Abdominal Doppler Ultrasound:

Principles and Clinical Insights

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Objectives

- Describe the basic principles and mechanics of Doppler ultrasound technology, including how it measures blood flow and velocity within the abdominal organs.
- Discuss the role of Doppler in evaluating the abdominal vessels.
- Differentiate normal, abnormal, and indeterminate waveforms.

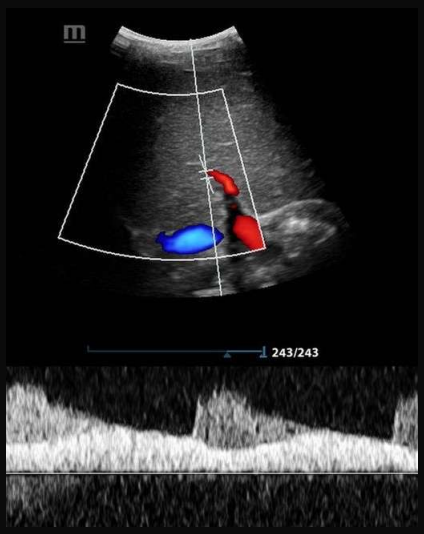

Image: Goss Personal File

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Topics to be discussed

Doppler Principles → Hepatoportal Assessment → Mesenteric Vessels

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Doppler Physics

- Understanding the physics and technical parameters of Doppler is critical for accuracy of waveform morphology, direction, and velocity.

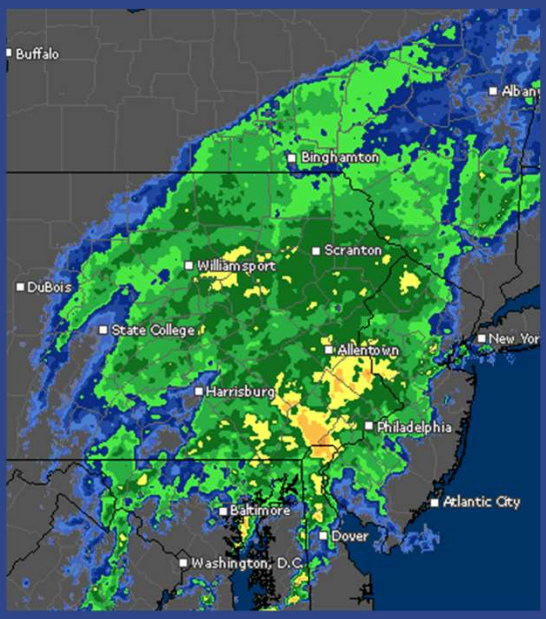

Image: Accuweather, Inc. https://www.accuweather.com/en/us/bloomington/55420/september-weather/333859

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Doppler effect

- The Doppler effect states the relationship between the transmitted frequency of the transducer and the frequency of the return waves. This provides the machine with information as to the color to be displayed and which side of the baseline the waveform components are displayed.

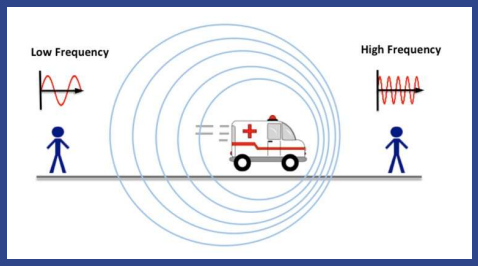

Image: Science Ready https://scienceready.com.au/pages/dopplers-effect

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$$F_D = \frac{2 f_o v \cos\theta}{c}$$

- Key components of the Doppler equation are the transmitted frequency and the cosine of the angle to calculate an accurate velocity.
  - The sonographer controls both factors.
- The transmitted frequency is often preset; however, it can be changed for Color and Pulsed Wave Doppler. Thus, if we look at the relationship, in theory, if you wanted a larger Doppler shift you would use a higher transducer frequency. If aliasing is occurring, you would use a lower Doppler frequency. Most often, the frequency within the preset is at the lower end and is acceptable.

