Instructor's Digital Curriculum Resource-

For Techniques in Noninvasive Vascular Diagnosis-4th edition.

by Robert J. Daigle, BA, RVT, RVS, FSVU, FSDMS

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Chapter 16.
Abdominal Doppler

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Definitions for this chapter

- Xiphoid process
  - small cartilaginous process (extension) of the lower part of the sternum
- Hepatic - pertains to the liver
- Umbilicus- your belly button
- A-P. Anterior-Posterior dimension
- Renovascular Hypertension
  - high blood pressure caused by decreased blood flow to kidney

Definitions for this chapter

- Flank- from the patient's side
- Kidney "poles" – the ends of the kidney
- Parenchyma- the essential or functional elements of an organ
- RI- Resistivity Index A-B/A
- Porta hepatis –
  - the transverse fissure on the visceral surface of the liver where the portal vein and hepatic artery enter and the hepatic ducts leave.

Definitions for this chapter

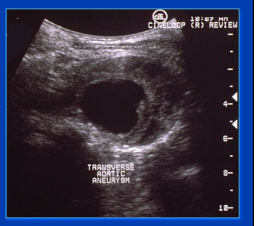
- Tardus-parvus waveform
  - A waveform of delayed rise time (tardus) and low amplitude (parvus). Found distal to severe stenosis or occlusion.
- NPO- nothing by mouth
- Splenomegaly- enlarged spleen
- Hepatofugal - flow AWAY from the liver
- Hepatopetal - flow TOWARDS the liver

Abdominal Doppler

- Abdominal Aorta for aneurysm/ stenosis
- Renal arteries/veins
- Mesenteric arteries
- Portal venous system
- Hepatic vasculature

Abdominal Aortic Aneurysm (AAA)

- Dilatation and expansion of arterial wall
- May contain thrombus, platelet aggregates, debris.



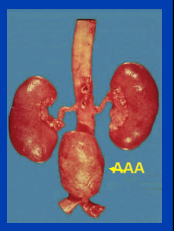
abdominal aortic aneurysm

AAA

- If aorta exceeds 3 cm in diameter, = aneurysm
- Annual mortality rate in USA about 15,000
- Only 10-25% of patients survive rupture
- 90% of abdominal aneurysms occur below renals

Risk Factors

- Tobacco abuse.
- Hereditary/family history.
- Advanced age.
- Male gender (men are 5 times more likely to develop AAA than women).
- High cholesterol.
- Obesity.



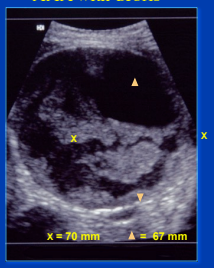
Symptoms

- Most intact aortic aneurysms do not produce symptoms.
- Palpable pulsatile mass in abdomen on examination.
- Back pain.
- Abdominal pain.

AAA Complications

- Rupture
  - Risk is high if AAA diameter is ≥ 5 cm
- Thrombosis
- Embolization
- Males over 60 yrs. old–highest risk group

AAA with debris

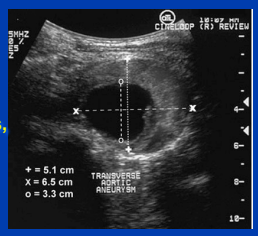


Method

- Place the patient in a supine position.
- Use a 2.5 - 5.0 MHz curved linear array transducer.
- Position the transducer in transverse plane in midline between the xiphoid process and the umbilicus and identify the aorta.

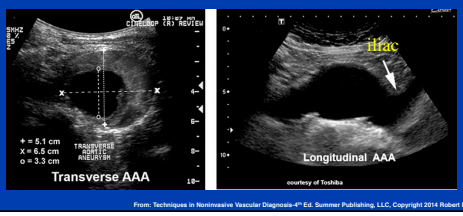
Aneurysm Diagnostic Method

- Scan aorta from renals to iliacs and select the area of largest diameter.
- Measure A-P and lateral distance of the outside walls,
- Measure residual lumen



AAA - Longitudinal

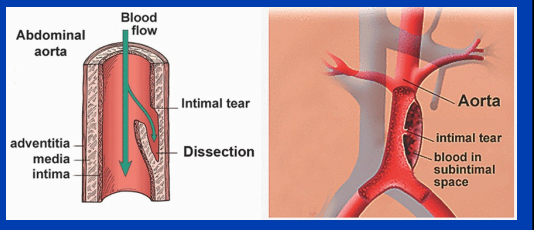
- Does aneurysm extend into iliacs?
- Are renal arteries involved?
- If AAA is within 2 cm of the celiac or SMA, renals are probably involved.



