Renal transplant Doppler: vascular complications of renal transplants

Rosalie Vis BS, RDMS, RVT

Introduction

• Indications for renal transplant Doppler
  • Surgical techniques
  • Renal Transplant Protocol – AIUM
  • Intrarenal Doppler waveforms
    – Normal & Abnormal Findings
  • Extrarenal Doppler waveforms
    – Normal & Abnormal findings
  • Post biopsy vascular complications

Indications for Renal Tx Doppler:

• Baseline after transplantation
• Decreased urine output
• Evaluate vascular patency
• BUN or creatinine: significant/rapid increase
• Hypertension (RAS) or bruit (AVF)
• Pain, fever, sepsis (pyelonephritis)
• Possible fluid collection
• Hematuria (post biopsy AVF, hydronephrosis)
• Follow-up of abnormal findings seen on prior
Surgical Techniques:

**Deceased Donor:**
- A portion of the donor aorta & IVC are left attached to the MRA and MRV
- Called a Carrel patch

**Live Donor:**
- Donor MRA and MRV are attached directly to the recipient artery and vein.
- End-to-end or an end-to-side anastomosis

Variant anatomy: two renal arteries

A. If from a deceased donor: Carrel patch
   See two anastomoses with the recipient artery

B. If from a live donor:
   The individual arteries can be joined such that there is essentially a single donor vessel at the anastomosis with recipient artery

Donor Kidney- Multiple arteries

It is helpful to read the surgical report prior to scanning a transplant.
En Bloc Renal Transplant:

- **En bloc** = together at the same time
- Kidneys obtained from donors <5 years of age
- Involves transplantation of both donor kidneys into a single recipient and using the donor aorta and vena cava for vascular anastomosis.
- The donor aorta functions as the main renal artery.
- The donor IVC functions as the main renal vein.
- Full evaluation on both kidneys

Renal Transplant Protocol - AIUM

- **Intrarenal arteries (RI):**
  - (PW) interlobar: sup, mid, inf
  - (PW) segmental: sup, mid, inf
  - color/power Doppler of parenchyma for a global assessment of perfusion
- **Intrarenal veins:** multiple
  - color and/or spectral
- **Main Renal Artery (PSV):**
  - Evaluate the entire length
  - Especially at areas with focal aliasing and anastomosis
  - Multiple angle corrected velocity measurements
- **More than one MRA?**
  - Complete evaluation on each
- **Main renal vein:**
  - entire vein + anastomosis
  - color and spectral
- **External Iliac Artery/CIA:**
  - cephalad to anastomosis
  - Color and spectral
- **External Iliac Vein/CIV:**
  - cephalad to anastomosis
  - color and spectral
- **Complete grayscale evaluation**
  - Transplant, perirenal area
  - Bladder and color of jet

Vascular Anatomy
Normal Waveform Examples
Adjust the color and spectral Doppler scale throughout exam.

Normal Intrarenal Doppler Waveform:
- Sharp early systolic peak
- Short acceleration time (<70 msec)
- Forward flow throughout diastole
- Low RI (<0.7)

Anatomy of a Spectral Doppler Waveform:
A. Point A indicates the beginning of systole
B. Point B, early systolic peak
C. Point C, peak systole
D. Point D, end of diastole.
Acceleration Time:
- Time to early systolic peak
- Point A indicates the beginning of systole
- Point B, early systolic peak
- Time - x-axis

Normal Acceleration Time (AT) is <70 msec
- Delayed acceleration time is > 100 msec

Increased Acceleration Time:
- This intrarenal Doppler finding can give a clue that a proximal stenosis may be present.
- >100 msec is abnormal

Tardus Parvus Waveform:
- Prolonged systolic upstroke (increased acceleration time) = tardus
- Diminished amplitude (decreased velocity) = parvus
- Complete absence of early systolic peak

(Resistive Index = low or high)
- This waveform is produced by a stenosis at any point proximal to the artery being studied
- Used to confirm renal artery Stenosis
Tardus Parvus Waveform:

Intrarenal tardus parvus waveforms can add specificity to the diagnosis when a MRA stenosis is identified.

