Duplex Ultrasound of the Renal Arteries

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Duplex Ultrasound

- Developed in the 1970s by Eugene Strandness and others at University of Washington
- Combines B-mode imaging with Doppler velocity spectral analysis and color Doppler imaging to evaluate blood flow and vascular pathology
- Forty year history of success as a safe and accurate noninvasive diagnostic tool

In the Beginning

- Early work on renal duplex ultrasound
Renal Artery Anatomy

- A “busy” area of the retroperitoneum
  - Superior mesenteric artery
  - Renal vein
  - IVC
  - Duodenum
  - Pancreas
- Multiple renal arteries present in 20% of humans – size and pattern vary; may arise anywhere along mid-distal aorta

Finding the Artery
The Nephron

- Afferent arteriole
- Glomerular capillaries
- Efferent arteriole
- Glomerular capsule
- Renal tubule and collecting duct containing filtrate
- Peritubular capillary

The Glomerulus

Diseases of the Renal Arteries

- Atherosclerosis
- Fibromuscular Dysplasia
- Thromboembolism
  - Dissection
  - Aneurysm
  - Coarctation
- Post-transplant
Vascular Diseases of the Kidneys

- Renal Artery Stenosis
- Renal Artery Aneurysm
- Renal Artery Embolism
- Nephrosclerosis
- Glomerulosclerosis
- Vasculitis - Autoimmune

Renovascular Hypertension

**WHAT IT IS:** A clinical syndrome of hypertension caused by reduction of renal arterial flow severe enough to activate the renin-angiotensin-aldosterone axis

**WHAT IT ISN'T:** Hypertension in the presence of renal artery stenosis

**HOW TO MAKE THE DIAGNOSIS**

- Easy Part: Identify a “significant” renal artery lesion
- Difficult Part: Verify activation of the renin-angiotensin-aldosterone system
Renovascular Hypertension

- Patient Profile
  - New onset HTN at extremes of age
  - Accelerated hypertension
  - Refractory hypertension
  - Hypertension + Worsening renal function
  - Hypertensive crisis
  - Flash pulmonary edema
  - Documented diastolic BP consistently > 100 mmHg
  - Caucasian ethnicity

Renovascular Hypertension

- Methods for renal artery imaging
  - Duplex ultrasound
  - CTA, MRA, DSA

- Methods to assess R-A-A axis
  - Plasma renin or aldosterone assay
  - Selective renal vein renin sampling
  - Radionuclide flow/function studies

Renal Artery Duplex

- CAN:
  - Assess renal size
  - Detect stenosis
  - Assess medullary and cortical flow
  - Detect other pathology – aneurysm, cyst, etc.

- CANNOT:
  - Provide proof of renovascular hypertension
  - Provide a tissue diagnosis for parenchymal disease
Indications for RA Duplex

- Abdominal bruit
- Refractory Hypertension
- Renal Insufficiency
- Unilateral small kidney
- Prior renal artery intervention

Renal Artery Scan Protocol

- High resolution system
- 3-5 MHz linear and curved array transducers
- Fasting patient
- Midline or flank approach
- Measure pole-pole length
- Flow velocities (PSV, EDV) in proximal aorta, main renal arteries, cortex and medulla
- Color flow of segmental and parenchymal arteries
RENAL ARTERY – Normal Waveforms

Waveform Curiosities:
Early and Late Systolic Peaks

Diagnostic Parameters

• Velocity spectral analysis
  - Peak systolic velocity (PSV) in proximal aorta
  - Peak systolic velocity in main renal artery – proximal, mid, distal
  - Renal-aortic ratio (RAR) = PSVrenal/PSVaorta
  - PSV and end-diastolic velocity (EDV) in cortical and medullary vessels
• Presence of post-stenotic turbulence
• Color duplex flow patterns including aliasing
• Overall patterns of parenchymal flow and various flow indices
Renal Doppler Parameters

RENAL ARTERY DOPPLER (ABNORMAL WAVEFORMS)

Direct vs. Indirect Criteria

• DIRECT:
  • PSV within stenosis
  • Renal-aortic ratio
  • B-mode spectral, and color-flow findings

• INDIRECT
  • Distal RA and parenchymal waveform analysis
  • Acceleration and flow indices
Systolic Acceleration

- Acceleration Time (AT) - measured from end of diastole to peak of systole; normal variously defined as <70-100 msec
- Acceleration Index – defined as
  \[ \frac{PSV-EDV}{AT} \]
  Normal <300 cm/sec²

Parenchymal Flow

Renal Duplex Indices

- Pulsatility Index = \[ \frac{PSV-EDV}{\text{Mean velocity}} \]
- Resistive Index = \[ \frac{PSV-EDV}{PSV} \]
- Diastolic ratio = \[ \frac{EDV}{PSV} \]
Doppler Indices

- Resistive Index: normal range 0.3 – 0.7
- Pulsatility Index: normal < 1.3

RENAL DOPPLER PARENCHYMAL WAVEFORMS

NORMAL PARENCHYMAL SIGNALS
ABNORMAL PARENCHYMAL SIGNALS

Diagnostic Criteria

- Atherosclerosis: usually occurs at orifice of renal artery or proximal third of main RA
  - PSV > 180 cm/sec in proximal renal artery
  - Renal-aortic ratio > 3.5
  - Post-stenotic turbulence
  - Color aliasing
- Fibromuscular Dysplasia: usually occurs in mid- to distal renal artery
  - Use renal artery PSV velocity ratio > 2
RENAL ARTERY STENOSIS
ANGIOGRAPHY/DUPLEX CORRELATION

Angiography and Duplex correlate and demonstrate a severe >60% stenosis.

Renal Fibromuscular Dysplasia

Because lesion is not orificial, do not use RAR or "traditional" criteria for FMD.

Ratios within the renal artery can be useful. Doubling of velocities correlates with >50% stenosis.

FIBROMUSCULAR DYSPLASIA
Treatment of Renovascular HTN

- Medical
- Interventional
  - Renal artery bypass
  - Renal artery stent angioplasty
  - Renal denervation
- At this point there is major ongoing controversy over the relative efficacy of medical vs interventional management of RVH

Renal Denervation

For resistant hypertension, with intolerance or inefficacy of three or more antihypertensive drugs (incl. a diuretic) proven by ambulatory BP monitoring

- No secondary causes of hypertension
- No history of renal artery angioplasty or stent
Renal Denervation

Box 1 Unmet needs in RDN

- Randomized blinded studies
- Use of 24-h ABPM to enroll patients and to assess BP reduction
- Comparison of RDN efficacy and safety when using different procedures
- Long-term maintenance of efficacy and safety
- Impact in morbidity and mortality reduction
- Cost-benefit balance studies
- Standardized certification of RDN centers

Summary

- Duplex ultrasound of the renal arteries is reasonably accurate for identifying vascular pathology such as atheroma, FMD, aneurysm, and dissection
- Advantages are safety, noninvasive, inexpensive, portable, repeatable
- The test of choice for initial evaluation or screening
- Management of renal artery stenosis has always been controversial; no definitive evidence-based guidelines