IMAGING IN KIDNEY TRANSPLANTATION
Agenda

- Patient OH: Initial presentation
- Kidney transplantation: Menu of tests
- Routine imaging for kidney donors
- Selected post-transplant complications
- Resistive Index
- Patient OH: Follow-up
- Summary
Agenda

- Patient OH: Initial presentation
- Kidney transplantation: Menu of tests
- Routine imaging for kidney donors
- Selected post-transplant complications
- Resistive Index
- Patient OH: Follow-up
- Summary
Patient OH: Initial presentation

- CC: 65 y.o. female with history of hypertension since early 20s, recently diagnosed T2DM, begun on hemodialysis one year prior for end-stage renal failure presents for living-related kidney transplantation
- 28 y.o. son presents as possible donor
Agenda

- Patient OH: Initial presentation
- Kidney transplantation: Menu of tests
- Routine imaging for kidney donors
- Selected post-transplant complications
- Resistive Index
- Patient OH: Follow-up
- Summary
Kidney transplantation: Menu of tests

- CT angiogram may be used to evaluate a potential donor for pathology and to define the donor anatomy
- Ultrasound is the key study for monitoring a renal transplant, and serial ultrasound is often useful
- CT may be useful as an adjunct in certain cases
- The renal transplant is easily accessed for ultrasound because of its placement in the iliac fossa, close to the skin
Site of renal transplant

Schwartz’s Principles of Surgery online
Agenda

- Patient OH: Initial presentation
- Kidney transplantation: Menu of tests
- **Routine imaging for kidney donors**
- Selected post-transplant complications
- Resistive Index
- Patient OH: Follow-up
- Summary
Routine imaging for kidney donors

- Imaging must exclude pre-existing renal pathology in the donor.
- It is important to define the anatomy of the donor, including the size of the kidneys and the number of renal arteries and veins. Approximately 20% of people have multiple renal arteries.
- Usually, the left kidney is preferred for transplantation because the left renal vein is longer and allows for easier anastomosis once transplanted into the recipient.
Axial CT of kidneys of OH’s donor

Axial CT, split bolus contrast study

No renal masses, hydronephrosis, or nephrolithiasis

Cyst on left kidney

PACS, BIDMC
Phases of CT for renal imaging

- **Corticomedullary phase**: 20 to 90 seconds after contrast administration; represents early preferential blood flow to the renal cortex
- **Nephrogenic phase**: 2 to 4 minutes after contrast administration; homogeneous opacification of renal parenchyma
- **Excretory phase**: Contrast opacifies the collecting system (5 minutes or more)
- **Split bolus study**: can be used to minimize radiation
Measurement of left renal vein from IVC

Left kidney has single renal vein and artery
Right renal artery and SMA with common origin

View of donor right kidney on coronal reconstruction

Measurement of right renal artery from aorta

Right renal artery and SMA with common origin
3D digital reconstruction of donor kidneys, anterior view
3D digital reconstruction of donor kidneys, posterior view
Patient OH: Surgical course

- The donor surgery was performed laparoscopically; the recipient’s surgery was delayed because of hyperkalemia of 7.0.
- While the recipient underwent urgent dialysis to treat her high potassium, the kidney was placed on ice and was exposed to prolonged cold ischemia time.
- Once the recipient surgery began, the renal vein was anastamosed successfully, but the renal artery anastamosis was complicated by iliac artery dissection. This required the kidney to be removed and placed on ice while a segment of the iliac artery was resected, exposing the transplant to additional cold ischemia time.
Agenda

- Patient OH: Initial presentation
- Kidney transplantation: Menu of tests
- Routine imaging for kidney donors
- **Selected post-transplant complications**
- Resistive Index
- Patient OH: Follow-up
- Summary
Post-transplant complications

1. Parenchymal transplant pathology
   - Acute tubular necrosis
   - Acute and chronic rejection
   - Infection

2. Pre-renal problems
   - Arterial thrombosis
   - Renal artery stenosis
   - Venous thrombosis
   - Renal vein stenosis
Post-transplant complications

3. Post-renal
   - Obstruction of calyceal system or transplanted ureter

4. Fluid collections
   - Hematoma
   - Urinoma
   - Lymphocele
   - Abscess
Comparison patient 1: Graft infection

Mild thickening of the urothelium
Dilated calyces

Transverse ultrasound
PACS, BIDMC
Image courtesy of Dr. Robert Kane
Imaging characteristics of graft infection

- Infection can result from ascending infection, hematogeneous seeding, or contiguous spread
- Diagnosis typically made clinically, as no radiologic changes may be seen
- When changes are present, they may include:
  - Focal or diffusely granular, echogenic renal cortex
  - Loss of corticomedullary junction
  - Thickening of perirenal fat
  - Uroepithelial thickening
  - Dilated calyces
- Ultrasound may also be used to exclude perinephric abscess
Comparison patient 2: Fluid collection

Sagittal ultrasound
PACS, BIDMC

Fluid collection
Transplanted kidney

Image courtesy of Dr. Julia Rissmiller
Imaging characteristics of fluid collections

- Perinephric collections are demonstrated in up to 50% of transplant recipients
- Clinical findings often required to help differentiate between hematoma, urinoma, lymphocele, and abscess; appearances are non-specific
- 6% of patients will develop a urinoma (from anastomotic leaks or ureteric ischemia); on ultrasound, well defined, anechoic, may be associated with hydronephrosis
- Hematoma: small, perirenal; echogenic heterogeneous solid mass acutely; later complex cystic structure with internal echoes, strands, or septations
- 15% will develop a lymphocele (result of surgical disruption of the iliac lymphatics, occurs 4-8 weeks post surgery); well defined, anechoic or with fine internal strands
Agenda