Aortic Dissection

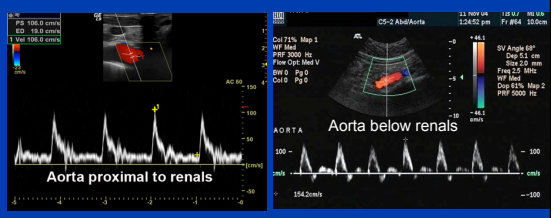
- Dissection is a tear in the intima.
- Blood enters the subintimal space
- A false channel can occur or a "hematoma" in the aortic wall.
- The dissection encroaches on the lumen creating a stenosis

Aortic Dissection



Aorta Flow Patterns

- Above renals, low resistance
- Below renals, high resistance



Renal Doppler

Hypertension in USA

- **60 million patients with hypertension in**
- **> 10 million with hypertension caused by:**
  - Chronic renal disease.
  - Renal artery disease (≈ 400,000).
  - True renovascular hypertension (≈ 260,000), i.e., not everyone with renal artery stenosis has hypertension.

Renovascular Hypertension Causes:

- **Atherosclerosis, usually in the proximal renal artery, is the most common etiology**
- **Fibromuscular dysplasia (FMD)**
- **Dissection and/or extension of an aortic dissection**
- **The renal artery stenosis must be ≥ 70% before it's likely to cause hypertension**

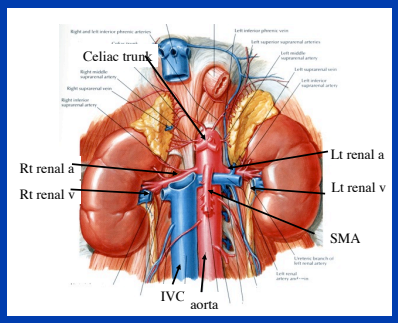
Renovascular Hypertension Causes:

- **There is a resulting decrease in blood pressure and flow within the kidney.**
- **Release of Renin into blood stream**
- **Renin is converted into angiotensin II with resultant vasoconstriction, sodium & water retention.**

Renal Doppler Indications

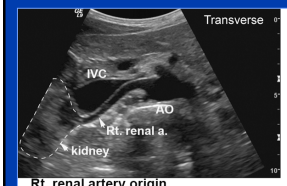
- **Uncontrolled hypertension, especially in younger patients.**
- **Decreasing renal function.**
- **Abdominal bruit.**

Abdominal Vasculature

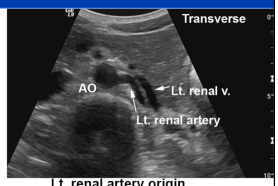


Frank Netter drawing

Transverse scan, renal artery origins



Rt. renal artery origin.

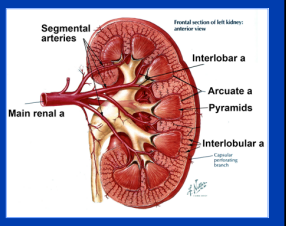


Lt. renal artery origin

Images courtesy of Cindy Owen and GE Healthcare.

Renal Anatomy

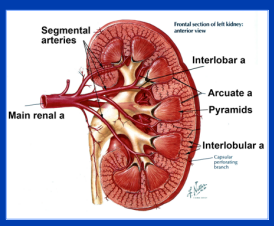
- Segmental renal arteries are branches of the main renal artery they enter through the renal hilum.
- Interlobar arteries arise from the segmentals; they penetrate the renal parenchyma and run between the renal medullary pyramids.



- Main renal artery
- Segmental renal artery (at hilum)
- Interlobar arteries (renal pyramids)
- Arcuate arteries
- Interlobular arteries

Renal Anatomy

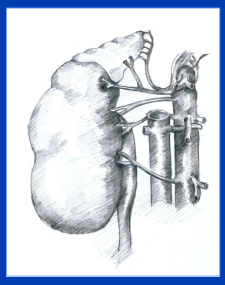
- Arcuate arteries branch from the interlobars and turn at the cortico-medullary junction to course parallel to cortex surface.
- Interlobular arteries (cortical branches) extend into the cortex.



- Main renal artery
- Segmental renal artery (at hilum)
- Interlobar arteries (renal pyramids)
- Arcuate arteries
- Interlobular arteries

Accessory Renal Arteries

- May arise from aorta, above or below the main renal arteries.
- On the right side, they may pass anterior to IVC.
- They may also arise from the SMA or iliac arteries.



