



Visceral Vascular Ultrasound

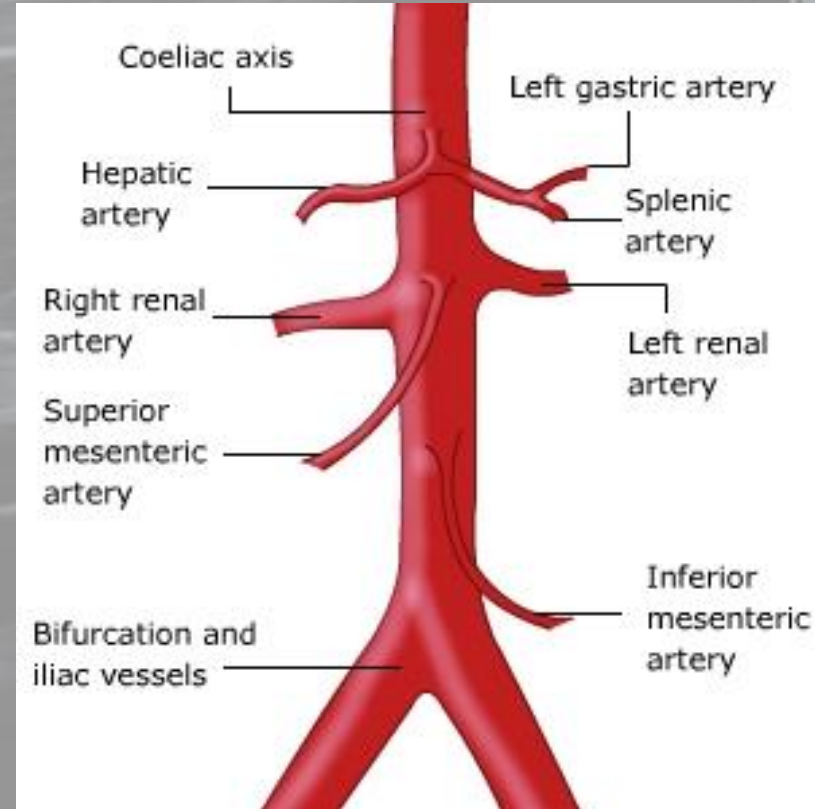
Joel Thompson, MD, MPH
Borg & Ide Imaging

Objectives:

- Review major abdominal vascular structures
- Identify normal peak systolic velocity (PSV) for major abdominal arteries.
 - Be able to name a disease process that affects the PSV for each artery.
- Protocol imaging studies to help increase the sensitivity and accuracy of visceral vascular examinations.

Abdominal Aorta

- Diaphragmatic (aortic) hiatus
- Bifurcation into right and left common iliac arteries at L4 level.
- Both paired and unpaired branches.



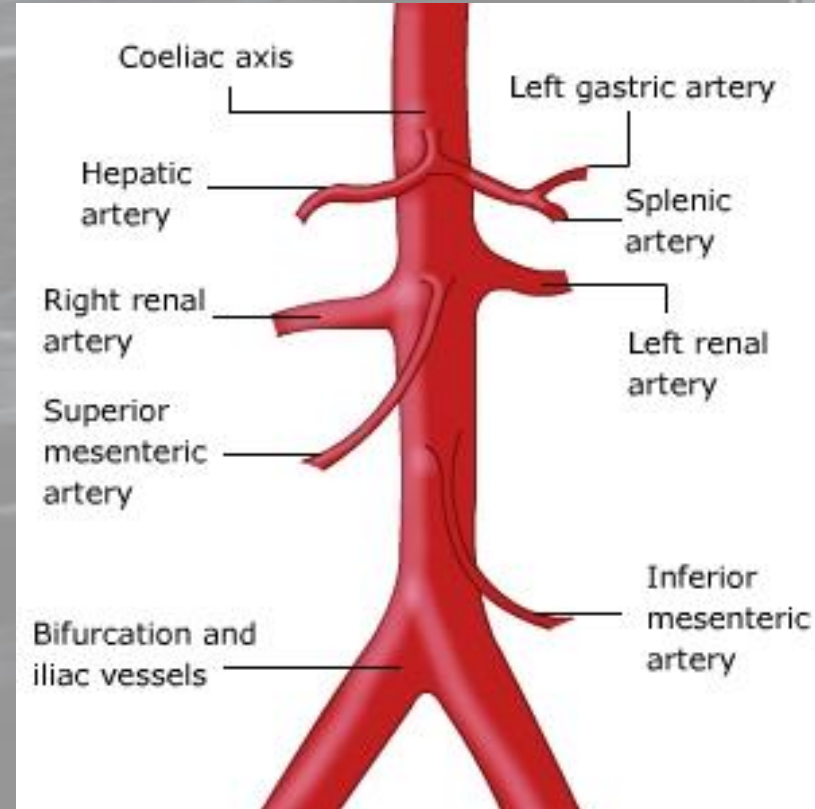
Abdominal Aorta

Unpaired Branches

1. Celiac Axis (T12 level)
2. Superior mesenteric artery (SMA, L1 level)
3. Inferior mesenteric artery (IMA, L2 level)

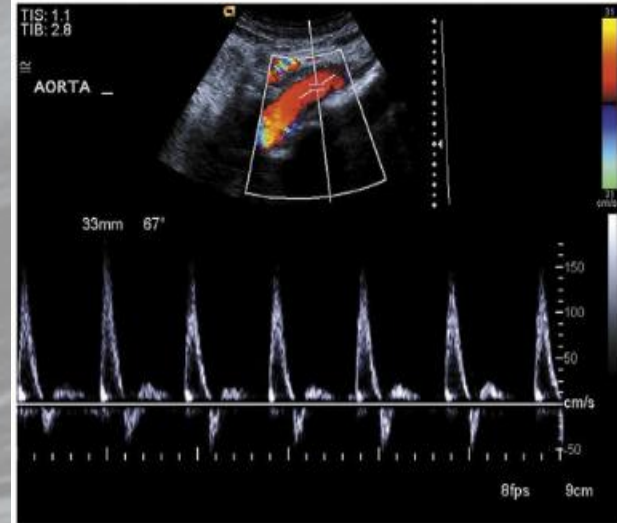
Paired Branches

1. Inferior phrenic (T12); rarely visualized
2. Renal Arteries (L2 level)
3. Gonadal Arteries (L2 level)
4. Lumbar arteries (posterior)

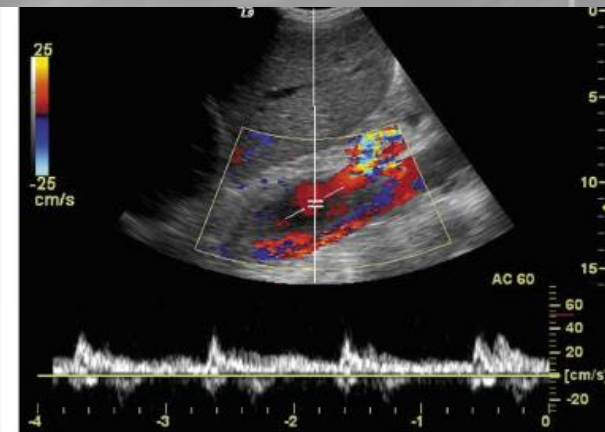


Abdominal aorta

- Triphasic (high resistance) waveform.
- More diastolic flow in proximal aorta above the level of the renal arteries
- PSV 110 cm/sec when young and walls more elastic; decreases to 70-100 cm/sec with age.
- Slower and more turbulent flow within an aortic aneurysm, due to increased diameter and decreased resistance to blood flow.



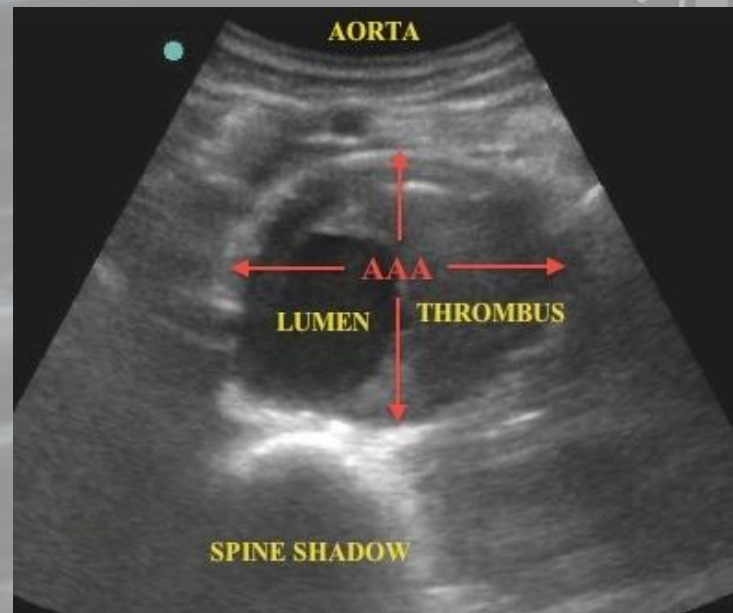
A



B

Abdominal Aortic Aneurysm

- 4-8% incidence in males age 60 and older
- 2-5x risk if smoker, hypertension, or peripheral artery disease.
- Male:female ratio of 4:1.
- AAA of 5.5 cm or greater has an annual risk of rupture of 16%.
 - Laplace's law: wall surface tension = radius x blood pressure
 - Emergent repair carries a mortality risk of 40%.
- Perioperative mortality for endovascular repair 1%.



AAA Screening

- Screening recommendations by vascular surgeons:
 1. All males age 60-85 years.
 2. Females age 60-85 years with cardiovascular risk factor
 3. Age >50 years and family history of AAA.
- AAA follow-up by size:
 - <3 cm no further surveillance
 - 3-4 cm ultrasound annually
 - 4-4.5 cm ultrasound every 6 months
 - >4.5 cm referral to vascular specialist.
- Screening has 45-49% reduction in incidence of AAA rupture.

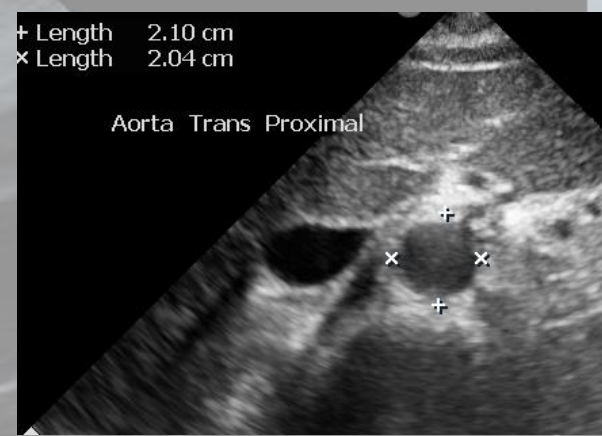
AAA Screening

- Patient fasting 8-10 hours to reduce bowel gas.
- 2.5 MHz curvilinear transducer
- Use compression to move aside bowel loops, or left lateral decubitus to reduce gas.
- Measure outer wall to outer wall



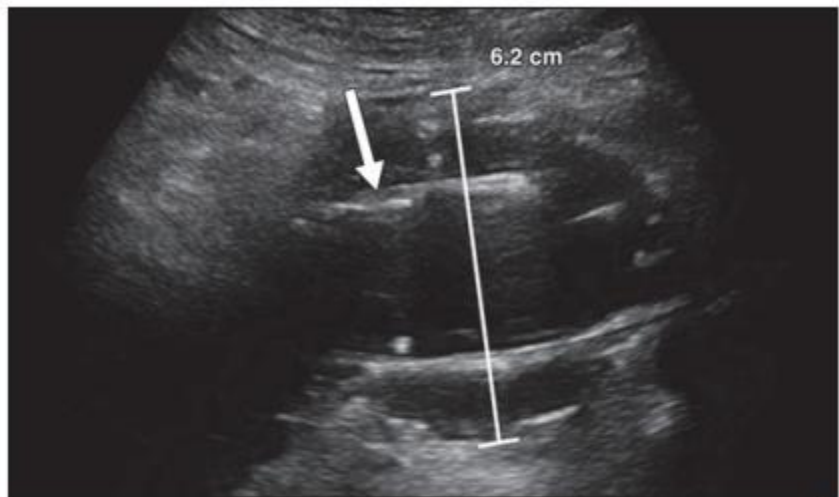
AAA Screening

- Measurement locations:
 - proximal (below diaphragm, near celiac artery)
 - mid (near level of renal arteries)
 - distal (above iliac bifurcation).
 - longitudinal and transverse images of proximal common iliac arteries.
- Image in plane parallel to the long axis of the lumen (for AP dimension) and perpendicular to long axis of lumen (for transverse dimension). Transverse may be obtained in coronal plane.
- Aneurysm: maximum dimension >3 cm or 1.5x greater than more proximal measurement. Document relationship to renal arteries and aortic bifurcation.