Significant stenosis in external iliac artery

Measuring Resistive Index:

Indicator of renal dysfunction and downstream resistance

Caliper Placement:
Point C - Peak Systole
Point D - End Diastole

Low resistive index is normal (< 0.7)
Elevated resistive index (> 0.75)
Elevated Resistive Indices:

- Normal acceleration time (< 70 msec)
- Elevated Resistive Index (RI) (> .75)

Pulsatility Index/Tissue Pulsatility Index

Pulsatility Index is also an indicator of downstream renal resistance.

\[
\text{PI} = \frac{\text{PSV} - \text{EDV}}{\text{MeanV}}
\]

Normal values: 1.36–1.56

Increased Resistive Indices (or PI):  

- Increased RI is an indicator of:  
  - Acute/Chronic transplant rejection  
  - ATN (acute tubular necrosis)  
  - Renal vein thrombosis (a specific waveform)  
  - Graft infection  
  - Compressive perinephric fluid collections  
  - Obstructive hydronephrosis.
Acute Rejection:
Develops within 1 to 3 weeks after transplantation
Symptoms:
- Flu-like symptoms
- Low-grade fever
- Graft site tenderness
- Asymptomatic
- Rapid rise of creatinine (frequent blood draws)
Ultrasound Findings:
- Swelling of the graft
- Decreased parenchymal blood flow (arcuate, interlobar)
- Elevated Resistive Index /Pulsatility Index
Treatable if caught early – adjust immunosuppression
Requires biopsy to confirm (differential diagnosis = ATN)

Chronic Rejection:
- A progressive decline in renal function beginning 3 months or more after surgery
- May ultimately lead to renal failure
- Decrease in kidney length, thinned cortex
- Doppler features:
  - Elevated RI
  - No diastolic flow
  - Early diastolic flow reversal
- Requires biopsy

Acute Tubular Necrosis (ATN)
- Delayed function after renal transplant.
- This condition is seen more frequently when the transplant is from a cadaver.
- Delayed graft function can occur as a result of factors such as low blood pressure during CPR.
- Expect to see ATN for 10 days to a few weeks in a kidney from a deceased donor.
- Kidney may not make urine for days.
Acute Tubular Necrosis:

- Elevated resistive index
- Absent diastolic flow
- Early diastolic flow reversal
- Cannot be differentiated from rejection

Compressive perinephric fluid collections

- Page kidney phenomenon – increased resistance due to compression of the renal parenchyma by structures.
- Leads to absent or reversed diastolic flow
- Severe acute tubular necrosis can develop
- Graft loss can result if not caught early.
- May require decompression
- Example: subcapsular hematoma

Subcapsular hematoma
Renal Vein Thrombosis (RVT):

- Onset: within the first post-operative week
- Symptoms: Abrupt onset of oliguria
- Grayscale:
  - graft enlargement
  - decreased echogenicity
- More often with left renal transplants
- Arterial waveforms have a specific appearance.

Renal Vein Thrombosis:

- Reversal of flow from early diastole to end diastole (below the baseline)
  - Causes of RVT:
    - Surgical difficulty
    - Compression of the renal vein
    - Prolonged bed rest
    - Coagulation disorders
    - Propagation from extremity
- Reversal of flow limited to early diastole is seen with severe rejection or acute tubular necrosis of the graft.

Transplant Renal Vein Thrombosis - Left CIV Compression:
Renal Vein Thrombosis:
- Reversal of flow throughout diastole in main renal artery (holodiastolic flow reversal)
- The additional finding of absent venous flow is diagnostic for RVT.

Intrarenal Veins:

Normal Main Renal Artery (MRA):
- Sharp systolic upstroke
- Forward flow throughout diastole.
- Peak Systolic Velocity < 200 cm/sec
Main Renal Artery Stenosis (RAS)
Common complication
>Three months post transplant
Symptom: severe hypertension
Deceased Donor: less common
Live donors: renal artery stenosis occurs at anastomosis
Pediatric donors or recipients: due to the small size of the MRA

Main Renal Artery Technique:
• Increase the color Doppler scale so that the majority of the vessel is displayed in a solid color.
• Look for focal areas of aliasing (mosaic pattern on color image)
• Doppler angle less than 60 degrees
• Obtain multiple samples
• Record highest velocity

Main Renal Artery Stenosis:
• Obtain multiple velocities with good angle correction throughout the area of aliasing.
• Look for elevated velocities greater than 200 cm/sec.
9 times out of 10 will be over calling stenosis if only the PSV is used
**MRA/CIA Ratio**

**Significant MRA Stenosis:**
PSV MRA > 200 cm/s

(AND)
Velocity Ratio of the MRA/CIA ≥ 2.0

(AND)
Kidney has tardus parvus waveforms

**Not significant stenosis:**
If MRA is >200 cm/s

(but) Ratio < 2.0

(and) no tardus parvus

---

**Elevated MRA Velocity – Stenosis?**

1) Is the velocity in MRA >200 cm/sec? **Y/N**
2) Is the PSV in the MRA twice that of the proximal vessel (EIA or CIA) **Y/N**
3) Do we see tardus parvus waveforms in the intrarenal arteries? **Y/N**

(Tardus parvus is seen when proximal stenosis is > 80%)
Other Considerations - MRA

- Transplant renal arteries are more tortuous than native renal arteries.
- Flow normally accelerates around curves or kinks.
- Velocity is elevated when there is a small angle at the anastomosis.

