# Understanding the Role of US in Hypertension

JOHNS HOPKINS MEDICINE

M. Robert De Jong, Jr., RDMS, RDCS, RVT, FSDMS, FAIUM
Radiology Technical Manager, Ultrasound
The Russell H. Morgan Department of Radiology and Radiological Science
The Johns Hopkins Medical Institutions
Baltimore, Maryland

## 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

## Pathophysiology

- 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 a usually in association with intervention

Neumyer MM and Blebea J, Duplex Evaluation of the Renal Arteries, Noninvasive Vascular Diagnosis: A Practical Guide to Therapy

## 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

Neumyer MM and Blebea J. Duplex Evaluation of the Renal Arteries, Noninvasive Vascular Diagnosis: A Practical Guide to Therapy

## 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%
    - 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

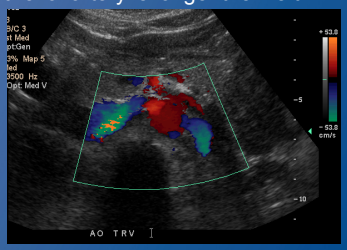
- At hilum the main renal artery divides into anterior and posterior segmental arteries
- Segmental arteries become the interlobar arteries
  - Course alongside the renal pyramids

## 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

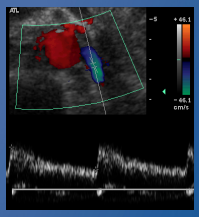
## Renal Arteries

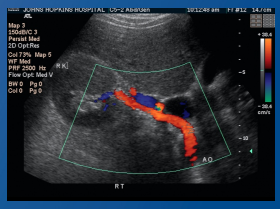
- 20 - 30 % of cardiac output
- Right renal artery is longer then left



## 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?

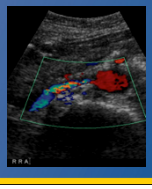
- Swallowed air
  - Eating
  - Drinking
  - Chewing gum
  - Swallowing saliva
  - Talking
- Normal breakdown of certain undigested foods in intestine

## Renal Duplex

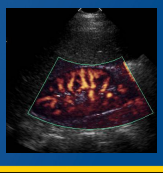
- Gray Scale
  - Longitudinal
    - Medial
    - Midline
    - Lateral
  - Transverse
    - Up
    - Mid
    - Low
  - Kidneys
    - Length
      - 9 -12 cm
    - Echogenicity
    - Pathology


## Renal Duplex

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



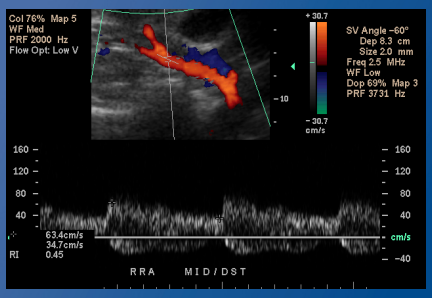
- Power
  - Renal perfusion
  - Origin of arteries
    - Less angle dependent



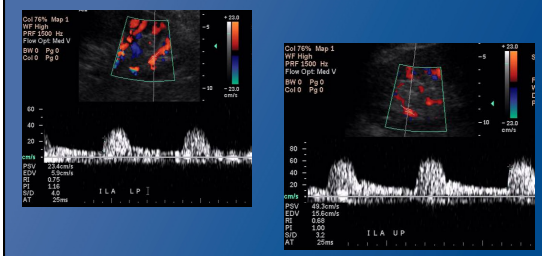
## Spectral Doppler

- 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

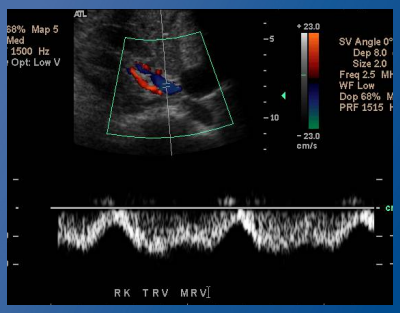
## Track Entire Length of Artery




## Intrarenal Signals



## Main Renal Vein




## 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

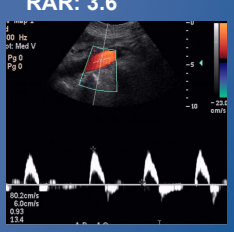
Weber TM, Robbin ML, Lockhart ME. The Kidneys. *Clinical Doppler Ultrasound*. 2014