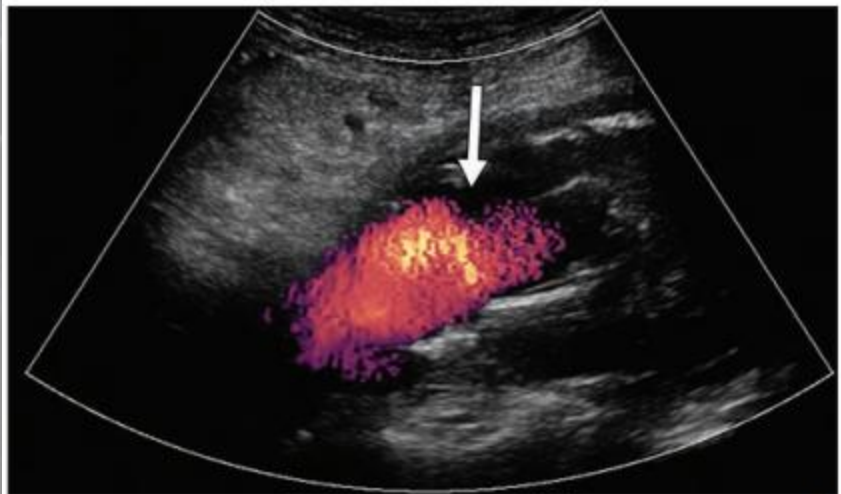


US evaluation of EVAR

- Color Doppler of proximal, left, right iliac attachments
 - Document flow in SMA and renal arteries
 - Look for flow in aneurysm sac.
-
- Endoleaks:
 1. Between proximal/distal end of stent and aortic wall
 2. Retrograde filling via a branch
 3. Defect or tear in graft
 4. Porous graft
 5. Endotension (enlarging sac without visible leak)



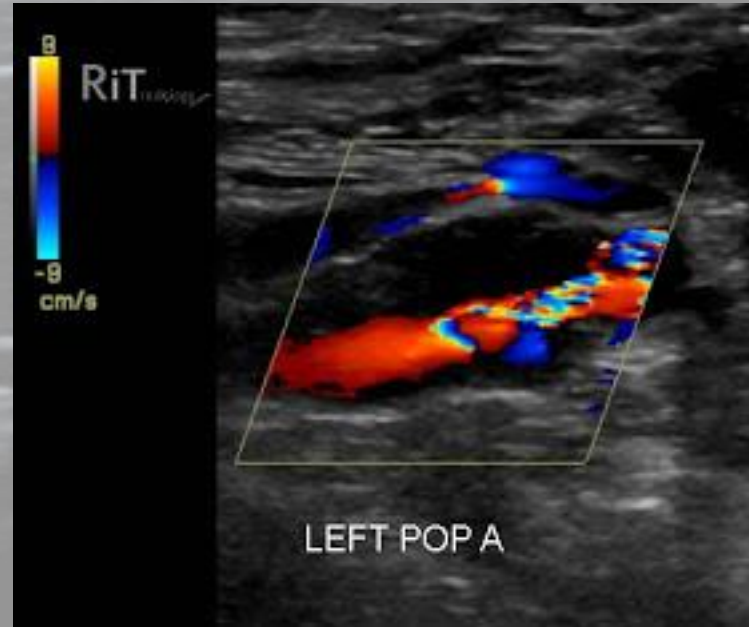
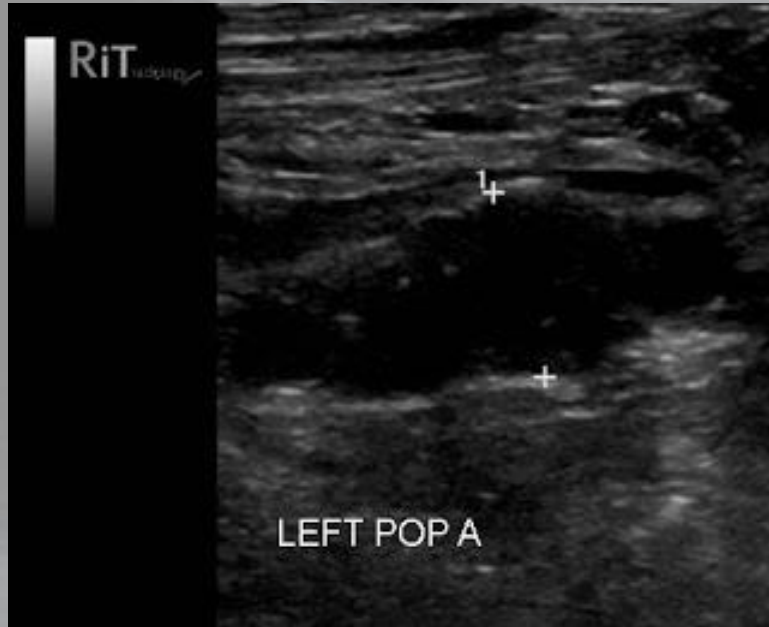
A



Picel et al. AJR 2014..

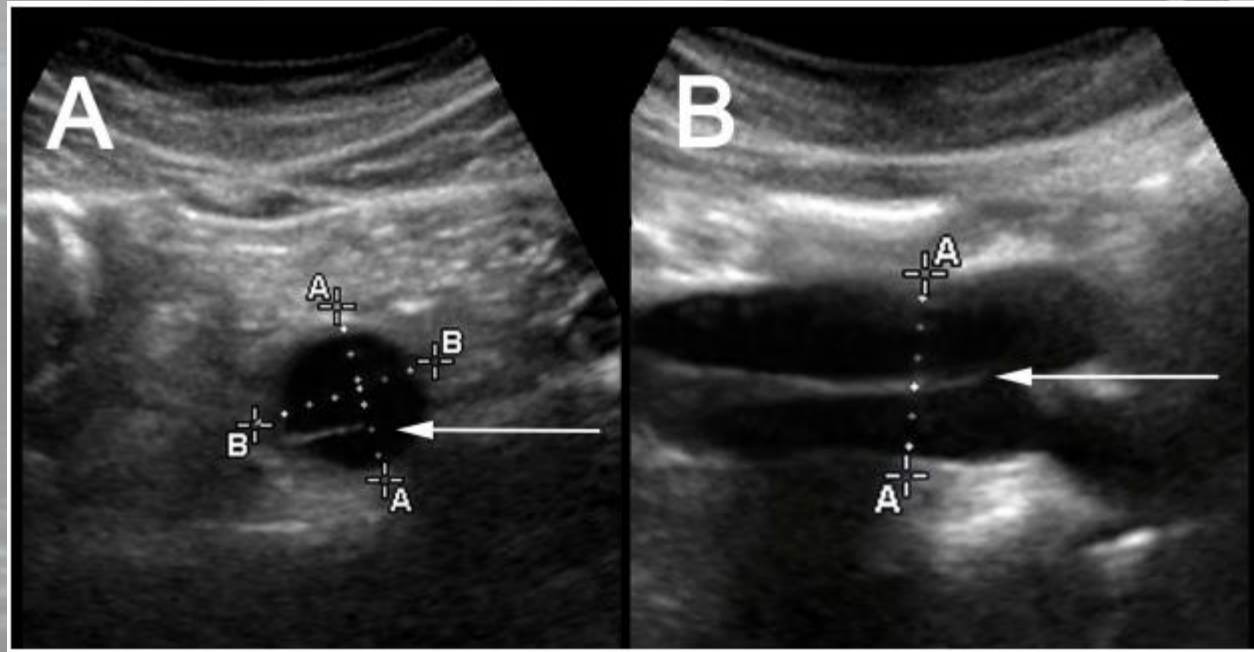
B

Finding on LE Doppler US:



- 4% of people with AAA have a popliteal artery aneurysm (1.5x proximal diameter).
- 30-50% of people with popliteal aneurysm have AAA.

Aortic Dissection



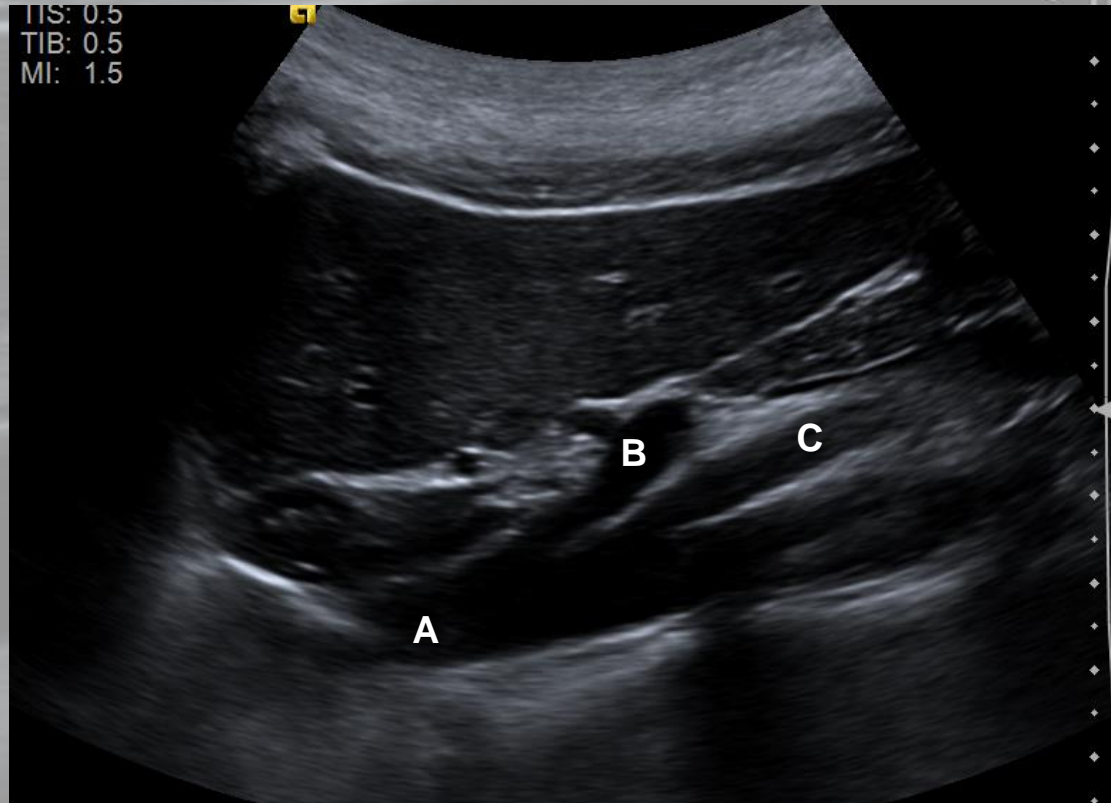
- In the abdomen, usually a continuation of thoracic aortic dissection.
- Separation of medial and intimal layers of the vessel wall.
- False lumen: usually larger, may be thrombosed. To and fro on spectral Doppler.
- True lumen has elevated PSV.
- Evaluate patency of major branches.

What vessels are being imaged?

A: Aorta

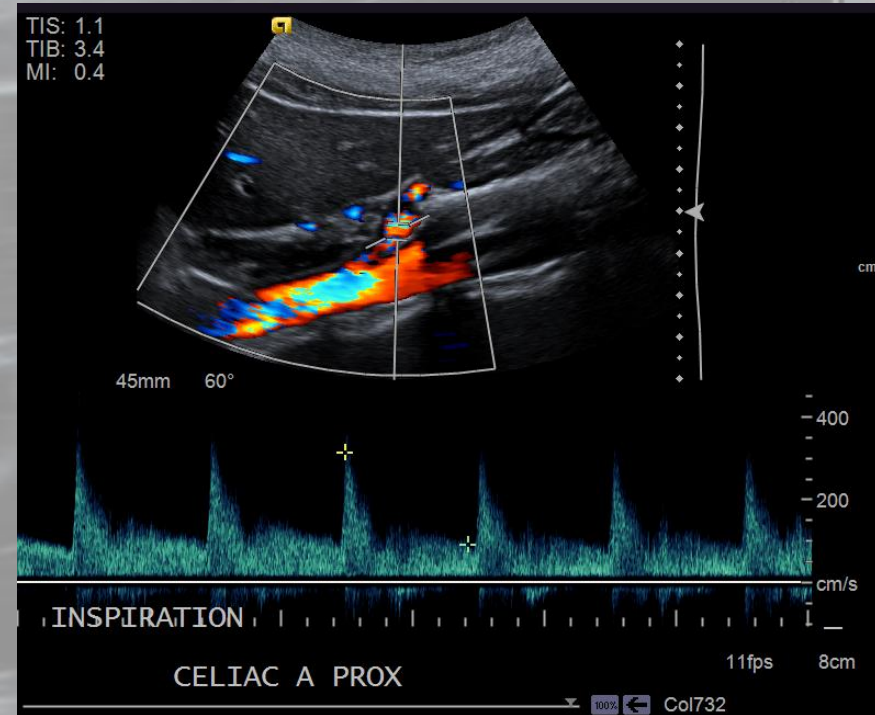
B: Celiac axis

C: SMA



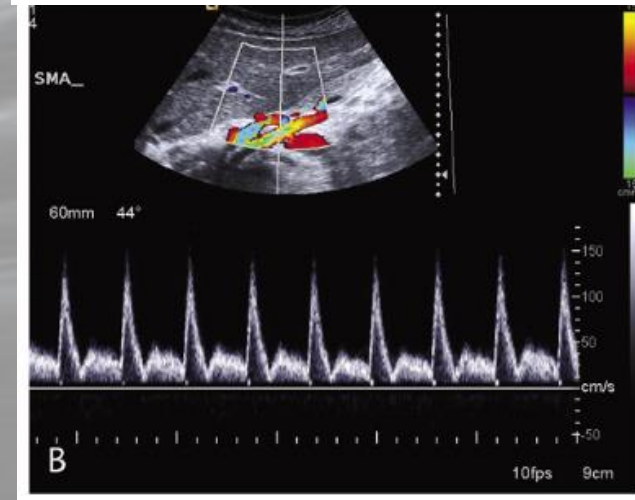
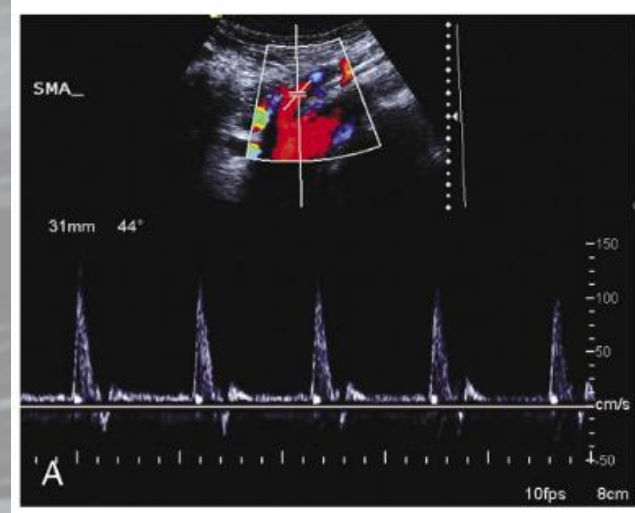
Celiac axis

- Celiac axis arises anteriorly
 - 3 branches: splenic, left gastric, and common hepatic arteries.
- First 2 cm of celiac axis is high resistance (biphasic)
- Distal celiac axis and its branches are low resistance.