Renal Doppler Purpose:

- Identify vascular etiology of hypertension
- Prevent renal failure due to permanent parenchymal changes
- Evaluate renal transplants for complications (twists, kinks, stenosis and rejection)

Renal Doppler

- Direct method
  - interrogates entire renal artery, and renal parenchyma, bilaterally
- Indirect Method
  - uses the segmental renal arteries for determining main renal artery disease.

Renal Doppler Patient Preparation

- Overnight fast (clear liquids and medications OK)
- Morning exam
- Patients should be well dehydrated: some labs request that patients drink 16 oz of water 30 minutes before the exam
- No chewing gum or tobacco, and no smoking prior to exam

Renal Doppler Patient Preparation

- Pt. supine with slight head elevation
- 2.5 - 3.0 MHz transducer (5.0 MHz on thin patients may work)

Imaging the Right Kidney

- Image kidney through the liver from Rt. anterior approach
- Position the transducer obliquely to elongate the kidney
- Measure kidney length
- Normal adult kidney is 9-12 cm
- In Transverse, scan pole to pole, look for a mass or cyst

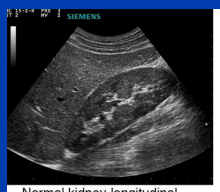
Left Kidney

- With patient in a supine position, scan laterally though intercostal space, or anteriorly (more difficult).
- With the patient in slightly oblique position lying on the right side, scan from lateral or posterior planes.
- Alternatively, with patient in decubitus position, scan through the posterior axillary line.
- Measure kidney length and compare to contralateral side

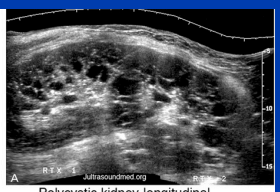
Left Kidney

- Elongate the kidney and measure kidney length, compare to contralateral side
- In Transverse, scan superior pole to inferior pole, look for a mass or cyst(s)
- Note: The spleen may be used as an acoustic window to the left kidney.

Kidneys



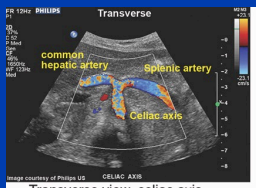
Normal kidney-longitudinal



Polycystic kidney-longitudinal

Main Renal Arteries

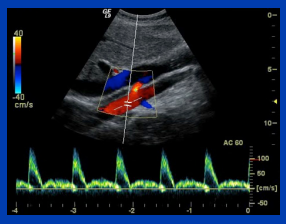
- In transverse plane in midline approach, identify the aorta and locate the celiac artery and the superior mesenteric artery (SMA). Identify the renal artery origins just distal to SMA .



Transverse view, celiac axis

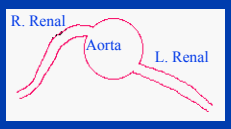
Rt renal a. from transverse abdominal anterior approach

- In longitudinal plane, 2-3 cm distal to xiphoid process, obtain Doppler waveforms from the aorta and measure/record the aortic peak systolic velocity (PSV).
- If patient has an abdom. bruit, sample celiac and SMA



Renal Doppler Technique:

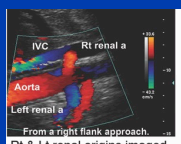
- **Transverse plane to aorta**



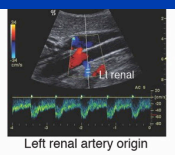
- **Obtain Doppler waveforms from multiple sites from origin to renal hilum, bilaterally**
- **Record PSV**

Renal Doppler Technique:

- Renals may also be accessed with patient on left side in Lt. lateral decubitus or shallow oblique positions
- In longitudinal plane, identify the Rt. Renal art. coursing towards the transducer, the Lt. coursing away



Rt & Lt renal origins imaged from right flank approach.

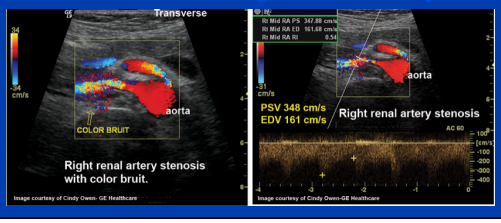


Left renal artery origin

Right renal artery origin

To Identify Stenosis

- **Look for regions of velocity increase and post stenotic turbulence.**
- **Carefully map these regions with spectral Doppler.**
- **Record the peak systolic velocity from the waveform demonstrating maximum velocity**