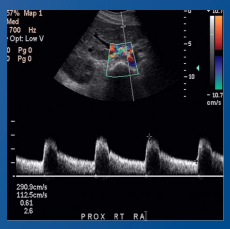
## Direct Diagnostic Criteria

- > 60% stenosis:
  - PSV 180-200cm/sec
  - RAR 3-3.5

  - House - AJR;1999:761
  - Hua - Ann Vasc Surg 2000;14:118

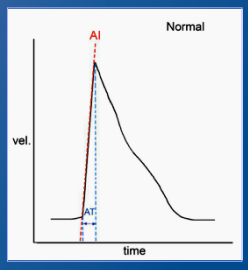
**RAS: Peak 290 cm/sec**
**Aorta: 80 cm/sec**
**RAR: 3.6**





## RAS Indirect Evaluation

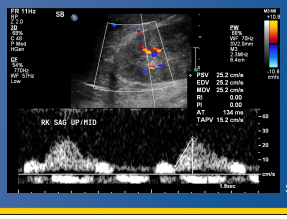
- Intra-renal waveform pattern
- Large sharply defined waveforms
  - Posterior lateral scanning
  - Use segmental arteries
  - Get kidney close to transducer




Stavros and al - Radiology;1992:184 487

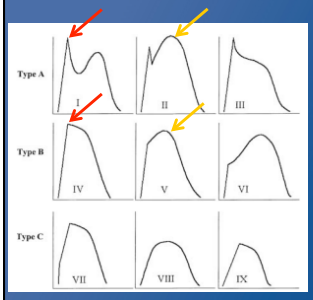
## Indirect Diagnostic Criteria

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



Stavros and al - Radiology;1992:184 487

## 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

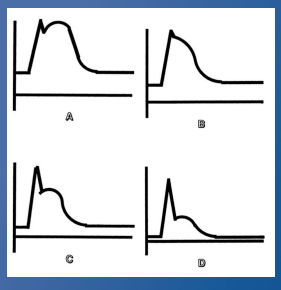
Soulez et al, *Radiographics* 2000

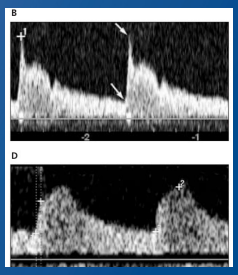
## Intrarenal Acceleration Time


- 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

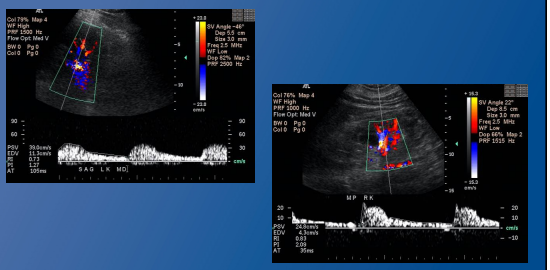
## Normal Waveforms



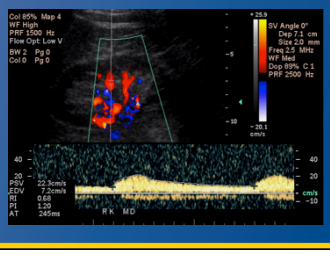

Stavros and al - Radiology;1992:184 487

## 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

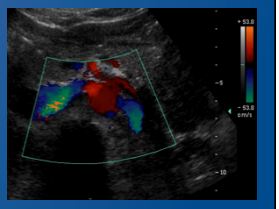
- Atherosclerosis
  - Plaque causing narrowing
  - Men > Women
  - Typically affects > 40 years
  - Involves origin and proximal renal artery
- Fibromuscular Dysplasia
  - Pattern of arterial wall thickening alternating with areas of small aneurysmal dilatation
    - String of pearls
  - Women > Men
    - 3 - 4:1
  - 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
    - Antiplatelet 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