Superior Mesenteric Artery

- Supplies jejunum, ileum, ascending and transverse colon. Vascular arcades.
- Cuff of retroperitoneal fat.
- Triphasic (high resistance) waveform when patient is fasting (Figure A).
- Post-prandially, increased systolic and diastolic velocities. Increased diameter. Low resistance waveform. (Figure B).



US of Mesenteric arteries

- Most atherosclerotic plaque at origins of these vessels.
- NPO for 8 hours
- Relax abdominal muscles by propping up head
- 2.5-5 MHz probe depending on body habitus.
- Celiac axis: angle corrected velocities to bifurcation
- SMA: angle corrected velocities for 5 cm
- Doppler exam technically not possible in 40% of population (body habitus, gas)

Mesenteric Artery Stenosis

PSV

Celiac >200 cm/sec

SMA >275 cm/sec

IMA >200 cm/s

PSV ratio (Mesenteric:Aorta) of 3-3.5:1

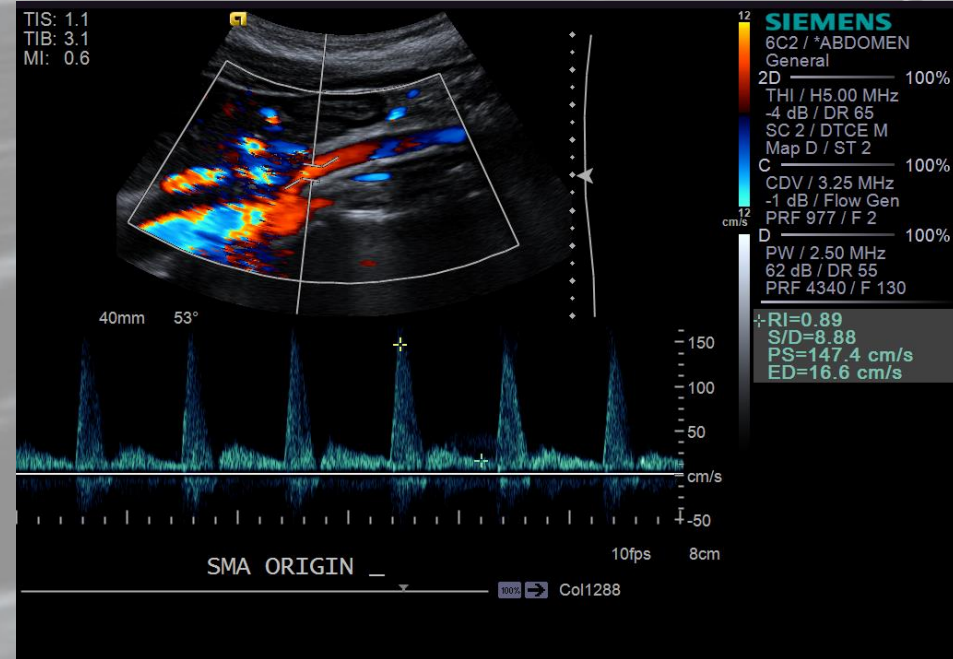
EDV

Celiac >55 cm/sec

SMA >45 cm/sec

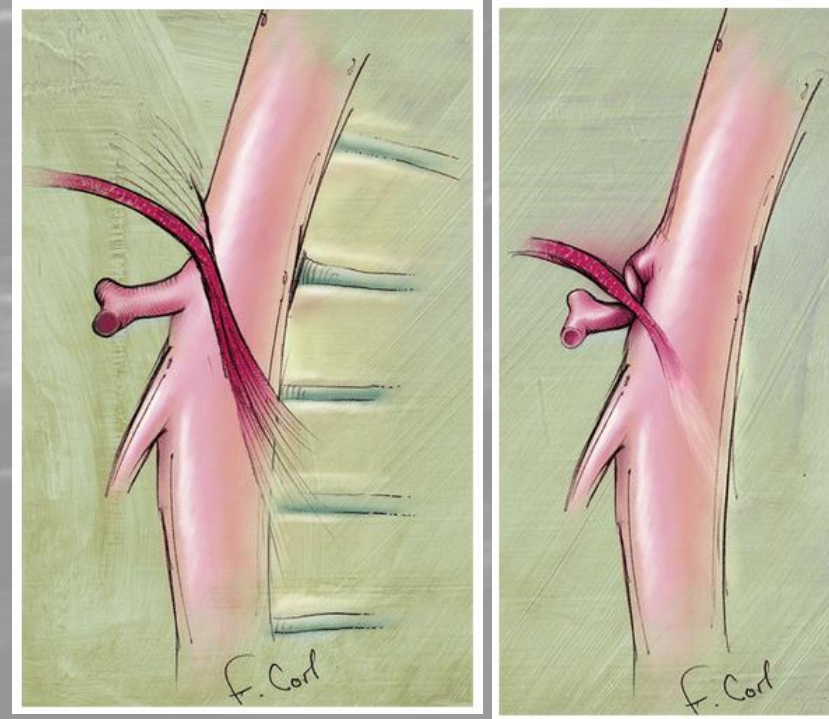
Distal Tardus Parvus waveforms.

Retrograde common hepatic artery flow 100% accurate for CA stenosis/occlusion.



Median Arcuate Ligament Syndrome

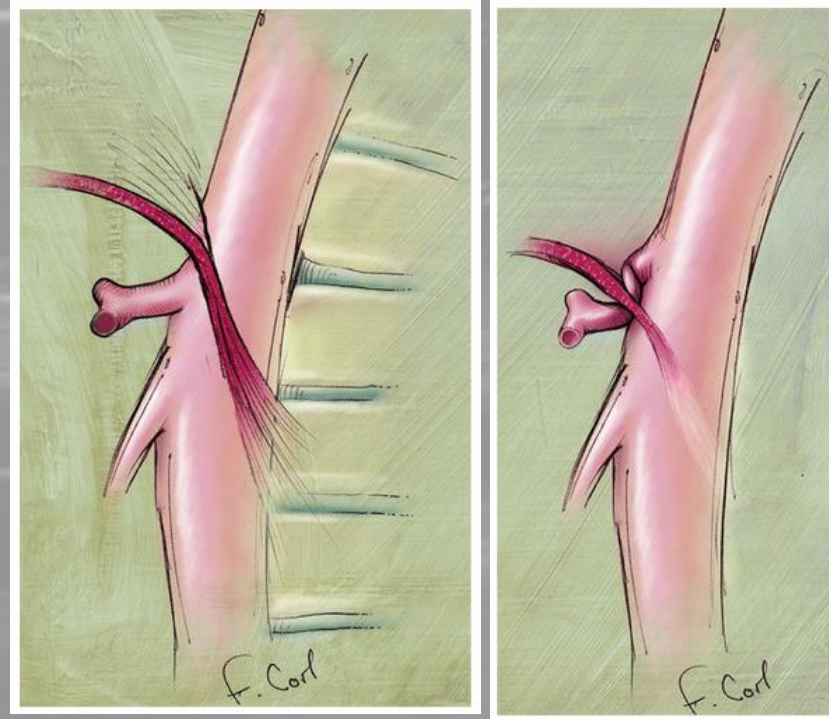
- Median arcuate ligament connects the diaphragmatic crura, forming anterior margin of aortic hiatus.
- Vague epigastric pain, especially post-prandial. Weight loss.
- Low lying in some patients, compressing celiac axis during expiration.



Median Arcuate Ligament Syndrome

Ultrasound assessment:

- Measure PSV in end-inspiration and end-expiration
- Elevated celiac axis PSV during end expiration in symptomatic patients raises possibility of MAL syndrome.

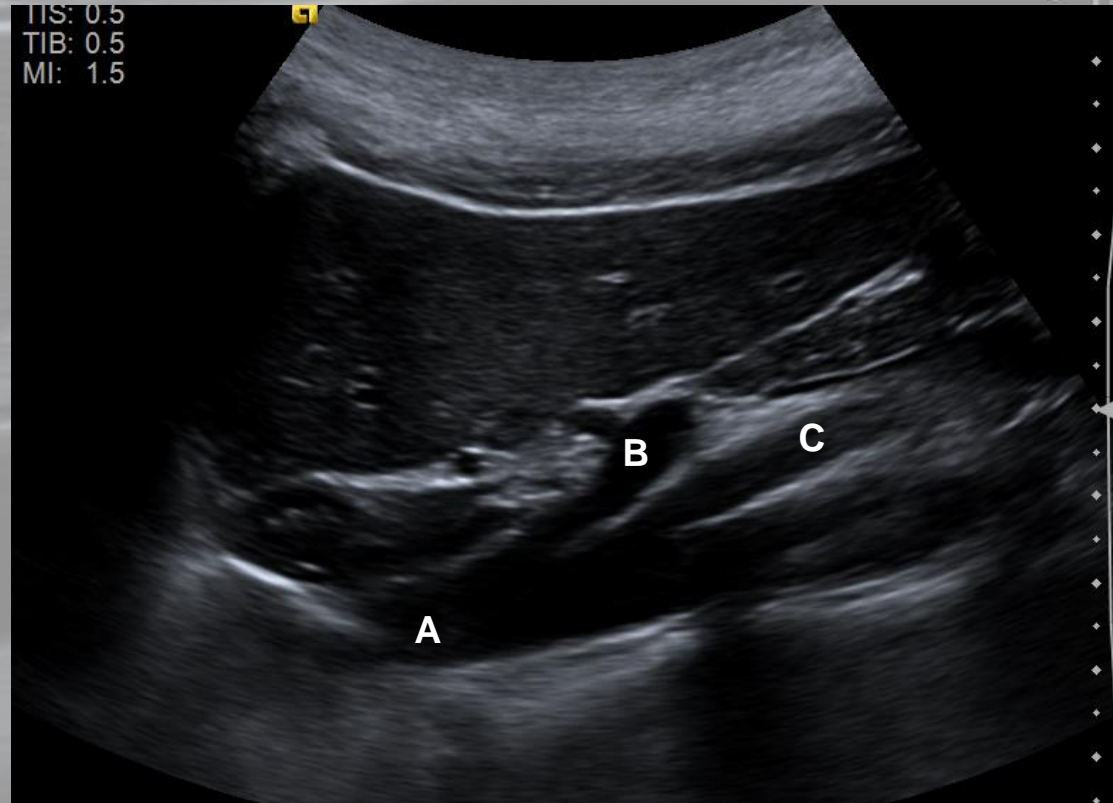


You know the anatomy of the vessels...

