Understanding the Role of US in Hypertension

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I have nothing to disclose

Objectives

• Discuss how to have a successful renal arterial study
• List some technical tips
• Discuss the limitations
Background

• Approximately 29% US population and 19% of Canadian population suffer from hypertension
  – Primary hypertension most common cause
• 1-6% have underlying renal disease as cause
  – Long term prognosis of these patients is worse than patients with primary hypertension
• Bilateral lesions 30% of population
• Prevent loss of renal mass and function

Pathophysiology

• 90% of cases attributable to atherosclerosis
  – Ostium and proximal 1/3 of the artery
  – 15 – 20% of patients will have lesions distally
• Risk Factors
  – Age, hypertension, tobacco use, coronary artery disease, peripheral vascular disease, hyperlipidemia, diabetes

• Fibromuscular dysplasia (FMD) is second most common cause
  – Less frequent
• Middle and distal renal artery
  – Can extend into the branches
• Bilateral 50%
  – If unilateral usually right side
• Responds well to angioplasty
Clinical Presentation

- Abrupt onset or worsening of chronic hypertension uncontrolled by medical therapy
- ACE inhibitor induced azotemia
  - Increased BUN and creatinine
- Unexplained renal insufficiency
- Discrepant renal size on renal US
- Abdominal bruit

Contrast Angiography

- Diagnostic study of choice
- Invasive, with a 3-5% complication rate
- Not advisable in patients with renal insufficiency
- Not a screening test, but usually in association with intervention

Non Invasive Imaging

- CTA
  - Nephrotoxic agent
  - Sensitivity 89% and specificity 99%
- MRA
  - Expensive
  - Sensitivity and specificity > 90%, can overestimate degree of stenosis
- Both useful as secondary confirmatory studies

MRI and CT

- Both are great for diagnosing RAS
- Concerns with radiation for CT
- Concerns with contrast media for both
- MRI not as good for mid to distal artery – FMD
- MRI may need to sedate patient
  - Pediatrics
  - "Anxious " Adult

Ultrasound

- Accuracy 90%
- Non invasive
- No radiation or contrast
- Less expensive
- Exam of choice in the initial evaluation for RAS

Pros of Ultrasound

- Non-invasive
- Accepted and well tolerated by patients
- Does not use contrast
- Widely available
- Portable
- Pediatric
  - No need for sedation
- Cost savings
Cons of Ultrasound

- Operator dependent
- Long scan times
- Sensitivity and specificity
  - Low of 50 - 60%
  - High of > 90%
    - European
    - North American
    - Various authors
- European
  - High of > 90%
- North American
- Use sonographers
- Various authors

Secrets for Success

1. Sonographer
   - Must have drive
   - Be dedicated
   - Have volume to keep skills

2. Time
   - 90 -120 minute studies
   - Improper scheduling
     - Leads to failure
     - Frustrates sonographer
     - Lead to increased health care costs
       - Referred to MRI

Understand Vascular Anatomy

- First lateral branch off of aorta
- Originate just distal to origin of SMA
- Right renal artery passes underneath the IVC
- Left more superior in location
- Renal veins are anterior to arteries
Renal Arterial Anatomy

- At hilum the main renal artery divides into anterior and posterior segmental arteries
- Segmental arteries become the interlobar arteries
  - Course alongside the renal pyramids

Renal Arterial Anatomy

- Interlobar arteries branch into arcuate arteries at corticomedullary junction
- Arcuate arteries travel across the top of renal pyramids and give rise to interlobular arteries
  - Tiny parenchymal branches that course toward the kidney surface

Renal Arteries

- 20 - 30 % of cardiac output
- Right renal artery is longer than left
Renal Arteries

- Renal vein is anterior to artery
- Low resistance signal

Protocols

- Based on standards and scanning guidelines of ultrasound societies and accrediting organizations

Why NPO??

- For reducing bowel gas in upper intestinal tract
- If not NPO in AM either just do it or reschedule
  - Do not make NPO and do later in day
What causes gas?