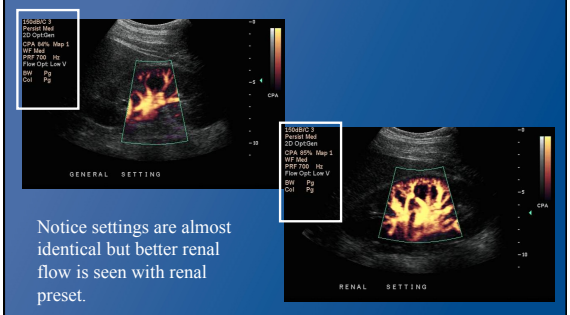
## Think About Image Optimization

- 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

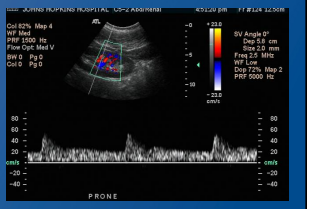
## Use Proper Preset




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

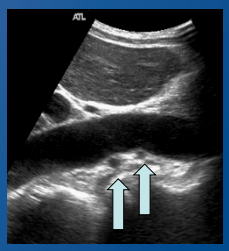
## Patient Positions

- Supine
- Oblique
- Decubitis
- 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

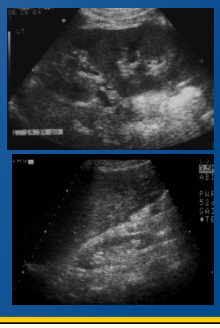
- Subcostal
- Intercostal
  - Use kidney as an acoustic window

## Renal Artery Exam

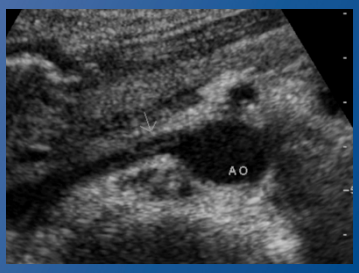
- 3 part exam
  - Gray scale
  - Color Doppler
  - Spectral Doppler
- Each part tells some of the story


## 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

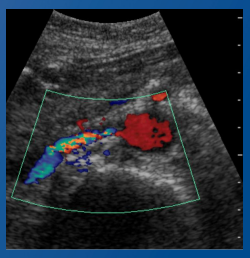


## Gray Scale



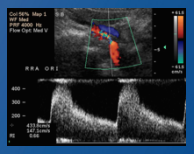
## Color Doppler

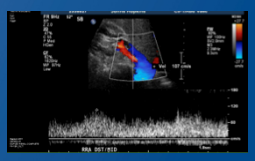
- Locate vessels
- Look for areas of aliasing or turbulent flow
- Assist with angle correction
- Verify flow or absence of flow



## Spectral Doppler

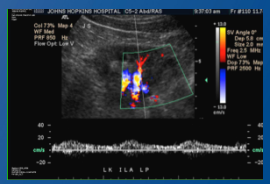
- Peak velocity
  - Aorta
  - Renal artery
- Post stenotic turbulence
- Tardus - Parvus
  - Acceleration time





## Tardus - Parvus

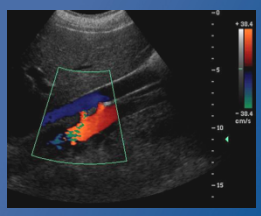
- Tardus
  - Late
  - Delayed systolic upstroke
- Parvus
  - Weak, small
  - Diminished amplitude
  - Rounding systolic peak
- Due to post-stenotic pressure drop

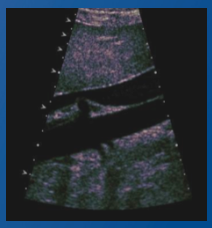


## Ultrasound Challenges

- 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?