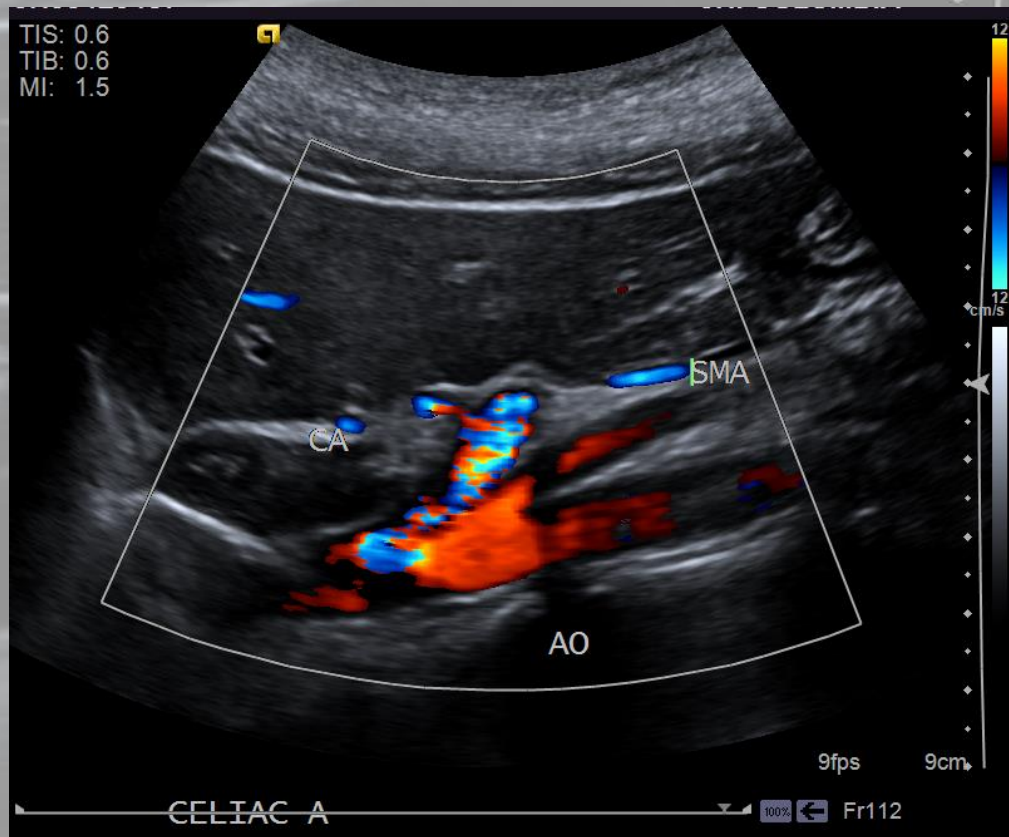
A: Aorta

B: Celiac axis

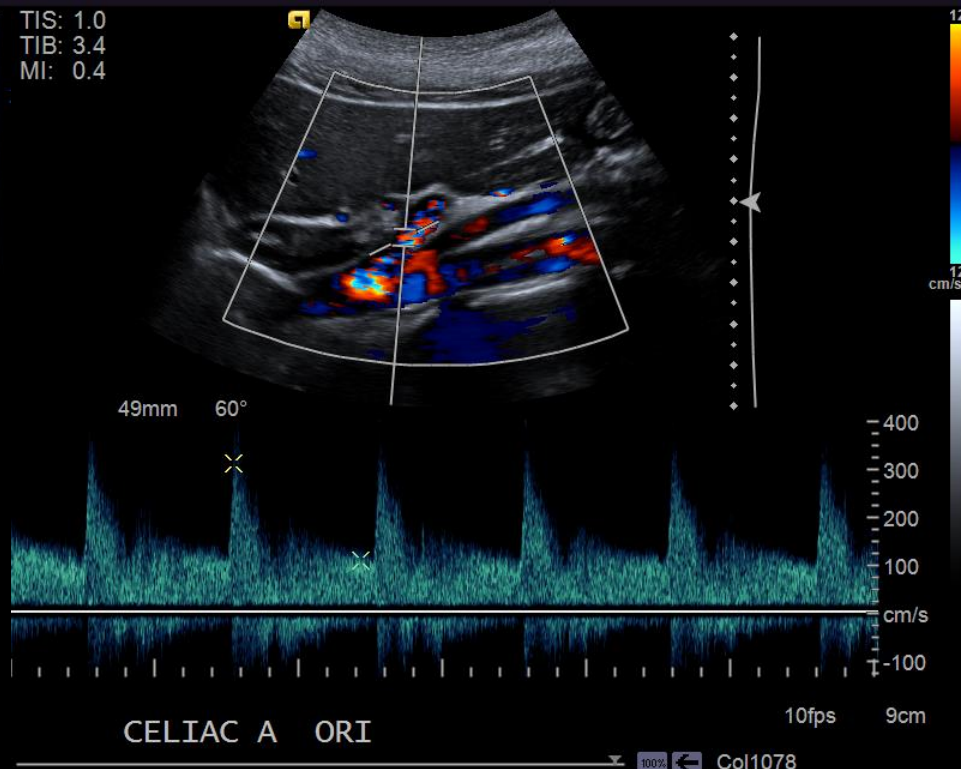
C: SMA



What do you do next?



What do you do next?



What do you do next?

PSV

Celiac >200 cm/sec

SMA >275 cm/sec

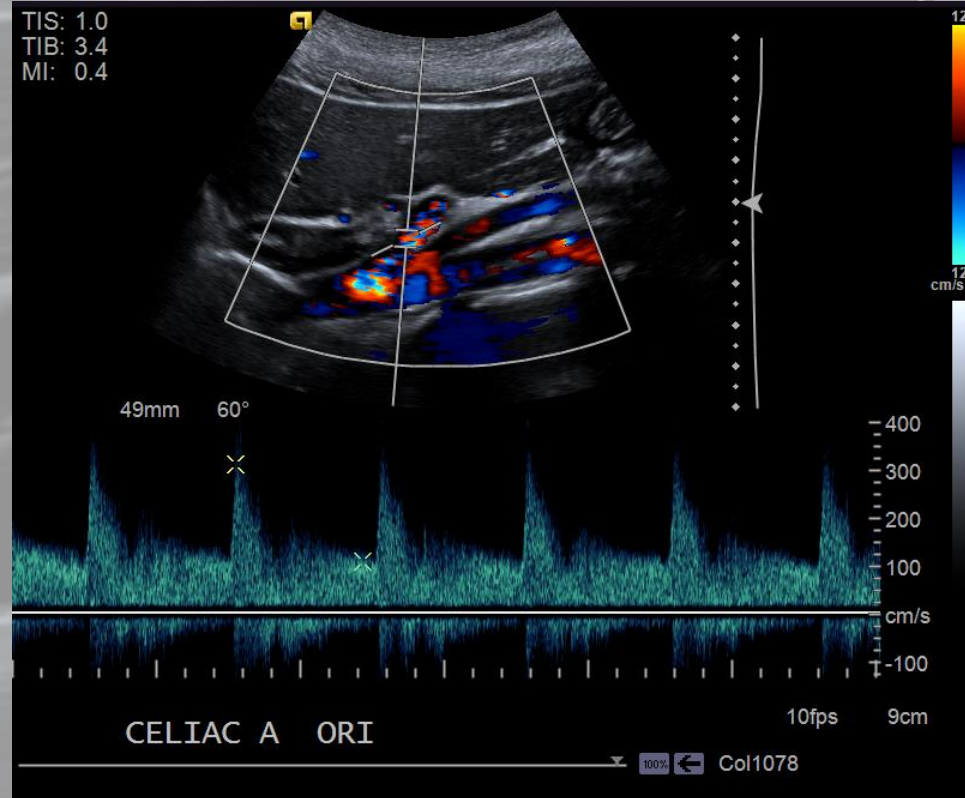
IMA >200 cm/s

PSV ratio (Mesenteric:Aorta) of 3-3.5:1

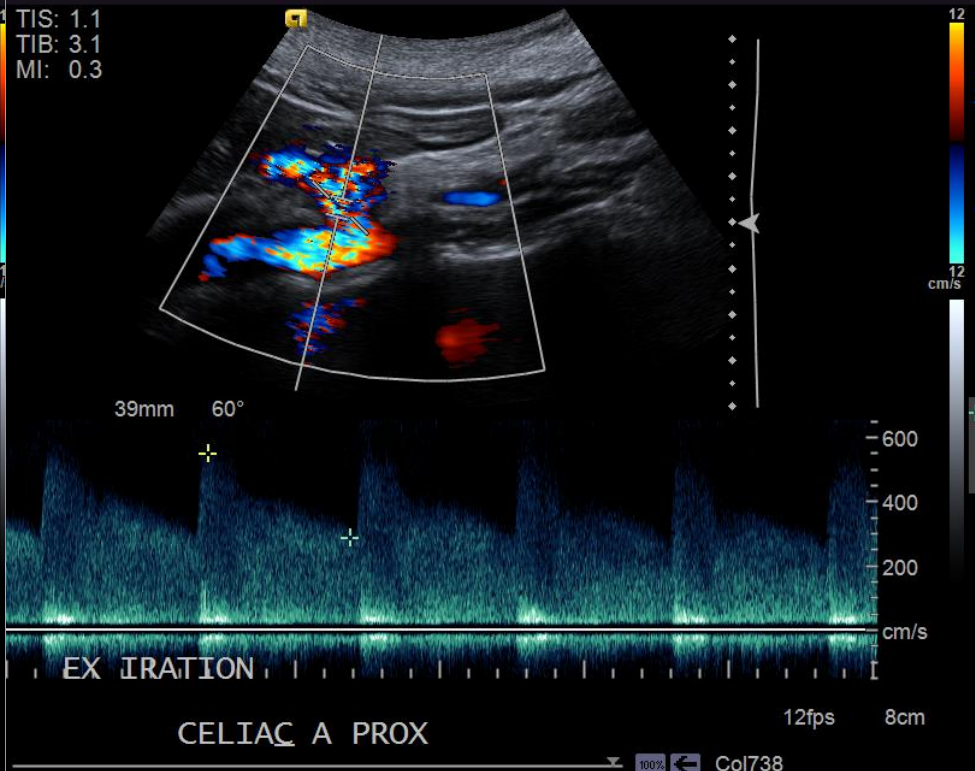
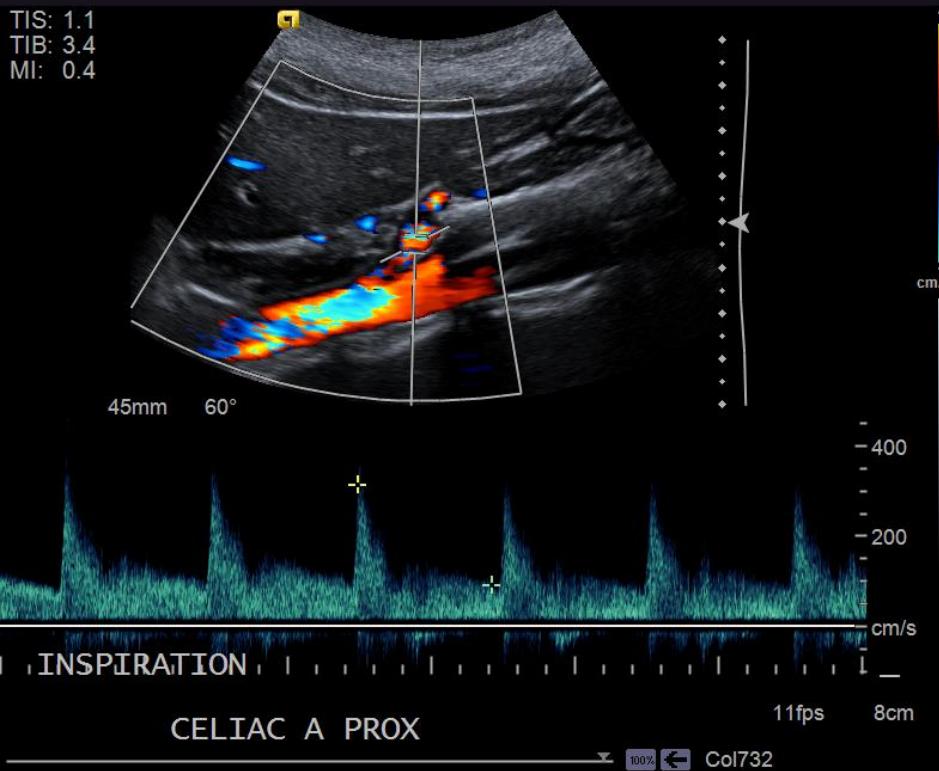
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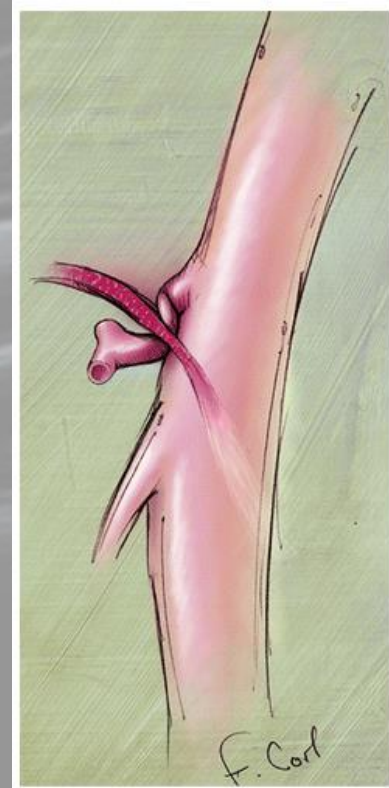
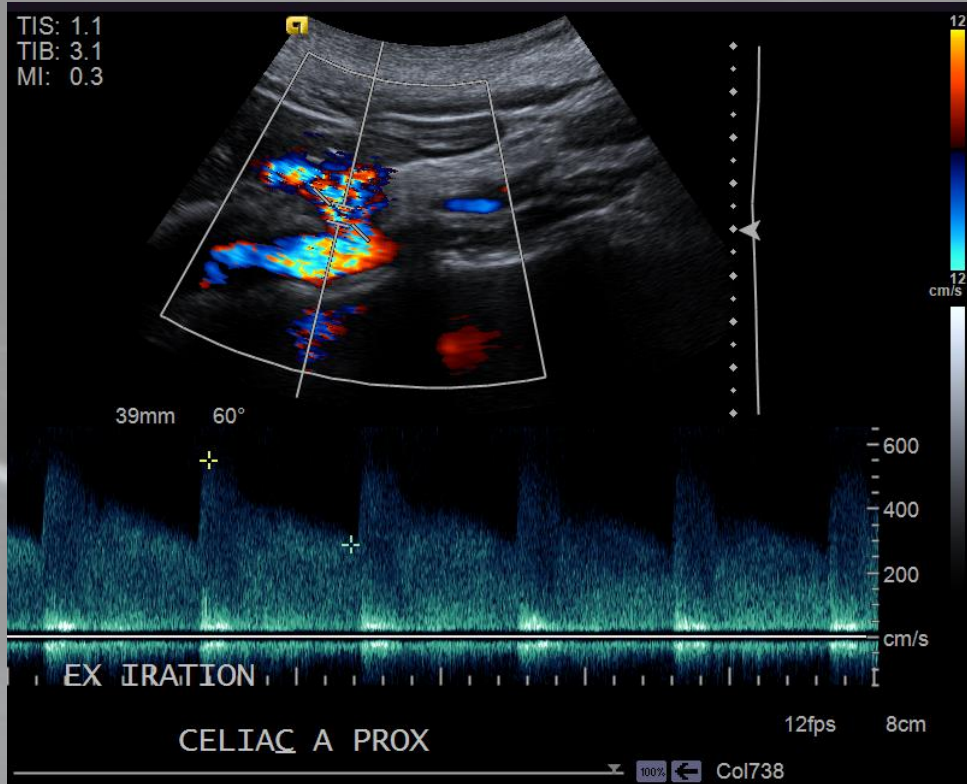


Check PSV with inspiration and expiration.