- Patient OH: Initial presentation
- Kidney transplantation: Menu of tests
- Routine imaging for kidney donors
- Selected post-transplant complications
- Resistive Index
- Patient OH: Follow-up
- Summary
Resistive Index: Measured on ultrasound

- A measure of resistance to arterial flow within the renal vascular bed
- Normal 0.7-0.8
- >0.9 concerning for graft dysfunction, especially renal vein thrombosis or ATN

$$RI = \frac{\text{Peak systolic velocity} - \text{Lowest diastolic velocity}}{\text{Peak systolic velocity}}$$
Resistive Index: Graphic depiction

\[
\text{Resistive Index (RI)} = \frac{\text{Peak Systolic Velocity} - \text{Lowest Diastolic Velocity}}{\text{Peak Systolic Velocity}}
\]

\[
\text{(RI)} = \frac{S - D}{S}
\]

http://www.radiology.co.uk/srs-x/tutors/renaltx/ren2.htm
Companion patient 3: Normal doppler flow

PACS, BIDMC

Normal resistive index of 0.76

Systolic upstrokes should be sharp

Color doppler ultrasound
Agenda

- Patient OH: Initial presentation
- Kidney transplantation: Menu of tests
- Routine imaging for kidney donors
- Post-transplant complications
- Resistive Index
- Patient OH: Follow-up
- Summary
Patient OH: Ultrasound 1 hour post-transplant

Medullary pyramids are hypoechoic
Hyperechoic fat of renal sinus
Cyst

Normal appearance of kidney on ultrasound
Patient OH: Doppler ultrasound of kidney 1 hour post-transplant

Doppler waveforms normal, but with blunted systolic upstrokes in segmental arterial branches.

Resistive index here on low side, due to smaller difference between systolic and diastolic flow.
Patient OH: Doppler ultrasound of renal artery and vein 1 hour post-transplant

Patent renal artery and vein
Patient OH: Doppler ultrasound of renal artery and vein 5 hours post-transplant.

Parvus and tardus waveforms concerning for stenosis.

Note scale changes.
Patient OH: Delayed graft function

- Though kidney transplants should begin functioning immediately after transplant, the patient was anuric overnight
- ATN is commonly the cause of delayed graft function, but renal artery thrombosis must be considered, as the latter requires emergent intervention to save the transplanted kidney
- Ultrasound is useful in assessing for flow within the renal artery and renal parenchyma
Patient OH: Doppler ultrasound of kidney post-op day 1 after 12 hours anuric

Very diminished arterial flow

No diastolic flow identified
Ultrasound findings were concerning for renal artery thrombosis, as there was significantly diminished flow in the renal artery.

The earlier findings of parvus and tardus waveforms were consistent with this diagnosis, as a thrombosis or a stenosis of the renal artery can result in tardus and parvus waveforms.

The patient returned to the OR emergently for thrombectomy.
Patient OH: Intraoperative ultrasound

- Initial thrombectomy was performed via arteriotomy with Fogarty embolectomy
- Intraoperative ultrasound was then performed

Thrombus seen in longitudinal view of artery

Cavity filled with saline for intraoperative ultrasound
Patient OH: Color doppler, intraoperative ultrasound

Thrombus seen in longitudinal view of artery.
Patient OH: Intraoperative color doppler post-thrombectomy

- Thrombectomy was repeated, resulting in improved flow

Improved flow following second thrombectomy but with residual intra-graft thrombus (not visible in this image)
Patient OH: Color doppler ultrasound morning following thrombectomy

Intrarenal vascularity nearly undetectable

Color doppler ultrasound, sagittal view

PACS, BIDMC
Patient OH: Color doppler ultrasound, morning following thrombectomy

Color doppler ultrasound, sagittal view

PACS, BIDMC
Patient OH: Doppler ultrasound, morning following thrombectomy

Reversal of diastolic flow in grossly patent renal artery suggests internal resistance to flow
Patient OH: Post-transplant nephrectomy

- Based on the serial ultrasounds, the transplanted kidney was determined to not to be viable, as evidenced by the lack of renal blood flow.

- The decision was made to perform a transplant nephrectomy. Radiologic imaging was critical in balancing the two important elements in clinical decision making. On one hand, the failure of the kidney was extremely disappointing to the recipient and to the family, especially to the recipient’s son, who was still in the hospital recovering from his operation. At the same time, the patient was at high risk for organ necrosis, infection, sepsis, and even death, given the significant immunosuppression she had received prior to the operation. The radiologic imaging guided the surgical team in this clinical decision making.

- Following the removal of the transplanted kidney, the patient recovered from the operation, was discharged from the hospital, and resumed dialysis.
Agenda

- Patient OH: Initial presentation
- Kidney transplantation: Menu of tests
- Routine imaging for kidney donors
- Resistive Index
- Selected post-transplant complications: Key findings
- Patient OH: Follow-up
- Summary
Summary

- Kidney donors require CT angiogram for assessment of renal artery and vein length and preexisting renal pathology.
- Ultrasound is the preferred imaging modality for evaluation of kidney allografts following transplantation.
- Post-transplant complications can include parenchymal transplant pathology, pre-renal problems, post-renal obstruction, and fluid collections.
- Nearness of ultrasound probe to kidney in pelvic location or in intraoperative study optimizes images.
- The resistive index can be calculated using doppler ultrasound; a high resistive index is concerning for renal vein thrombosis or ATN.
- Renal artery thrombosis is a rare but devastating complication, often resulting in graft loss.
- Complications of the renal artery may produce parvus and tardus waveforms on Doppler ultrasound.
References


Acknowledgments

- Dr. Gillian Lieberman
- Maria Levantakis
- Dr. Robert Kane
- Dr. Adam Jeffers
- Dr. Dan Siegal
- Dr. Iva Petkovska
- Laurie Sammons