• Swallowed air
  – Eating
  – Drinking
  – Chewing gum
  – Swallowing saliva
  – Talking
• Normal breakdown of certain undigested foods in intestine

Renal Duplex

• Gray Scale
  – Longitudinal
  – Medial
  – Midline
  – Lateral
  – Transverse
  • Up
  • Mid
  • Low
  – Kidneys
  • Length
    – 9–12 cm
  • Echogenicity
  • Pathology

• Color
  – Renal perfusion
  – Locating vessels
  – Angle correction guidance
  – Locate areas of aliasing

• Power
  – Renal perfusion
  – Origin of arteries
  • Less angle dependent
Spectral Doppler

- Angle corrected and peak velocity measured
  - Aorta
    - Level of Renal Artery
    - Distal to SMA
  - Renal Artery
    - Origin / Proximal
    - Atherosclerotic
    - Mid
    - FMD
    - Distal
  - Track entire vessel looking for highest velocity
- Acceleration Time and / or Index measured and angle corrected peak systolic velocity
  - Intrarenal
    - Upper
    - Mid
    - Lower
  - Renal Vein
    - Spectral Doppler signal

Track Entire Length of Artery

Intrarenal Signals
Diagnosis of Renal Artery Stenosis

- Elevated Peak Systolic Velocity
  - Peak systolic velocity of > 200 cm/sec suggested for 60% stenosis
  - Sensitivity 85% and specificity 92%
- Elevated Ratio of Peak Systolic Velocity in the renal artery compared to aorta
  - Key ratio: 3.5
  - 91% sensitivity and 91% specificity
- For fibromuscular dysplasia some use 2:1 ratio for > 50% stenosis
  - Atnip RG, Dimensions in Heart and Vascular Care 2013

Direct Diagnostic Criteria

- > 60% stenosis:
  - PSV 180-200cm/sec
  - RAR 3.5
  - House - AJR:1999:761
**RAS: Peak 290 cm/sec**  
Aorta: 80 cm/sec  
RAR: 3.6

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**RAS Indirect Evaluation**

- Intra-renal waveform pattern  
- Large sharply defined waveforms  
  - Posterior lateral scanning  
  - Use segmental arteries  
  - Get kidney close to transducer


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**Indirect Diagnostic Criteria**

- Indirect (intrarenal) evaluation:  
  - Prolonged acceleration time of 70 ms or 0.07 sec  
  - Parvus tardus waveform  
  - Its absence does not exclude RAS

Intarenal Artery Waveforms

Types A and B
- Normal
- Sharp systolic upstroke
- Early systolic peak (which may be different than the peak systolic velocity)

Type C
- Abnormal
- Rounding of the waveform
- Slow systolic upstroke

Soulez et al, Radiographics 2000

Intrarenal Acceleration Time

- In renal artery stenosis, there may be loss of the early systolic peak and so measurement should be made at the first point of deflection.
- Parvus tardus waveform

Soulez et al, Radiographics 2000

Normal Waveforms

RAS on left. AT > 105 ms

Measuring AT and AI

• Use faster sweep speed to stretch out signal for more accurate measuring

How We Use Both Criteria

• Direct
  – See area of stenosis
• Indirect
  – Portable exams
  – Technically limited exams
  – Compare upper, mid, and lower poles
    • If all normal
      – Probably not a hemodynamically significant stenosis
    • If one area is abnormal
      – Look for stenotic accessory or segmental artery
Renal Artery Duplex

• Why do this dreaded examination?
  – Long exam
  – Tedious
  – Fight for your images
  – They get a CT or MRI anyway
  – The patients get impatient
    • I get impatient
    – I am exhausted by the end of the study
    – Could do more patients in the same time frame

Renal Artery Duplex

• Why do this dreaded examination?
  – Challenging
  – Test your skills
  – Every patient is different
  – Rewarding
    • Especially when we prove we are equal to or better
      then CTA or MRA
    – Nothing like the sound of a high grade stenosis
    – Best interest of the patient
      • No renal killing contrast agent
      – Fun!!
        • Beats scanning gangrenous toes!