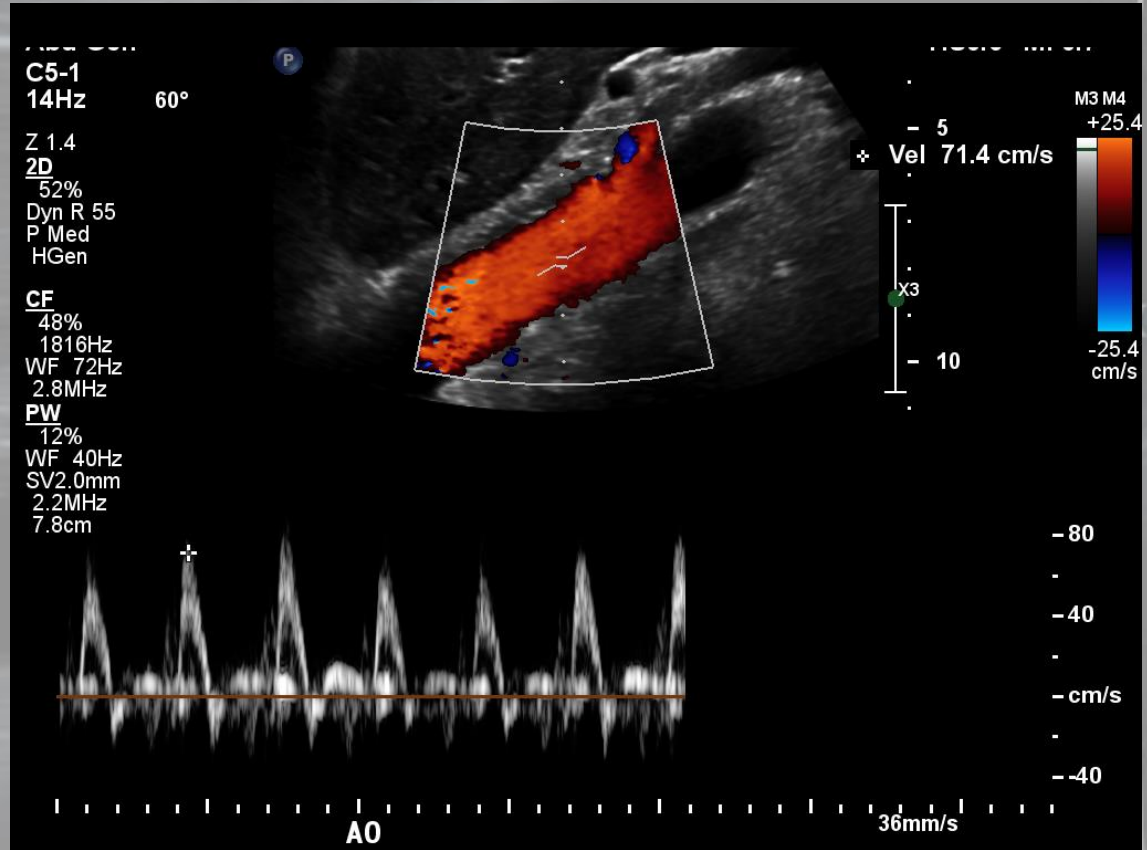


Median Arcuate Ligament Syndrome

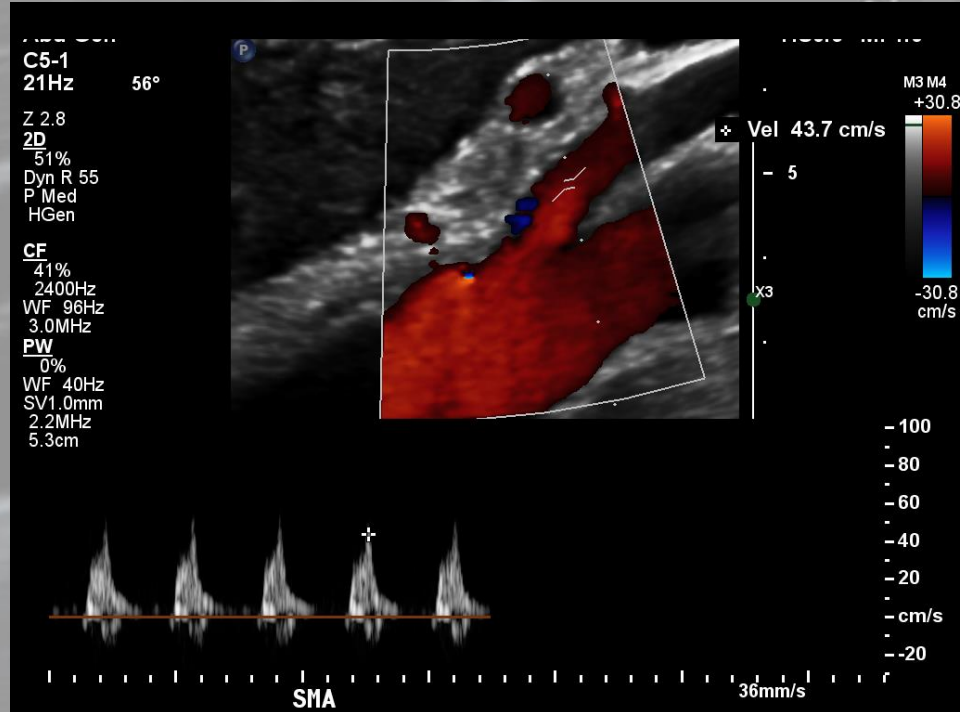
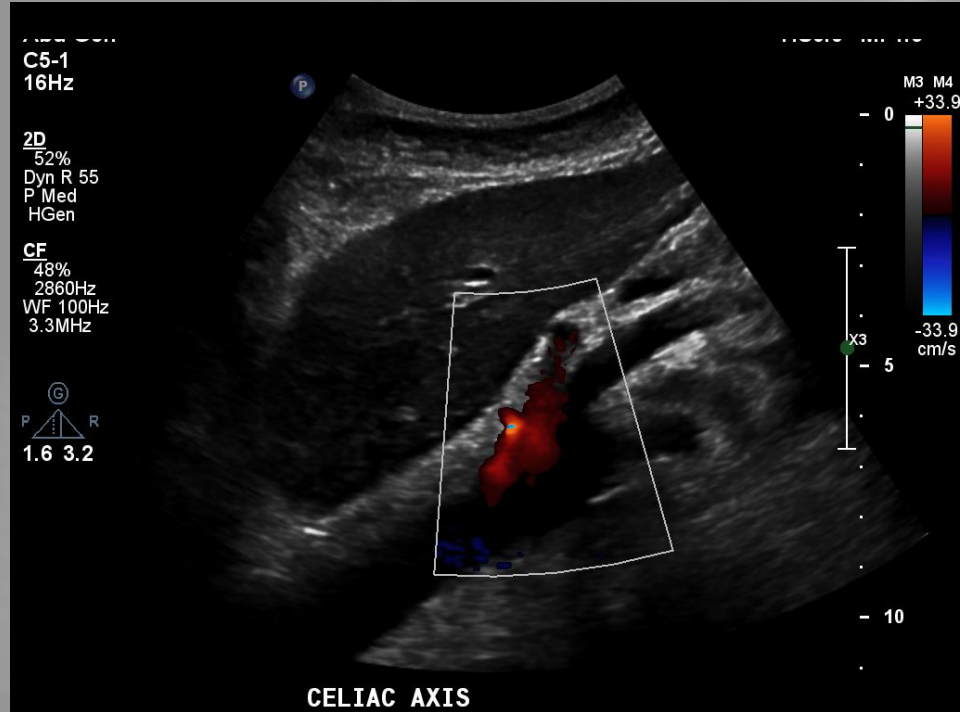
Elevated PSV that is further increased with expiration = MALS



Abdominal pain out of proportion to exam. AFib.



What abnormalities do you see?

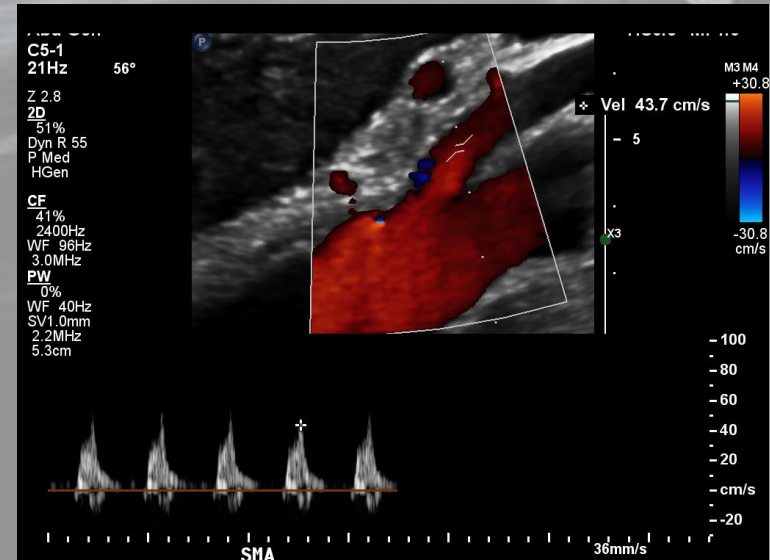
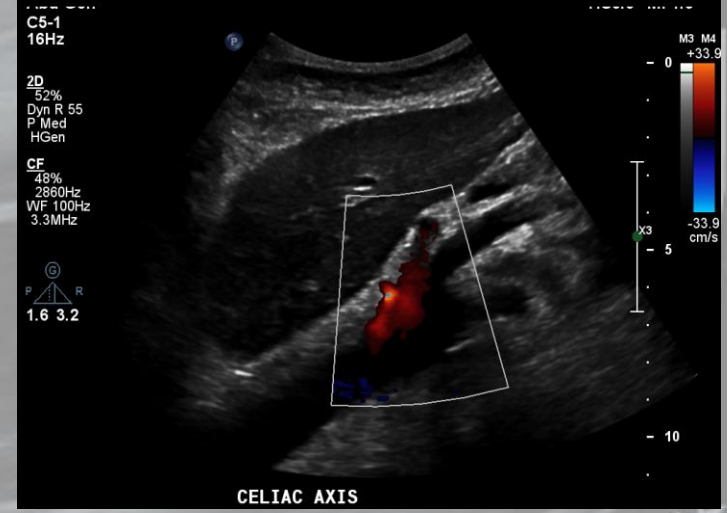


What was the sonographer looking for?



SMA thrombosis.

- Decreased or absent diastolic flow (increased RI).
- Decreased flow on color Doppler image.
- Distal obstruction/high grade stenosis.
- In this case due to clot embolization from A Fib.



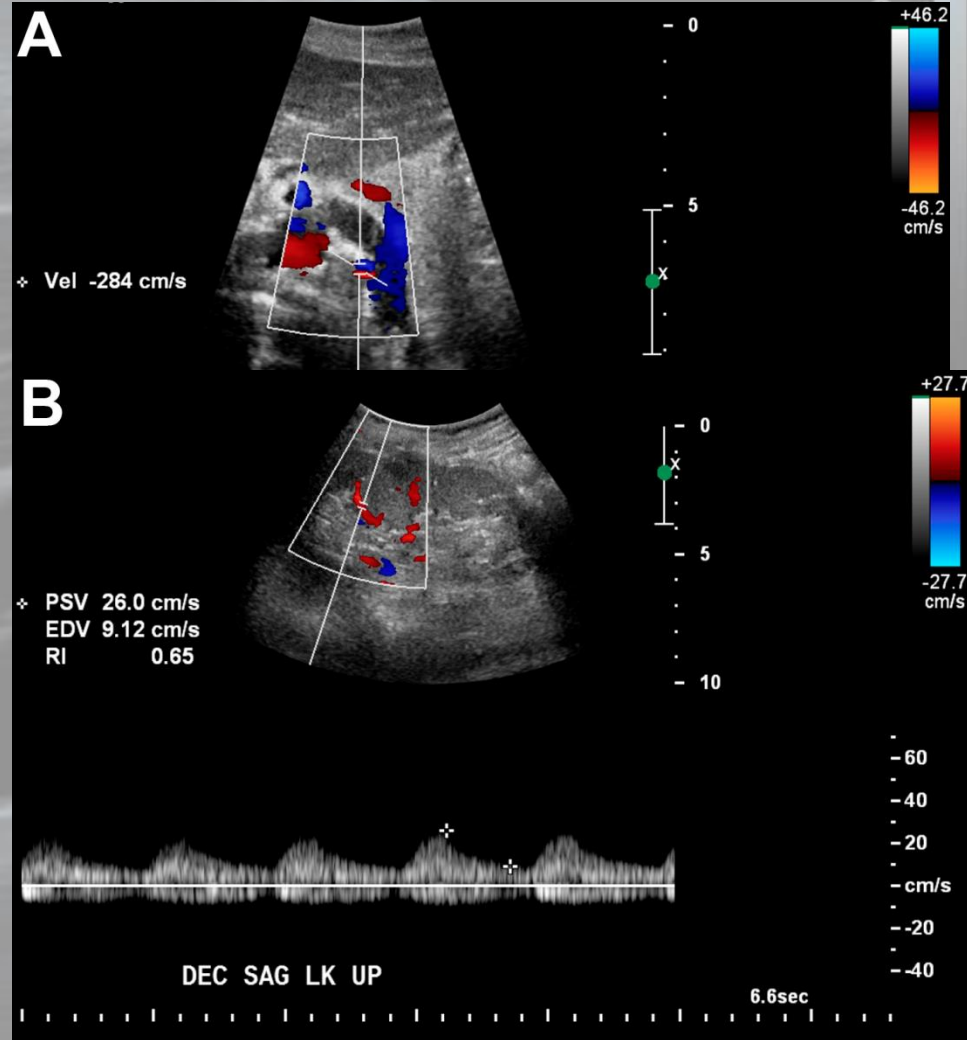
Mesenteric Ischemia

- Pain after eating. Pain out of proportion to exam.
- CT Angiogram if acute thrombus suspected.
- Chronic: Doppler US may be initial evaluation. Usually due to atherosclerosis, although stenosis does not mean mesenteric ischemia is present due to extensive collateral blood supply.