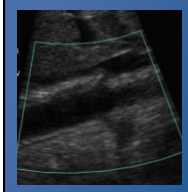
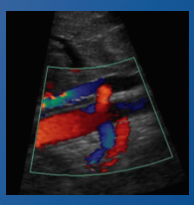
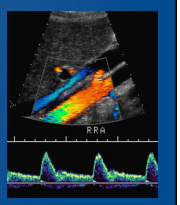
- Anterior approach
  - Nothing
- What are our options?
  - Give up
  - Reschedule and hope someone else gets that patient
  - Recommend MR or CT

## 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 !!!

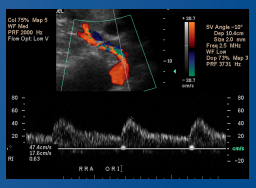
## Right Kidney

- Origin
  - Coronal
    - Patient supine, oblique or decubitus

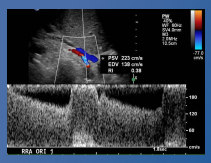




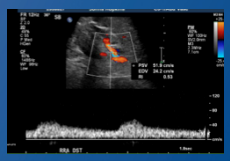
## Right Kidney

- 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

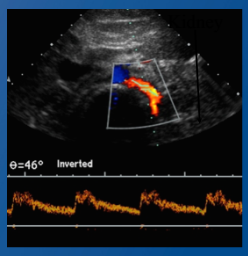




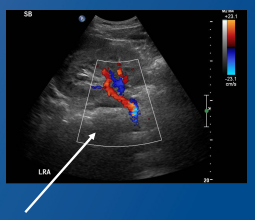
## Left Kidney

- Left renal artery is a short straight line to aorta



## Left Kidney

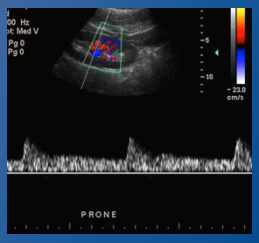
- Left side up
- Use kidney as acoustic window
- Usually constant angle
- Track down to aorta




Aorta - little / no flow as it is perpendicular

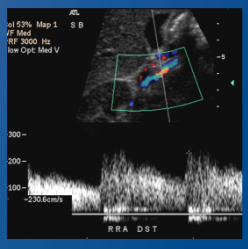
## Both Kidneys

- Prone for intra-renal signals

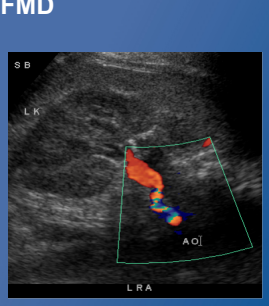


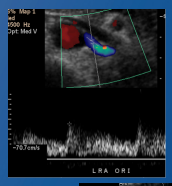

## Both Kidneys

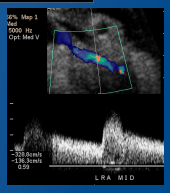
- Use your color
- Look for areas of high flow
  - Especially useful for FMD



## FMD

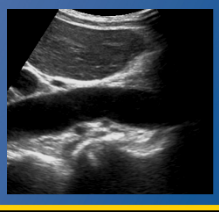


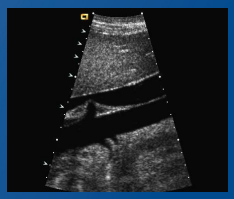




## Accessory Renal Arteries

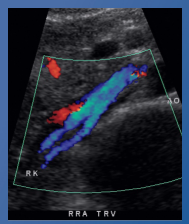
- Use coronal view
  - Good for right and left
- Sagittal of IVC for right

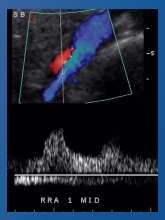


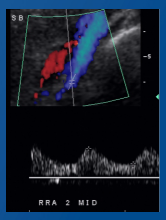


## Accessory Renal Arteries

- Doppler each artery



## Hypertensive Emergency

- Severe hypertension
  - Diastole > 120 mm/Hg
  - Potential life threatening organ damage
    - Brain
      - Intracranial hemorrhage
    - Heart
      - MI
      - Dissection
    - 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

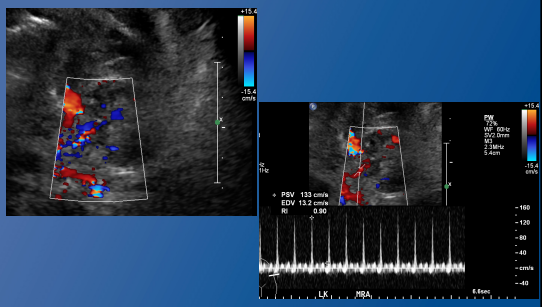
## Pediatric Hypertension

- 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

rdejong@jhmi.edu