Hypertension

• Defined as blood pressure > 140/90
• Is a risk factor for
  – Cardiovascular disease
    • Myocardial infarction
    • Heart failure
    • Aneurysms
  – Stroke
  – Renal failure
  – Eye damage
  – Shortened life expectancy
Hypertension

- **Primary hypertension**
  - 90-95% of patients
  - No specific medical cause can be found
    - Multiple factors
      - Stress
      - Visceral obesity
      - Potassium deficiency
      - Salt sensitivity
      - Vitamin D deficiency
      - Genetics
        - 30% of patients

- **Secondary hypertension**
  - Results from an identifiable cause
    - Cushing’s syndrome
    - Hyperthyroidism
    - Hypothyroidism
    - Pheochromocytoma
    - Cocaine use
    - Renal artery stenosis

Renovascular Hypertension

- Hypertension primarily caused by renal artery stenosis
- 1 - 10% of hypertensive patients
- Most common curable cause
- Renal disease can cause hypertension, but hypertension can also cause renal disease
  - We need to check out those kidneys and flow

Renovascular Hypertension

- Narrowed renal artery impairs circulation of blood to kidney
- Deprivation of blood stimulates the kidney to produce the hormones, renin and angiotensin
- These hormones, along with aldosterone from the adrenal gland, cause constriction and increased stiffness in the peripheral arteries
- Results in high blood pressure
Effects of Hypertension on Kidneys

• Damages intrarenal vessels
• Stops removing waste and extra fluid
• Causes BP to raise even more
• Renal failure
  – HTN one of leading causes

Clinical Indications for RAS

• Hypertension difficult to control
• Hypertension associated with renal failure
• Severe hypertension
  – Diastolic blood pressure >110 mm Hg
• Onset of hypertension before age 30 or after age 50
• Sudden onset of hypertension
• Generalized atherosclerosis
• Abdominal or flank bruit

Renal Artery Stenosis

• Atherosclerosis
  – Plaque causing narrowing
  – Men > Women
  – Typically affects > 40 years
  – Involves origin and proximal renal artery

• Fibromuscular Dysplasia
  – Pattern of arterial wall thickening alternating with areas of small aneurysmal dilatation
    • String of pearls
  – Women > Men
    • 3:1
  – Average age 30 - 40 yrs
  – Most commonly affects mid to distal renal artery
    • Secondly affects internal carotid artery
Management of Renal Hypertension

- Medical Management:
  - Combination of
    - Blood pressure control
    - Lipid lowering medication
    - Antiplated therapy
- Interventions:
  - Renal Angioplasty
  - Renal Stenting

Renal Artery Exam

- One of the most technically challenging exams
  - Deep arteries
  - Small arteries
  - Move with respiration
  - Covered by gas
  - Origin usually around 90°

Need the Right Equipment

- Transducers
  - Types
    - Curved linear array
      - Push bowel gas out of the way
    - Phased or vector array
      - Getting between ribs
  - Frequencies between 2-5 MHz
Think About Image Optimization

- Gray Scale Controls
  - Harmonics
  - Compound Imaging
  - Dynamic Range
    - Make image contrasty to bring out arteries

Think About Image Optimization

- Doppler Controls
  - Color velocity scale
    - Increase to accentuate elevated velocities
    - Eliminates venous flow
  - Color and Doppler gain
    - Sometimes overlooked
  - Color Priority
    - Overwrite gray scale
  - Output power
    - Improve Doppler signal

Use Proper Preset

Notice settings are almost identical but better renal flow is seen with renal preset.
**Patient Positions**

- Supine
- Oblique
- Decubitus
- Prone
- All the above
  - Workout for the day!
- Move the transducer and the patient
  - Optimize anatomy and angles

**Scanning Planes**

- Sagittal
  - IVC for RRA
  - Good view to look for multiple arteries
- Transverse
- Coronal
  - Banana Peel view