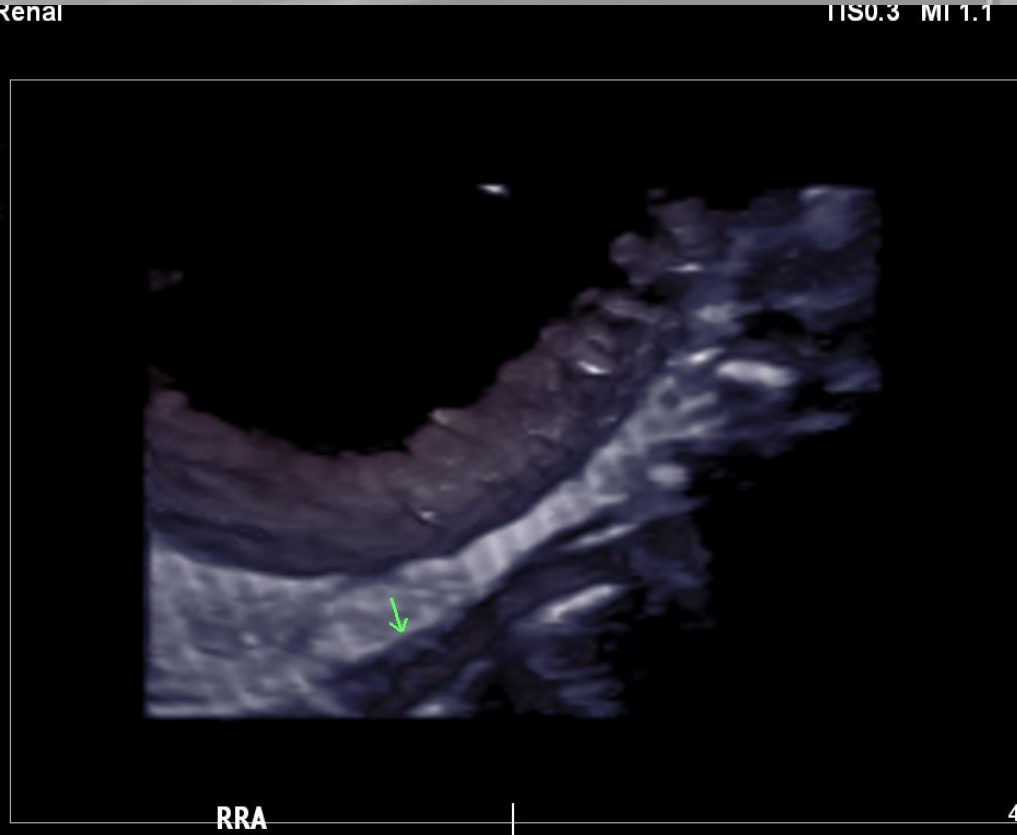
Renal Artery Stenosis

- Paired arteries at the L2 level.
- Renal artery stenosis / renovascular hypertension:
 - In older patients, at origin due to atherosclerosis (90% of cases).
 - In young patients, mid renal artery due to fibromuscular dysplasia.
- Criteria:
 - Renal artery PSV >200 cm/s (suggest stenosis 60% or greater)
 - Renal:Aortic Ratio PSV 3.5:1
 - EDV >150 cm/s (suggests stenosis 80% or greater).
 - More distal findings such as tardus parvus helpful to confirm stenosis, but absence doesn't exclude stenosis.

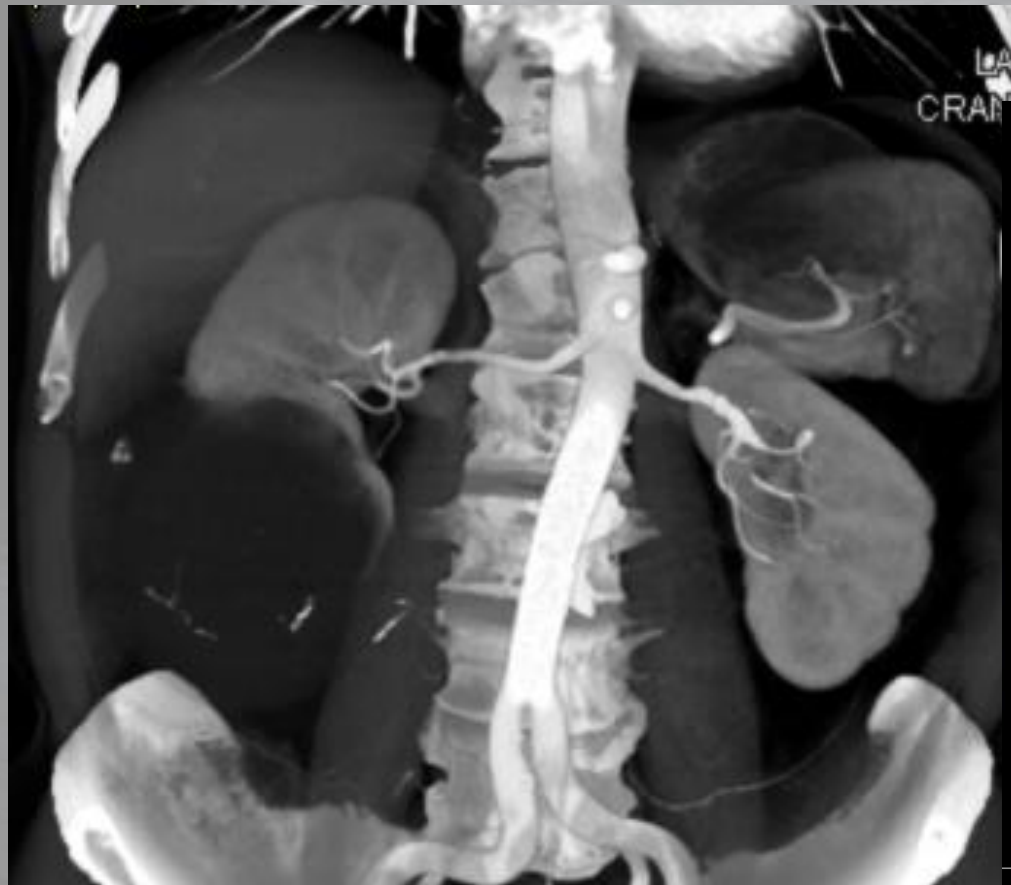
- Criteria:
 - Renal artery PSV >200 cm/s (suggest stenosis 60% or greater)
 - Renal:Aortic Ratio PSV 3.5:1
- 20-30% patients have one or more accessory renal arteries, difficult to visualize and interrogate by US.



Fibromuscular Dysplasia (without stenosis)

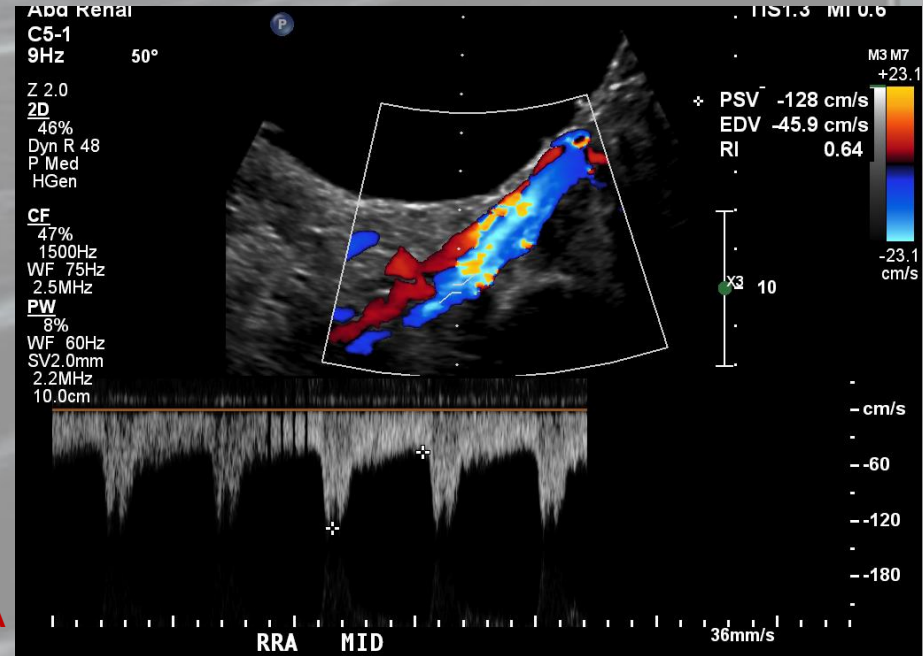


FMD



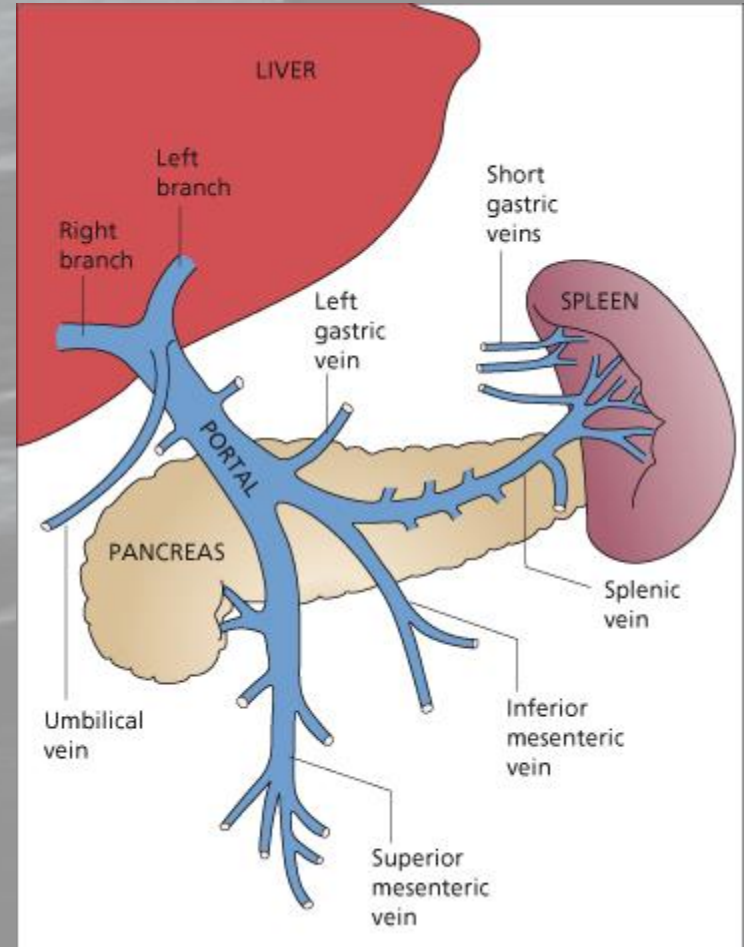
Renal Artery Evaluation

- 12 h fast to decrease bowel gas.
- 2.5-5 MHz transducer via anterior abdominal wall or the flank.
- Right RA beneath the IVC.
- Identify left RA by first finding left RV; artery is directly behind it.
- Pitfall, inferior mesenteric artery, but IMA should be high resistance.



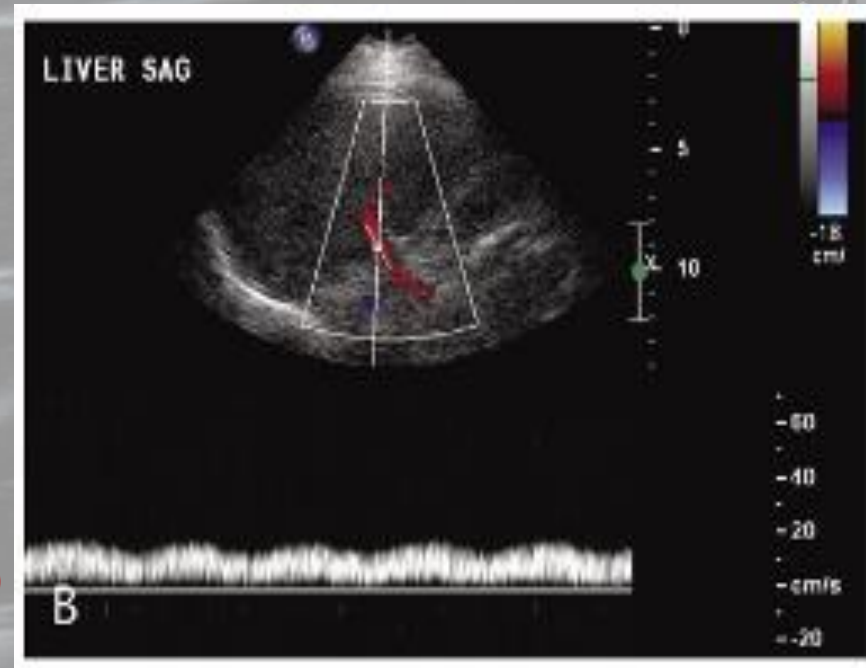
Portal Venous System

- Main portal vein formed by confluence of splenic vein and superior mesenteric vein.
- 5-8 cm in length.
- Splits into right and left portal vein branches



Main Portal Vein

- Slow flow, 16-40 cm/s.
- Cardiac variability in waveform
 - Hepatic vein pressures transmitted to portal venous system via sinusoids.
- Gently undulating waveform.
 - Trough is during diastole when right atrium contracts.
 - Should always be hepatopetal (towards liver)



4 ways portal venous waveform can change:

1. Increased pulsatility
 - Right heart failure, tricuspid regurgitation
 - Arteriovenous shunting or fistulas
2. Slow flow (<16 cm/s)
 - Prehepatic (portal vein thrombosis)
 - Hepatic (cirrhosis)
 - Post hepatic (CHF, tricuspid regurgitation, hepatic vein thrombosis)
3. Hepatofugal flow (retrograde) due to portal hypertension.
4. Absent flow (bland or tumor thrombus).

