Duplex Ultrasound of the Renal Arteries

DIMENSIONS IN HEART AND VASCULAR CARE 2013
PENN STATE HEART AND VASCULAR INSTITUTE

ROBERT G. ATNIP MD
PROFESSOR OF SURGERY AND RADIOLOGY

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

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

Renovascular Hypertension

- 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

- PSV aorta
- PSV stenosis

## Renal Artery Doppler (Abnormal Waveforms)

- Renal artery stenosis
- Post stenotic turbulence
- Dampered flow signal

## Direct vs. Indirect Criteria

<table>
<thead>
<tr>
<th>Direct</th>
<th>Indirect</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSV within stenosis</td>
<td>Distal RA and parenchymal waveform analysis</td>
</tr>
<tr>
<td>Renal-aortic ratio</td>
<td>Acceleration and flow indices</td>
</tr>
<tr>
<td>B-mode spectral, and color-flow findings</td>
<td></td>
</tr>
</tbody>
</table>
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 
  \[
  \frac{[\text{PSV-EDV}]}{\text{AT}}
  \]
  Normal <300 cm/sec²

Parenchymal Flow

Renal Duplex Indices

- **Pulsatility Index** = \([\text{PSV-EDV}] / \text{Mean velocity}\)
- **Resistive Index** = \([\text{PSV-EDV}] / \text{PSV}\)
- **Diastolic ratio** = \(\text{EDV}/\text{PSV}\)
**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.
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

ESH Position Paper: Renal denervation – an interventional therapy of resistant hypertension


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
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

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