Epidemiology

Hypertension
- Affects 60 million Americans

Essential HTN
>95% of cases

Secondary HTN
1-5% of cases

Renovascular HTN
*accounts for majority of cases of secondary HTN

Other Causes:

Hyperaldosteronism

Cushing's Syndrome

Pheochromocytoma

Aortic Coarctation
Physiology of RAS

RAS $\rightarrow$ $\downarrow$ RBF $\rightarrow$ $\uparrow$ Renin $\rightarrow$ $\uparrow$ AII

Hypertension
Efferent Arteriolar Vasoconstriction
Maintains GFR!!

Key: RBF=Renal Blood Flow
AII=Angiotensin II
GFR=Glomerular Filtration Rate

If this compensatory mechanism fails, patient will experience renal failure!!
Clinical Presentation of RAS

- Onset of HTN in patient >60 or <20 y.o.
- Acute rise in B.P. above stable baseline
- Acute elevation in plasma creatinine
- Abdominal bruit
- Atherosclerotic disease (PVD, CAD)
- Unilateral small kidney (<9cm)

Patients presenting with any of the above findings warrant further evaluation for RAS…
Major Forms of RAS

1) Atherosclerotic
   - Accounts for 90% of cases of RAS
   - Often associated with diffuse atherosclerotic disease
   - Usually involves ostium and proximal 1/3 of renal artery
   - Progressive: unilateral → bilateral

2) Fibromuscular Dysplasia
   - Classically seen in young women
   - Etiology unknown
   - Can affect intima, media or adventitia of vessel
   - Involves distal 2/3 of renal artery and segmental branches
   - Aneurysmal appearance on angiography
Anatomy

Main Renal Artery
Segmental Arteries
Interlobar Arteries
Medulla (pyramids)
Minor Calices
Cortex

“Patient E.O.”

- 90 y.o. woman with a h/o CAD, CHF, HTN and hypercholesterolemia
- Over a period of 6 months, her previously well-controlled HTN has progressed and is currently refractory to treatment with maximum dosages of 4 antihypertensive medications
- Additionally, during this time, her Creatinine has increased to 1.5 from a baseline of 1.0-1.2
- No Abdominal bruit was detected on examination
Work-up of suspected RAS

Menu of tests

Invasive
- Conventional Angiography

Non-Invasive
- MR Angiography
- Renal Scintigraphy
- Doppler Ultrasound
MR Angiogram (MRA)

**General**
- 3-D anatomic reconstruction using MRI
- Sensitivity=100%; Specificity=96%

**Advantages**
- Excellent anatomic visualization (especially w/ gadolinium)
- Non-invasive, no contrast, no ionizing radiation

**Disadvantages**
- Costly
- Limited availability
- Claustrophobia
MRA of Patient E.O.

- MRA clearly demonstrates bilateral stenosis of proximal Renal Arteries

- Stenosis of Right Renal Artery
- Stenosis of Left Renal Artery

MRA clearly demonstrates bilateral stenosis of proximal Renal Arteries
MRA of Another Patient

Celiac Trunk
Superior Mesenteric Artery
Left Renal Artery with focal stenotic lesion
Right Renal Artery
Enlargement of Infrarenal Aorta (~4.2cm)

Click for 3-D Animation and Labels!
Renal Scintigraphy

General
- Assesses differential renal blood flow using Tc99m-MAG3, a compound that is NOT filtered, but IS secreted.
- PPV=85%; NPV=90% (in high risk patients)

Advantages
- Most Functional Study
- Preferred method in suspected Fibromuscular Dysplasia
- Non-invasive, no contrast

Disadvantages
- Poor at detecting Bilateral RAS
- Not as useful in elderly, as their HTN tends not to be renin-dependent
- Poor NPV
- Some exposure to radioactivity
**Renal Scintigraphy**

**Pre ACE Inhibitor**

This is a pre ACE Inhibitor renal scan of a patient with RAS. Notice that uptake and excretion of Tc99-MAG3 is symmetrical in the two kidneys. Thus, this patient is well-compensated and is able to maintain GFR.
Renal Scintigraphy

• After administration of an ACE Inhibitor, notice that the right kidney (on your right-hand side! As these are posterior views) has normal uptake and excretion, while the left kidney demonstrates significant retention of Tc99-MAG3, with impaired excretion. This implies a drop in GFR in the left kidney, and is a positive test for RAS.
Renal Scintigraphy in action...