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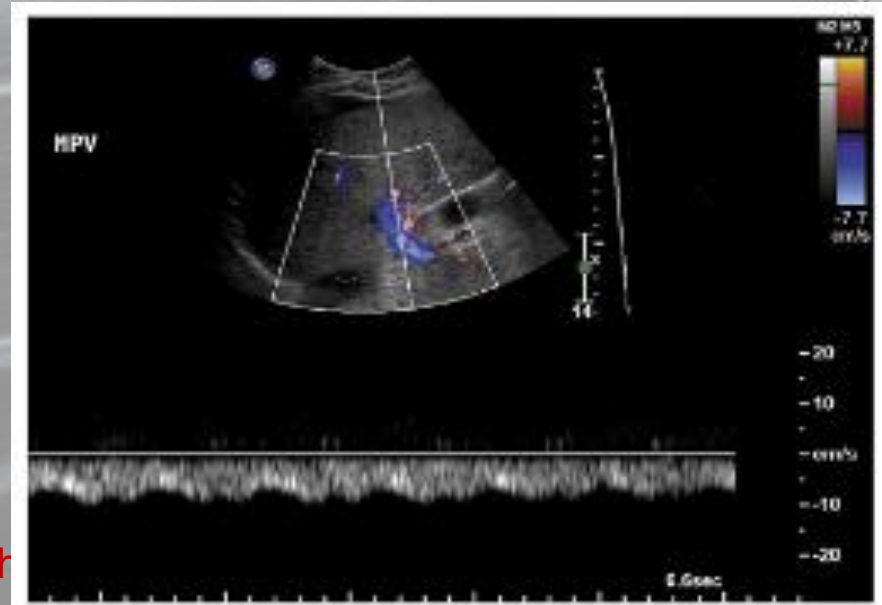
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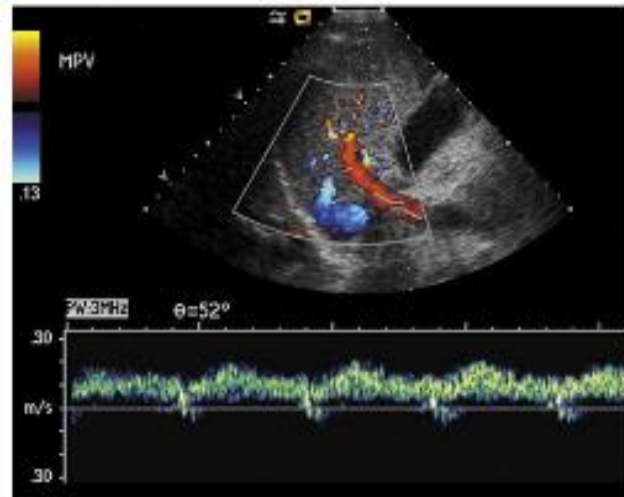
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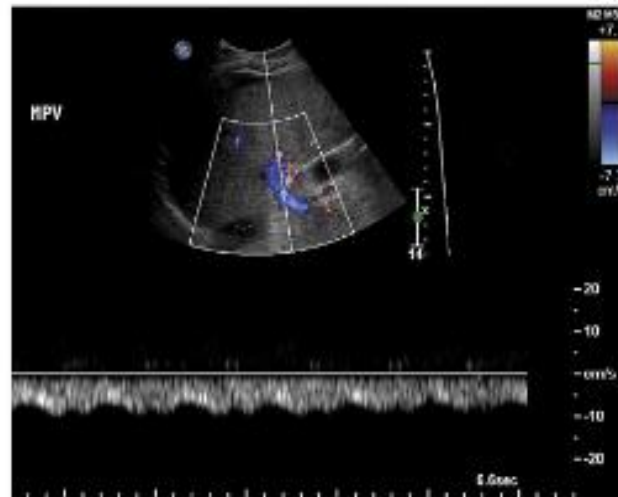
Portal venous waveforms



A

Mild portal hypertension.

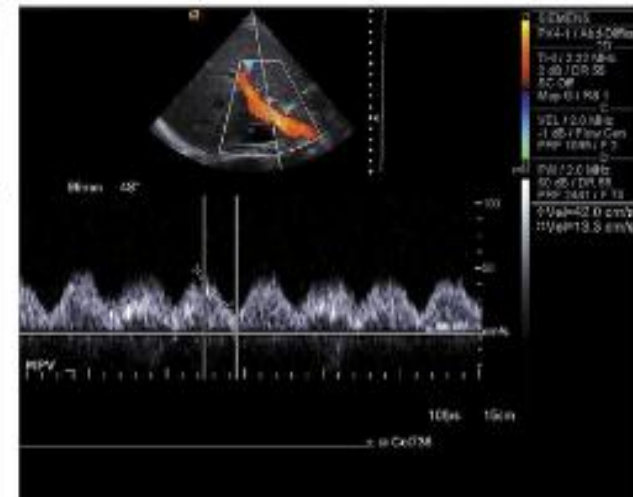
- Increased pulsatility



B

Severe portal hypertension.

- Hepatofugal flow.



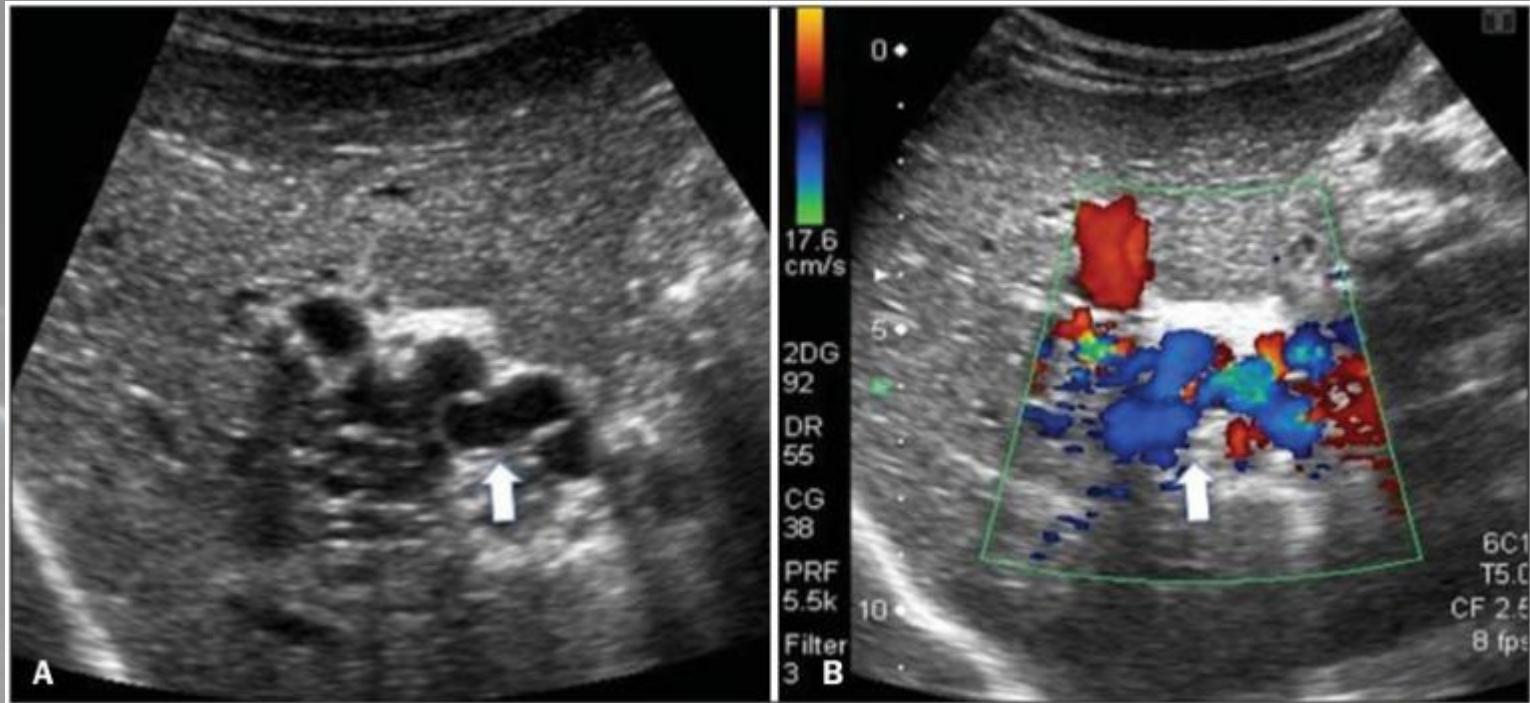
C

Tricuspid regurgitation.

- Pulsatile
- Peak/trough difference >15 cm/s.

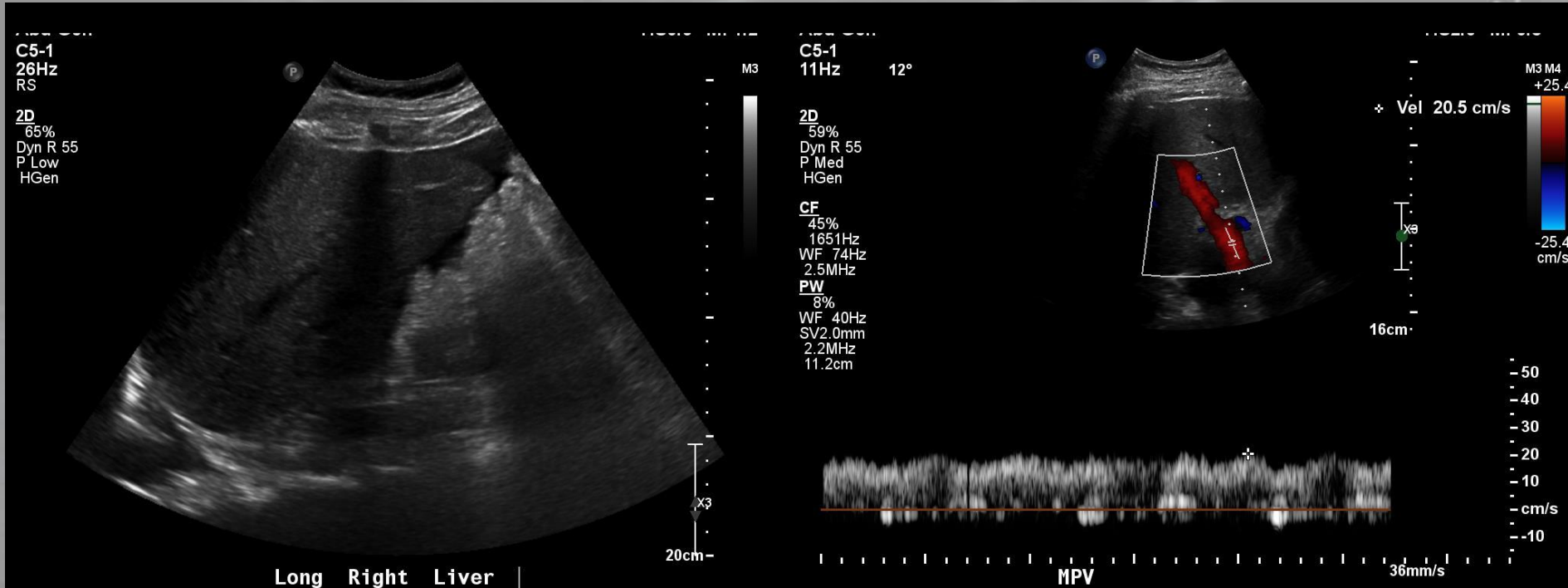
Cavernous transformation of the main portal vein.

- Takes months to develop, so typically seen with bland thrombus.



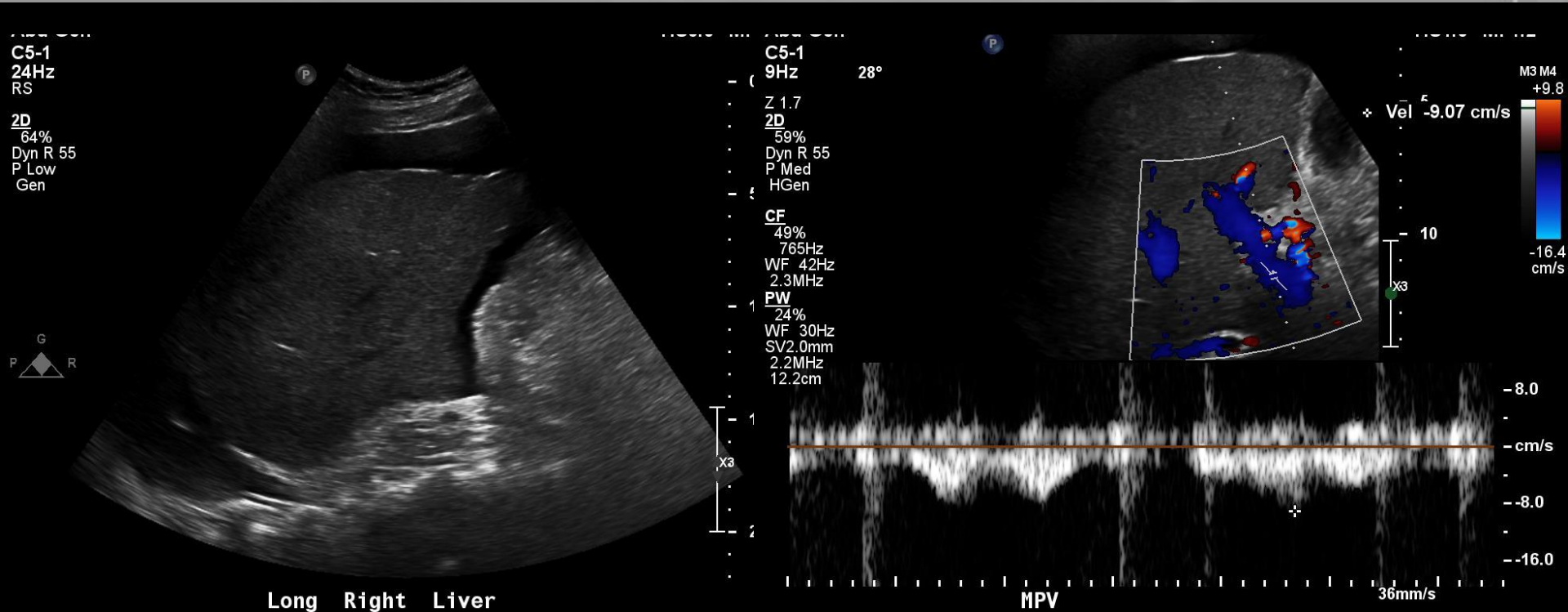
60 yo male. Increasing hyperbilirubinemia after BMT.