**Transducer Positions**

- Subcostal
- Intercostal
  - Use kidney as an acoustic window
Renal Artery Exam

- 3 part exam
  - Gray scale
  - Color Doppler
  - Spectral Doppler
- Each part tells some of the story

Gray Scale

- Measure length of kidneys
  - 9-12 cm
  - < 2 cm difference between sides
  - > 2 cm
  - Duplicated system
  - > 2 cm
  - Renal artery thrombosis
- Look for plaque or narrowing
**Color Doppler**

- Locate vessels
- Look for areas of aliasing or turbulent flow
- Assist with angle correction
- Verify flow or absence of flow

**Spectral Doppler**

- Peak velocity
  - Aorta
  - Renal artery
- Post stenotic turbulence
- Tardus - Parvus
  - Acceleration time

**Tardus - Parvus**

- Tardus
  - Late
  - Delayed systolic upstroke
- Parvus
  - Weak, small
  - Diminished amplitude
  - Rounding systolic peak
- Due to post-stenotic pressure drop
Ultrasound Challenges

- Bowel gas
- Accessory renal arteries
- Time consuming
- Very operator dependent
  - Long learning curve
  - Must have dedication and patience
- Patient cooperation
  - Give a small break between sides

Duplicated Renal Arteries

Defeatist Attitude

- Too big
- Too gassy
- Can’t hold their breath
- Always the patients fault
What Can I See?

- Anterior approach
  - Nothing
- What are our options?
  - Give up
  - Reschedule and hope someone else gets that patient
  - Recommend MR or CT

OR

- We can be a sonographer and use our talents and skills to obtain a diagnostic study
  - Doesn’t necessarily have to be textbook perfect
- Don’t get stuck in a protocol
  - Grab what you can see when you can see it !!!

Right Kidney

- Origin
  - Coronal
    - Patient supine, oblique or decubitus
Right Kidney

- Patient oblique and use kidney as acoustic window
  - Once you have it hold still and track it
  - Watch your angle
  - LISTEN for higher velocities

Right RAS

Left Kidney

- Left renal artery is a short straight line to aorta
Left Kidney

- Left side up
- Use kidney as acoustic window
- Usually constant angle
- Track down to aorta

Both Kidneys

- Prone for intra-renal signals

Both Kidneys

- Use your color
- Look for areas of high flow
  - Especially useful for FMD
Accessory Renal Arteries

- Use coronal view
  - Good for right and left
- Sagittal of IVC for right

• Doppler each artery
Hypertensive Emergency

- Severe hypertension
  - Diastole > 120 mmHg
  - Potential life threatening organ damage
    - Brain
      - Intracranial hemorrhage
    - Heart
      - MI
    - Kidneys
      - ARF

- Clinical
  - Eye findings
    - Hemorrhage
    - Papilledema

- Role of Ultrasound
  - Ischemia

Hypertensive Urgency

- BP > 180/110
  - No life threatening organ damage
- Renal disease
  - Glomerulonephritis

- Role of Ultrasound
  - Renal Duplex
    - RI

Pediatric Hypertension

- Infants
  - Thrombosis of renal artery or renal vein
  - Congenital renal anomalies
  - Coarctation of the aorta

- Children
  - Renovascular abnormalities
  - FMD
  - Renal parenchymal disease
  - Tumors
    - Wilms
    - Neuroblastoma
  - Obesity
  - White coat
Pediatric Hypertension

- Tumors or masses
  - Renal
  - Adrenal
- Structural anomalies of the kidneys
- Structural anomalies of renal vasculature
- Renal scarring suggests excessive renin release
- Asymmetry in renal size
  - Renal dysplasia
  - Renal artery stenosis

Atretic Renal Artery

Non-Vascular Causes of Hypertension
Pheochromocytoma

- Neuroendocrine tumor
- Arises from medulla portion of adrenal gland
- Causes sporadic HTN
- Orthostatic HTN

Conclusion

- With proper mindset and skills, these can be diagnostic scans
- Not every scan needs to be a work of art
- Every scan should be diagnostic

Thank You

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