Compression by fluid collection
* Propagation of clot from the iliac vein
* Faulty surgical technique
* Hypovolemia

On gray scale imaging non-specific finding of graft enlargement and hypo-echoic cortex may be noted. Doppler finding of RVT are more characteristic (Fig. 5) and include the absence of venous flow and reversal of diastolic flow within the renal artery.\textsuperscript{14,26,27}

**Intra-renal and extra-renal arteriovenous fistulas (AVF) and pseudoenurysm**

These occur very rarely following graft biopsy and mostly are small and clinically insignificant. AVFs are easily identified using color and duplex Doppler sonography.

The size of AVF determines the clinical significant and need for intervention. These are typically the result of surgical technique and are extremely uncommon. All pseudoanurysms are considered potentially serious with hazard of rupture.\textsuperscript{15,28,29}

**Renal transplant torsion**

This is an extremely rare complication unique to intra-peritoneal graft placement, resulting from graft rotation about its vascular pedicle leading to vascular occlusion and if not corrected, leads to necrosis and graft loss. The diagnosis may be made by serial gray -scale imaging showing a change in the orientation of the kidney. Doppler findings are variable.\textsuperscript{30}

**Ultrasound-guided graft biopsy**

Ultrasound-guided biopsy is safer than the blind biopsy as injury to the major intra-renal and extra-renal vessels can be avoided and we are surer of taking a satisfactory biopsy sample from the renal cortex. For cytopathologic evaluation, fine needle aspiration biopsy under ultrasound guidance can be performed with even less risk and discomfort.\textsuperscript{31-32}

**Conclusion**

Ultrasound examination is an accurate and non-invasive scanning modality for evaluating renal allograft dysfunction. Gray-scale imaging is ideal for hydrenephrosis and perinephric fluid collections and duplex Doppler sonography readily identifies vascular complications of renal transplantation. Ultrasound guidance for biopsy or FNAC has clearly minimized the risk and discomfort to the patients. However, sonography has proved to be unsatisfactory for identifying acute rejection. Preliminary work suggests that ultrasound contrast agents may allow small cortical vasculature to be analyzed and that this may be superior to resistive index determination for diagnosing rejection. Ultrasound contrast agents may potentially be very useful for transplant evaluation.

**References**

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Announcement

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