- Normal flow in MPV. Small volume perihepatic ascites.

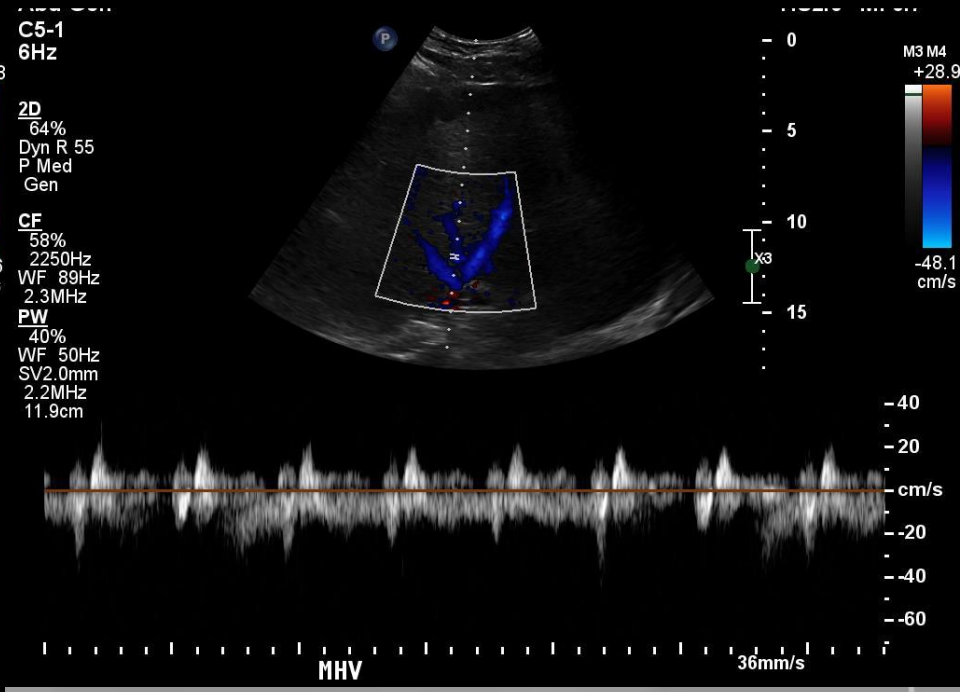
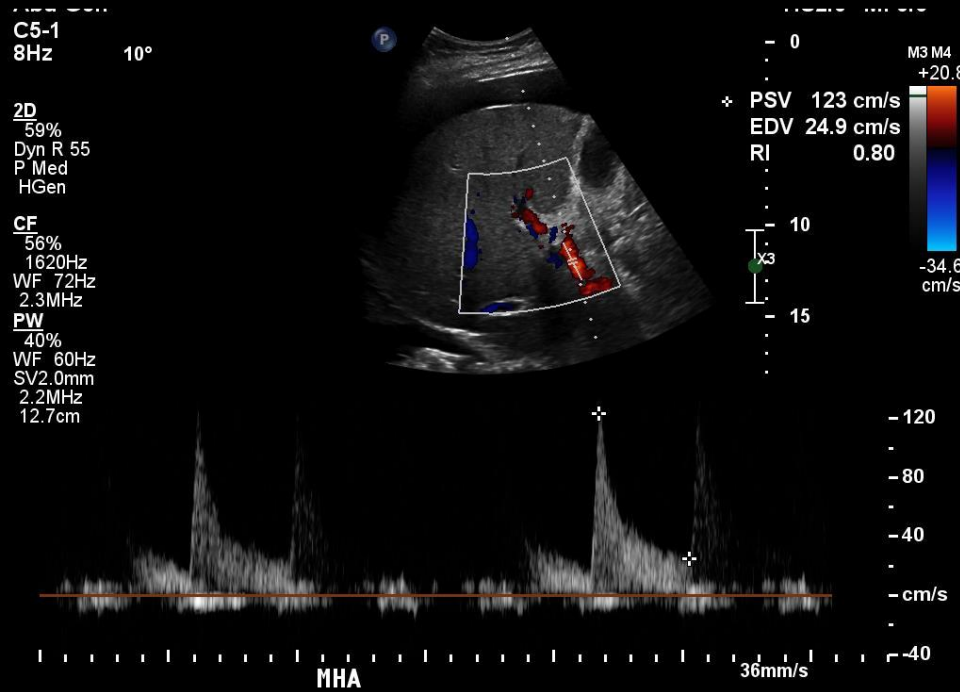


2 weeks later:

- Slow, hepatofugal flow in MPV, 8 cm/s. Increased ascites.



- Increased hepatic arterial RI. Patent IVC and hepatic veins.



4 ways portal venous waveform can change:

1. Increased pulsatility

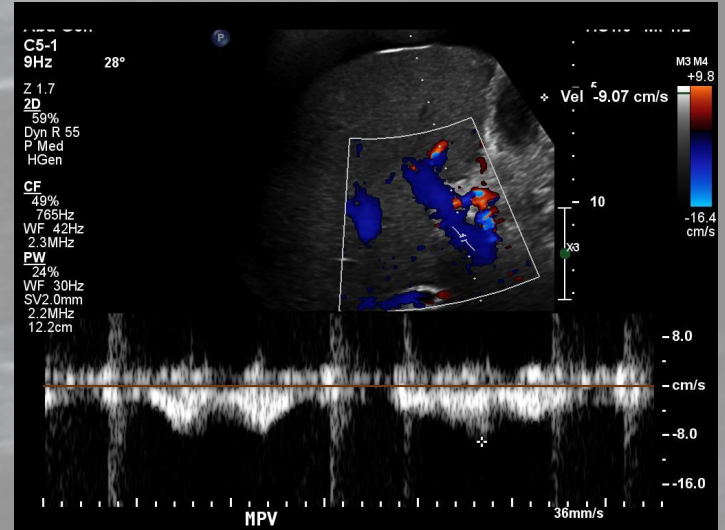
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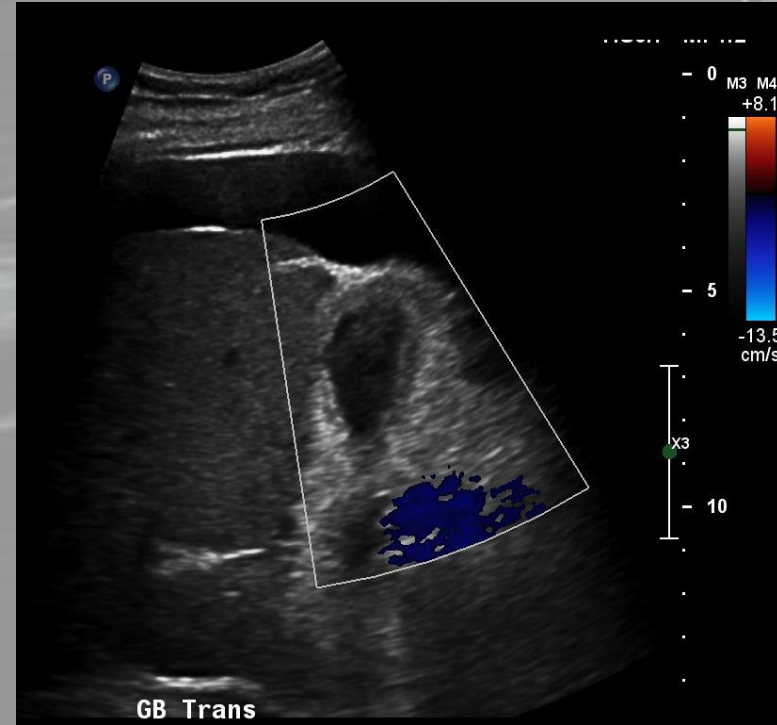
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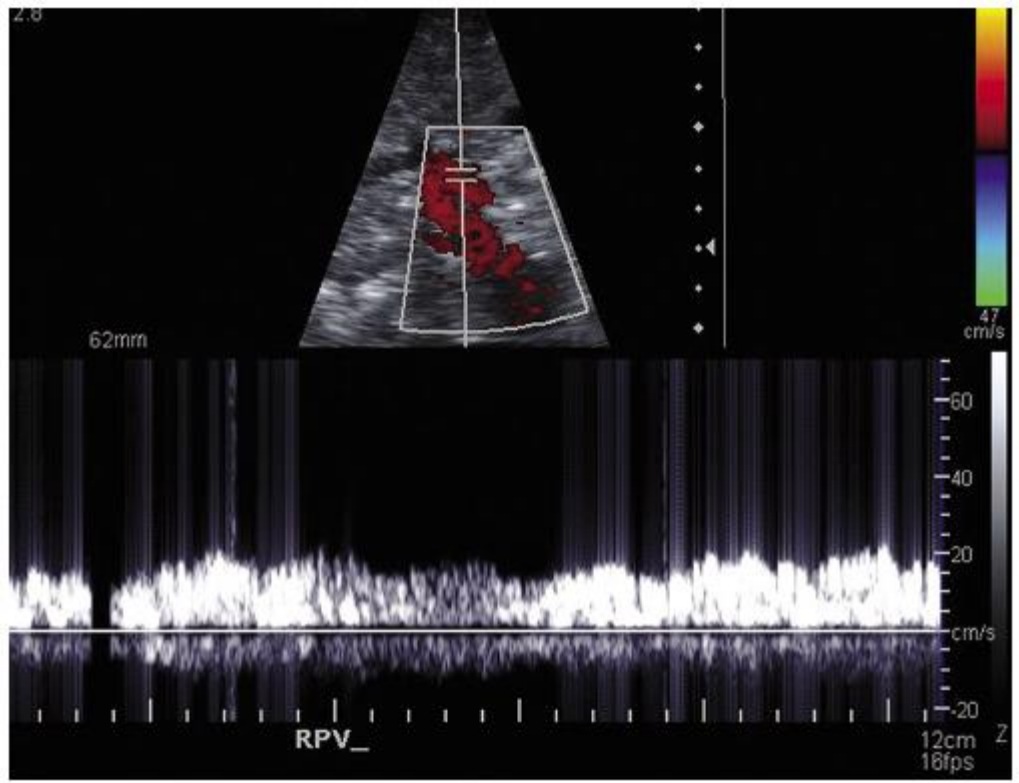


Hepatic veno-occlusive disease

- Toxic injury to liver sinusoids → sloughed cells embolize to hepatic venules → hepatic congestion.
- Ddx: Budd-Chiari syndrome
- Findings:
 - Hepatomegaly
 - Portal vein dilatation, increased pulsatility, hepatofugal flow if severe.
 - Increased hepatic arterial RI
 - Gallbladder wall thickening
 - Ascites



Don't miss portal venous air!



Numbers hard to remember... be sure to document mesenteric:aorta PSV ratio.

PSV

Celiac >200 cm/sec

SMA >275 cm/sec

IMA >200 cm/s

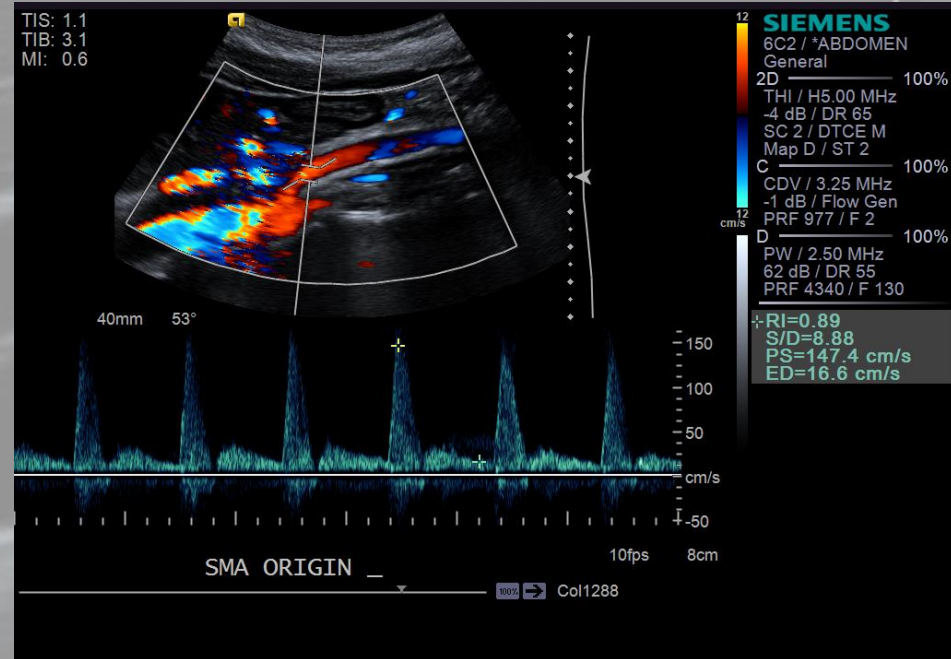
PSV ratio (Mesenteric:Aorta) of 3-3.5:1

EDV

Celiac >55 cm/sec

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Distal Tardus Parvus waveforms.





Visceral Vascular Ultrasound

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