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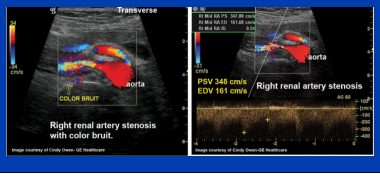
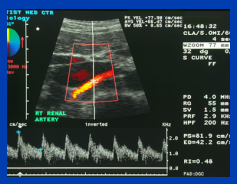


Renal Stenosis-RAR

- **A high measured velocity may be false due to a high > 70% Doppler angle- beware!**
- **Calculate the Renal/Aortic peak systolic velocity ratio (RAR), which is the highest velocity obtained in the renal artery divided by the peak velocity from the aorta.**

Main Renal Arteries- Normal Characteristics:

- High flow velocity (PSV 100 ± 20 cm/s.)
- Low resistance (RI < 0.75)
- High diastolic flow vel. (EDV 30 ± 5 cm/s)



Renal Doppler Criteria for > 60 % stenosis:

- Renal-Aortic Ratio (RAR) ≥ 3.5
- Peak systolic velocity (PSV) > 180 cm/sec
- Post stenotic turbulence
- Low flow in distal renal artery.

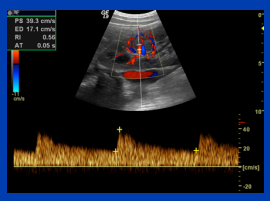
Renal Doppler- Renal A. Occlusion:

- No flow in a well visualized renal artery.
- Low amplitude signal from parenchyma
- Small kidney size (< 9 cm)

Technique within the Kidney

- Evaluate segmental and interlobar artery waveforms to indirectly assess main renal artery for significant stenosis or occlusion
- Use flank approach

Normal segmental artery flow



Parenchymal Technique:

- Obtain Dopp. waveforms from segmental arteries in the upper, mid and lower poles
- Calculate RIs from segmental arteries
- Obtain Doppler waveforms and assess waveform morphology from the interlobar and arcuate arteries.
- With color Doppler or Power Doppler, note overall kidney perfusion. Is it reduced unilaterally?

Parenchymal Technique:

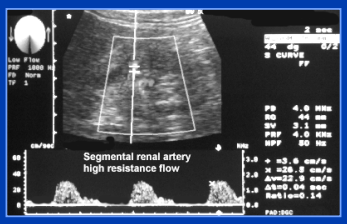
- Normal parenchymal flow is low resistance

Technical Note: Ask the patient to stop breathing momentarily after you have positioned the sample volume in the artery of interest. Turn on the Doppler and obtain your waveform quickly.

This method may help in all abdominal arteries

Renal Parenchymal Disease

- High resistance flow in kidney and main renal artery.
- Flow and Velocity is reduced.



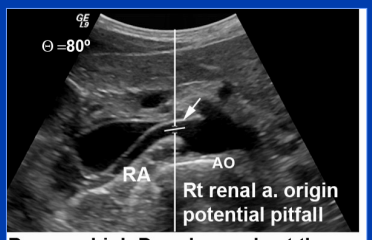
Renal Doppler
Physical limitations:

- Depth of renal arteries
- Motion of respiration
- Intraabdominal gas
- Obesity
- Previous abdominal surgery

Renal Doppler
Technical limitations:

- High technical failure rate (12- 25%)
- Accessory renal arteries (polar arteries.)
- Poor Doppler angles
- Long exam time (1-2 hrs)
- Requires very skilled tech/sonographer

"Tough" Doppler Angles at oriface.



Beware: high Doppler angle at the renal oriface can cause velocity measurements to be erroneously high

Indirect Renal Doppler

- This method can be useful when the main renal arteries cannot be imaged due to bowel gas, obesity, etc.
- Method assesses flow within the kidney for indirect evidence of main renal artery stenosis or occlusion
- Method requires careful technical and specific setup of Doppler parameters

Renal Doppler- Indirect Method
Patient Position

- Try these different patient positions to optimize access:
  - Supine or slightly oblique.
  - Right and left lateral decubitus posterolateral approach.
  - Use a lateral and /or flank approach.
- Use color Doppler to locate segmental arteries

Renal Doppler- Indirect method
Doppler Setup

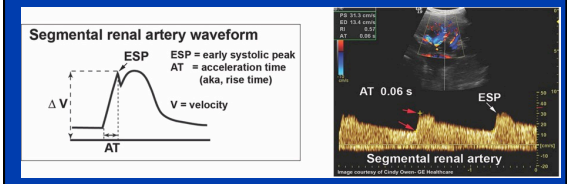
- Doppler frequency 3- 5 MHz
- Doppler angle in segmentals should be 0-30º
- Velocity scale to lowest that does not alias.
- Large sample volume (4-6mm)
- Spectral time sweep set to 2 or 3 seconds.
- Low wall filter (50-100 Hz)

Indirect method

- Don't scan through liver as this places the kidney too far from the probe surface. Try to minimize depth.
- Doppler sample segmentals in superior, mid, & inferior poles of kidney
- Measure acceleration time (AT), also called rise time (RT), and note the presence (or absence) of the early systolic peak (ESP).