Suspect that increased velocity is due to tortuosity when:
  - PSV of MRA > 200 cm/s
  - MRA/CIA ratio ≥2.0
  - Curvy vessel/small angle
  - Absent tardus parvus

Renal Artery Thrombosis (RAT)

- Rare less than 1%
- Immediately post-op/intraoperative
- Requires immediate diagnosis - thrombectomy or thrombolysis to prevent graft loss
- More common in:
  - Live donor transplant recipients
  - Complex arterial anastomoses
  - Pediatric transplants due to the small size of the main renal artery.

Renal Artery Thrombosis

Also caused by:
- Severe rejection
- Acute tubular necrosis

Doppler US shows absent arterial and venous flow.
Renal Artery Thrombosis

- Doppler Technique: Increase sensitivity for detecting slow blood flow.
  - Use power Doppler
  - low pulse repetition frequency (scale)
  - Increase color gain
  - low wall filters
- Pulsed wave Doppler is more sensitive than either color or power Doppler when determining if flow is present.

Renal Vein Stenosis:

- Renal vein stenosis is uncommon and can occur at the anastomosis
- May result from extrinsic compression
- Doppler US of the renal vein shows focal aliasing with a three- to fourfold increase in velocity compared to distal segments indicating a significant stenosis or kinking.
This is a normal waveform when obtained inferior to the renal artery anastomosis.

**External Iliac Artery:**

Inferior to the anastomosis we should see a high resistance waveform because at this point the vessel is only supplying the lower extremity.

**EIA Waveforms with Renal Tx**

• Superior to the anastomosis the EIA is supplying both the kidney and the lower extremity so we get a combination Renal/extremity waveform with forward flow throughout the cardiac cycle.

• If the kidney becomes high resistance the waveform superior to the anastomosis will reflect that and become high resistance.

**Iliac Arteries**

Tardus parvus in both external iliac arteries from a proximal stenosis in the aorta.

If the Rt EIA looks like this >>> Look at the left EIA.
Technique – Spectral Wall Filter

Use a low wall filter (color and Duplex) for slow flow.

Five-Year Survival Rate

Possible Kidney Donors:
- Parents
- Spouses
- Living unrelated donors
- Other living related
- Identical siblings
- Other siblings
- Cadavers

- Living unrelated donor kidney transplants had superior outcomes compared with cadaver transplants

Vascular Complications of Percutaneous Transplant Biopsy:
- Hemorrhage
- Hematoma
- Arteriovenous fistula
- Pseudoaneurysm
- Infarction
Hematoma:
- Abnormal connection between an artery and vein which can be created by a biopsy needle.
- Always obtain a post biopsy color Doppler image at site of needle tract.
- Relatively common
- Majority are small and insignificant
- Mosaic pattern – disorganized flow – tissue vibrations
- Can cause infarct

Arteriovenous fistula:
- Feeding artery will have high velocity, low-resistance waveform.
- The draining vein will become pulsatile – called arterialization
- Can cause hematuria when blood goes into the collecting system – may lead to obstruction of the ureter
Arteriovenous Fistulas:

- The abnormal connection between the artery and the vein can also cause a stem which may lead to ischemia and infarct.
- Color or power Doppler will show lack of vascularity.
- Similar findings can be seen in severe pyelonephritis.

Pseudoaneurysm:

- Grayscale findings similar to a simple renal cyst.
- Yin Yang sign.

Pseudoaneurysm Neck:

The pseudoaneurysm neck waveform will have a specific appearance. To-and-fro flow when the sample gate is placed in neck.
Pseudoaneurysms:

- Can be intrarenal or extrarenal
- Patient may have hematuria & low hematocrit

Conclusion:

- Renal transplant surgeons can be very creative in their approaches to surgery
- Cadaver kidney transplants have different issues than live donor transplants
- Obtaining quality Doppler waveforms is important:
  - Acceleration time/tardus parvus waveforms
  - Resistive Index/pulsatility Index
  - Flow reversal – early diastolic or holodiastolic
- Sometimes renal transplant Doppler exams truly are "stats"
- Be aware of post biopsy vascular complications
- Early detection enables earlier treatment and a better chance of saving the transplant.

Keep Calm & Fill Out Your Donor Card.
References:

- Renal Transplant Imaging and Intervention: Practical Aspects. Charles V. Zwirewich, M.D.
- Interventional Radiologic Management of Renal Transplant Dysfunction: Indications, Limitations, and technical Considerations. Katsuhiro Kobayashi, M.D.
- Intrarenal Color Duplex Ultrasonography. A Window to Vascular Complications of Renal Transplants. Jing Gao, M.D.