Post ACE Inhibitor

- Again, notice that there is marked asymmetry in function between the two kidneys, with normal uptake and excretion by the right kidney, but significant retention of radiolabeled MAG3 by the left kidney, with little or no excretion. Once again, this is a positive scan for RAS of the left renal artery.

Courtesy of Dr. Donohoe, BIDMC.
Doppler Ultrasound

General

- Evaluates post-stenotic, intra-renal vessels for alterations in normal renal waveforms
- PPV=99%; NPV=97% (in high risk patients)

Advantages

- Functional & Anatomic
- Inexpensive
- Non-invasive, no contrast, no ionizing radiation

Disadvantages

- Time-consuming (often >1-2 hours)
- Highly operator-dependant
- Limited by obesity and bowel gas
Doppler Ultrasound of Renal Arteries

Right Renal Artery

Abdominal Aorta

Left Renal Artery

Doppler Ultrasound Waveforms

Normal waveforms

- Rapid upstroke & early systolic peak (arrow)

RAS waveforms

- “Tardus & Parvus” waveform, i.e. slowed upstroke and low amplitude peak

⭐ Quantitative characterization of waveforms has not proven to be more sensitive than “pattern recognition” in doppler ultrasound detection of RAS.
Conventional Angiography

**General**
- Gold Standard
- “Digital Subtraction” angiography has allowed for use of decreased volume of contrast

**Advantages**
- Anatomic
- Allows for immediate intervention (PTCA/stent)

**Disadvantages**
- Invasive
- Iodinated contrast can be nephrotoxic in patients with renal failure!
- Exposure to ionizing radiation
…Back to our Patient “E.O.”:

• Given her clinical scenario of worsening HTN and renal function, along with the finding of bilateral RAS on MRA, the decision was made to proceed to Angiography for further imaging and possible intervention.
EO: Digital Subtraction Angiography

- A catheter is advanced through E.O.’s Left Femoral Artery into the upper Abdominal Aorta
- Contrast is injected, allowing for visualization of anatomy of Aorta, Renal Arteries, etc.
- Digital Subtraction involves “subtracting” an initial scout image (no contrast) from the aortogram, providing enhanced vascular detail

Bilateral Stenosis of Renal Arteries
EO: Angioplasty

- This fluoroscopic image shows the positioning of a guidewire in a segmental renal artery

- Contrast in collecting system

- Black dots represent proximal and distal ends of angioplasty balloon on catheter that has been advanced over guidewire into left renal artery

PACS, BIDMC.
EO: Angioplasty

- Injection of contrast allows for visualization of angioplasty balloon in relation to stenotic lesion

- 3 and 5 mm angioplasty balloons are then serially inflated

- A Corinthian stent, mounted on a 5 mm balloon, was then positioned and inflated
EO: Stent Placement

Stent
EO: S/P Stent Placement

- Upon injection of contrast, correction of stenosis is confirmed visually.
- In addition, pre- and post-procedure pressure measurements are compared:
  - Aortic Pressure = 159/49
  - Post Stenosis L. Renal Artery Pressure:
    - Prior to PTCA/Stent = 43/31
    - After PTCA/Stent = 172/55
- Similar stenting was carried out in the R. Renal Artery.
- Post-op, E.O. experienced return of both BP and Creatinine to her previous baseline.
Patient 2: Characteristic Angiographic appearance of Fibromuscular Dysplasia

- Beaded, aneurysmal appearance of distal Right Renal Artery in a young woman with refractory HTN and Fibromuscular Dysplasia

This figure represents one author’s algorithm for the evaluation of suspected RAS. However, as you have gathered from Patient E.O., there is considerable variability involved in how suspected cases of RAS are worked-up by various physicians, reflecting the controversy of the field.
References

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