Segmental Renal Artery Waveform

- Acceleration time (AT) and Early Systolic Peak (ESP)



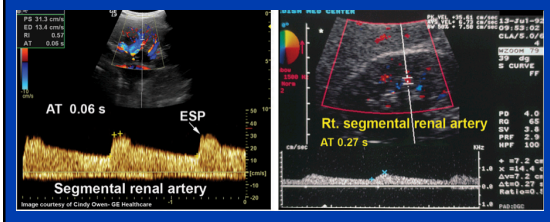
Segmental Normal Parameters

- Presence of ESP
- AT < 0.07 seconds
- Presence of continuous forward diastolic flow
- RI = < 0.75

Renal Doppler- Indirect
Criteria for > 60% main renal artery stenosis

- Acceleration time > 0.07- 0.1 sec. = grey zone
- Prolonged Acceleration Time > 0.1 sec.
- Tardus - Parvus waveform
- Loss of early systolic peak (ESP)
- Flattened systolic upslope
- Reduced color flow in kidney, unilaterally

Segmental Renal Arteries



Normal segmental

Abnormal, "tardus-parvus" waveform, rise time is 0.27 sec.

Patient with severe main renal artery stenosis, before and after renal artery angioplasty

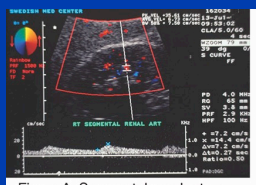


Figure A. Segmental renal artery before main renal artery PTA

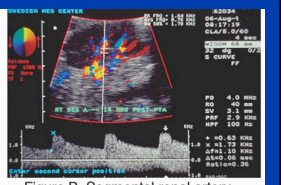


Figure B. Segmental renal artery Post -PTA

Renal Doppler - Indirect Limitations:

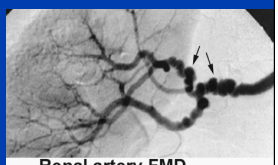
- Stenosis in accessory renal arteries (although unlikely to cause hypertension)
- Cannot differentiate occlusion from stenosis
- Needs meticulous technique
- Accuracy dramatically improves at > 70% stenosis.

Renal Doppler - Indirect Limitations:

- Parenchymal disease, with renal art. stenosis, may cause waveform to be "resistive"
- Low positive predictive value (PPV) & low Sensitivity in some reports
- When RI is ≥ 0.8, comparison to contralateral side is essential
- If indirect results are positive, or equivocal, main renals should be scanned.

Renal Fibromuscular Dysplasia (FMD)

- A non-atherosclerotic, non-inflammatory arterial disease of unknown origin.
- Fibrous thickening of the intima, media, or adventitia.
- Predominance in women (90%).
- Associated with hypertension.



Renal artery FMD

Renal Fibromuscular Dysplasia (FMD)

- Occurs in the mid to distal segments of the renal arteries.
- Also can occur in the carotid arteries.
- If renal artery stenosis is detected distal to the origin in mid segment, FMD should be suspected.

Renal artery FMD

Renal Doppler: Transplants

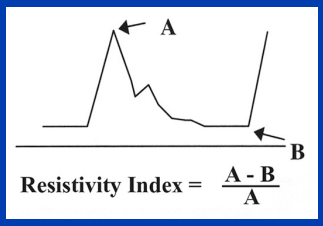
- Evaluate artery for kinks, stenosis, twists, and rejection.
- In rejection, segmental, interlobar and arcuate arteries show high resistance, low, no, or reversed diastolic flow
- Acute tubular necrosis and cyclosporine toxicity can mimic rejection

Renal Doppler: Transplants

- RI for rejection *:
  - normal 0.73 ± 0.04
  - abnormal > 0.8 ± .07
- RI is not universally accepted as a parameter for rejection.

* Fleischer AC, et.al, Duplex sonography of renal transplants.. J Ultrasound Med 1989;8: 89-94

Resistivity Index (RI)



Mesenteric Doppler

Purpose: to diagnose mesenteric ischemia

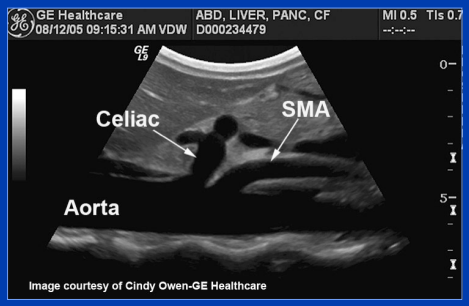
Mesenteric Ischemia

- Mesenteric ischemia is very uncommon due to extensive collateral pathways.
- Caused by athero occlusive disease at vessel origins.
- The celiac, superior mesenteric artery (SMA), and Inferior mesenteric artery (IMA) must be all be involved for bowel ischemia to occur.

Mesenteric Ischemia

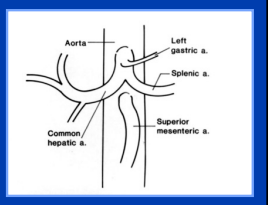
- May be chronic
- Acute- usually caused by embolization
- Symptoms include;
  - abdominal cramps and pain after eating
  - diarrhea, change in bowel habits
  - weight loss
- Also known as "fear of food" syndrome

Mesenteric Anatomy

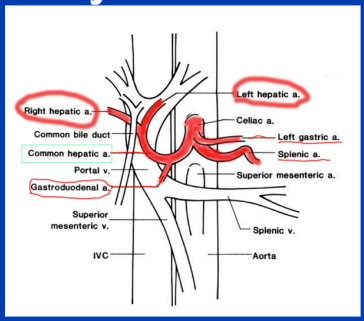


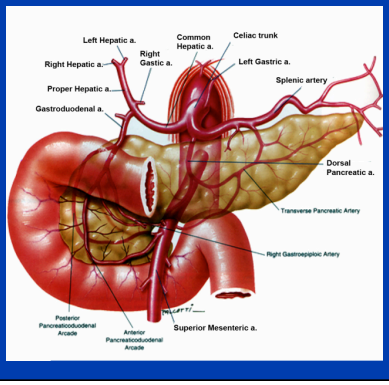
Mesenteric anatomy

- Celiac axis
  - Lt. Gastric A.
  - Splenic A.
  - Common Hepatic A.
- Superior Mesenteric A. (SMA)
- Inferior Mesenteric A. (IMA)

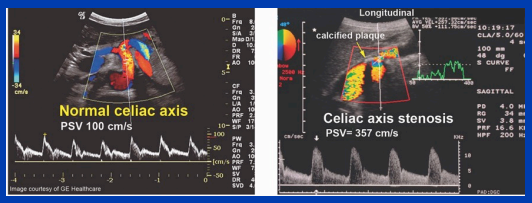


Common hepatic artery branches into:



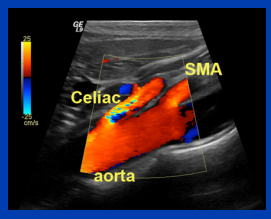


Celiac Axis



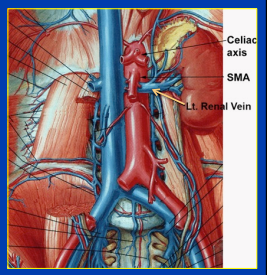
Superior Mesenteric Artery

- The next major branch of the aorta caudal to the celiac artery or axis.
- SMA supplies blood to the distal duodenum, small intestine, and the colon.
- In the transverse view, it's surrounded by a triangular region of fat.



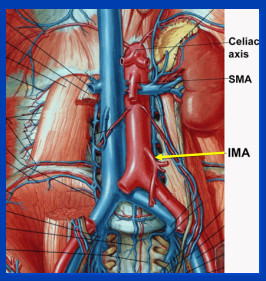
SMA

- In transverse, the left renal vein courses under the SMA and over the aorta



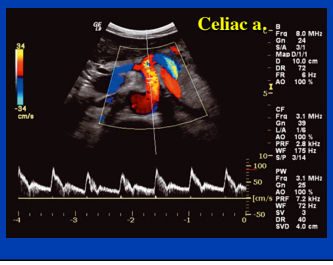
Inferior Mesenteric Artery (IMA)

- Arises from the aorta distal to the renal arteries.
- Supplies blood to the transverse, descending, and sigmoid colon.



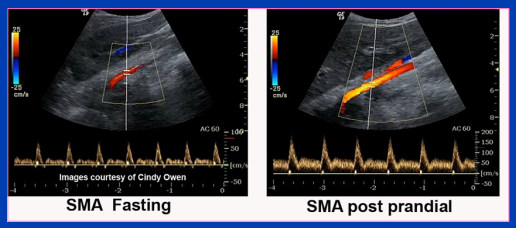
Mesenteric Doppler Flow Patterns:

- Celiac, Hepatic, Splenic - low resistance



Flow Patterns:

- SMA & IMA - variable
  - high resistance - fasting
  - low resistance- post prandium



SMA Fasting SMA post prandial

Mesenteric Doppler Technique:

- Patients should be in a fasting state for the exam.
- NPO overnight.
- Clear liquids and medications are OK.
- No chewing gum or tobacco, and no smoking prior to exam.
- Patient should be supine, with head elevated 10 - 30 degrees.

Mesenteric Technique

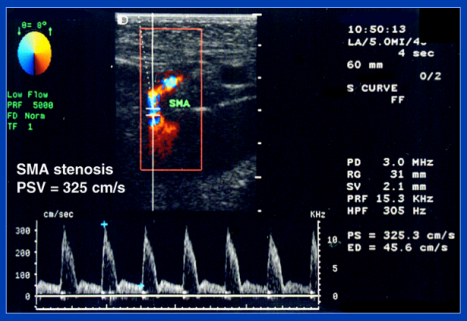
- A 2.5 - 5 MHz transducer is positioned slightly left of midline in longitudinal plane.
- Identify the aorta and obtain Doppler waveforms.
- Obtain spectra from all mesenteric vessels and measure peak systolic and diastolic velocities.

Mesenteric Doppler Criteria for >70% stenosis:

- Celiac > 200 cm/s & post stenotic turbulence
- SMA > 275 cm/s & post stenotic turb.

Moneta GL, et.al., Mesenteric Duplex scanning... J Vasc Surg 1993;17:79-87

>70% Diameter SMA Stenosis



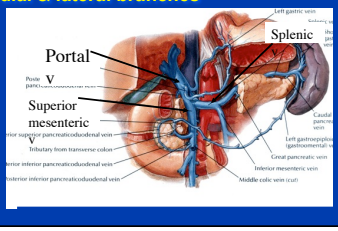
Other Mesenteric Doppler Applications

- Median arcuate ligament compression syndrome (MALS).
  - Intermittent compression of vessels by median arcuate ligament of diaphragm
- SMA compression syndrome
  - Compression of the third, or transverse, portion of the duodenum against the aorta by the SMA

Portal System

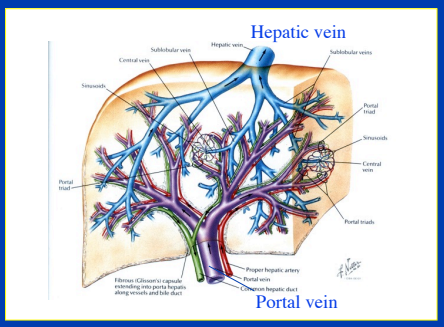
- Drains nutrient- rich blood from bowel and spleen into liver
- Has a capillary bed on each end of system.
- Portal vein and Hepatic artery provide blood supply to liver

- Portal vein is formed by:
  - Superior mesenteric vein & splenic vein
- Right portal vein:
  - anterior & posterior branches
- Left portal vein
  - medial & lateral branches



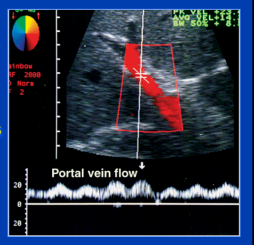
Portal Veins

- The portal vein courses intra-segmentally in the liver (within the lobes).
- It has very echogenic walls.
- The main portal vein increases in diameter to a maximum of < 13 mm near the porta hepatis.



Portal Vein - Normal

- Low velocity (20-40 cm/s), continuous flow
- No filling defects with color Doppler.
- Hepatopetal direction (towards liver)
- No varices
- Normal flow direction in potential collaterals



Portal Hypertension:

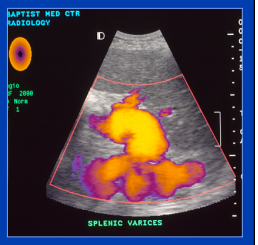
- Elevated pressure in the portal venous system due to increased impedance of flow through the liver

Portal Hypertension - etiologies

- Pre-hepatic
  - thrombosis of portal vein or splenic v.
  - extrinsic compression of Portal v.
- Intra-hepatic
  - cirrhosis, hepatic fibrosis, lymphoma
- Post-hepatic
  - IVC obstruction, hepatic vein obstruction, hepatic artery stenosis

Portal Hypertension can lead to:

- Ascites.
- Splenomegaly.
- GI - esophageal varices & bleeding.
- Jaundice.
- Signs of hepatic failure.

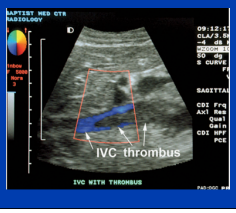


Portal Hypertension Technique:

- Measure Portal v. diameter (>13mm = bad)
- For all Doppler, use low PRF & wall filter
- Assess Portal vein velocity & direction
- Evaluate Portal v. and branches for thrombus
- Measure the spleen: enlarged? (>13 cm = bad)

Portal Hypertension Technique:

- R/O extrinsic compression of portal vein by tumor or mass
- Evaluate IVC for obstruction
- Porto-systemic collaterals present?



Common Porto-systemic Shunts

- Lt. Gastric vein, aka, coronary vein
  - Retrograde flow occurs in this vessel in 80-90% of PH
  - Increased pressure in this vein may cause esophageal varices
- Gastric varices occur:
  - Near the stomach (epigastrum)
  - Under the left lobe of liver
  - Near the spleen

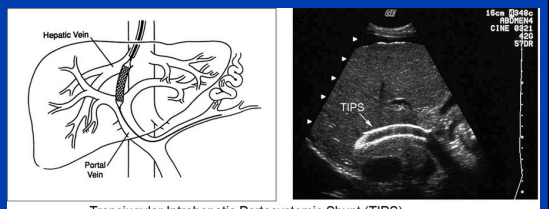
Porto-systemic Shunts - Other:

- Recanalized paraumbilical vein
  - heptofugal flow (away)
- Splenorenal shunt
  - splenic vein to left renal vein

Alleviation of Portal Hypertension

- Transjugular Intrahepatic Portosystemic shunts (TIPS)
  - Stent placement in liver parenchyma between portal vein and hepatic vein
  - Purpose: decompression of portal system
  - Does not address cause of P. hypertension
  - Does decrease symptoms of PH

Transjugular Intrahepatic Portosystemic shunts(TIPS)

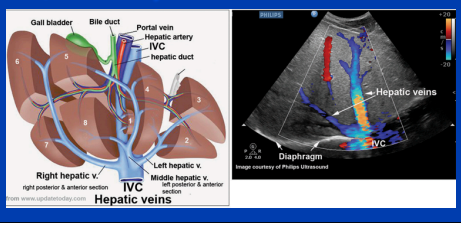


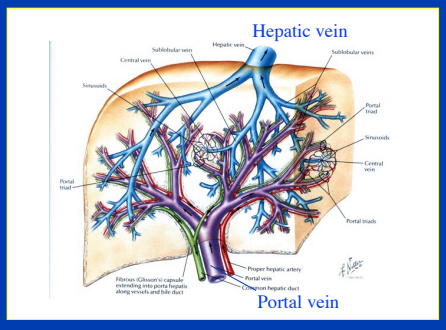
Transjugular Intrahepatic Portosystemic Shunt (TIPS)

Hepatic Vein Anatomy

- The hepatic veins drain into the IVC from the liver.
- There are three tributary vessels:
  - 1. Right hepatic vein drains the right hepatic lobe.
  - 2. Middle hepatic vein lies between the left and right hepatic lobes.
  - 3. Left hepatic vein courses between the medial and the lateral segments of the left lobe

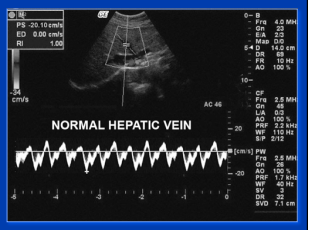
- Left and middle hepatic veins join before the IVC in 96% of individuals.
- Hepatic veins enlarge as they approach the diaphragm.
- These vessels are best imaged in transverse plane, subcostally.





Normal Hepatic Vein Flow

- Hepatofugal (away from liver).
- Pulsatile, due to right atrial pressure changes.
- Respiratory variation.



Budd-Chiari Syndrome

- Stenosis or obstruction of the hepatic veins.
- Hepatic outflow obstruction may be caused by:
  - Hepatomegaly.
  - Splenomegaly.
  - Ascites.
  - Extrinsic compression by a tumor.
  - Thrombus in the hepatic veins or IVC.