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Role of Doppler Angle

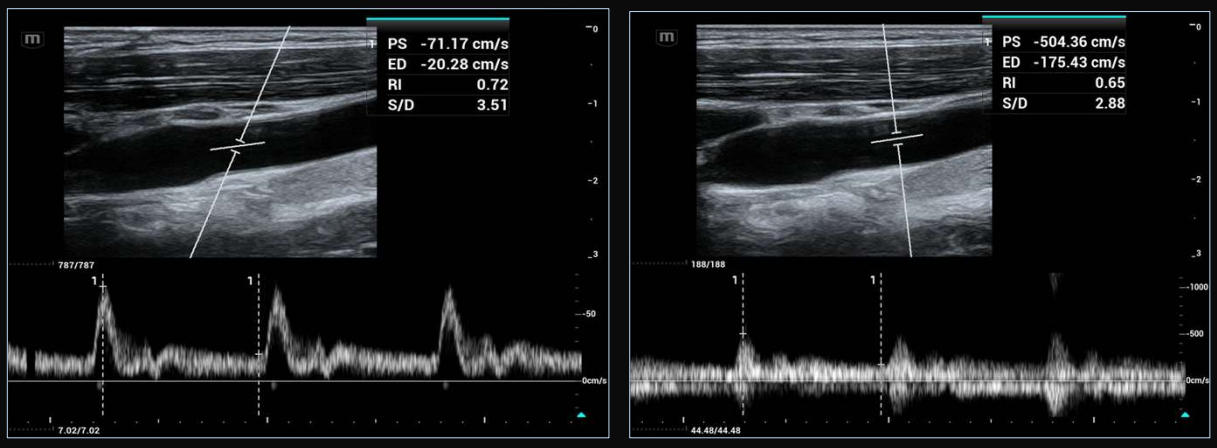

Image: Goss Personal File

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$$V = \frac{C \times f_{DOP}}{2 \times f_{o\,(transmit)} \times \cos\theta}$$

The math behind the cosine of the angle.

- As the angle of incidence to the flow increases, it decreases the cosine of the angle. Decreasing the cosine, increases the velocity. Small errors above the 60 degrees yields larger error in velocity.

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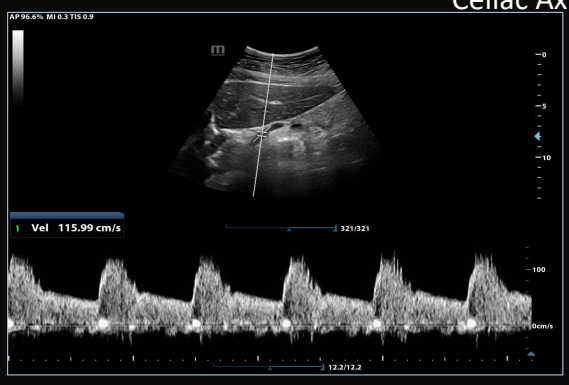
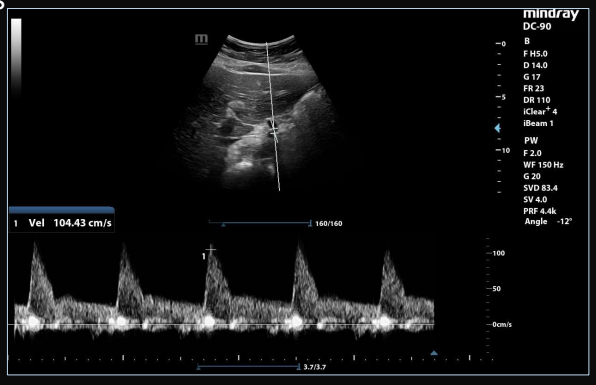
Small angle changes that are closer to and under 60 degrees, the velocity is not affected as much.

Celiac Axis



Angle: 35 degrees



Angle: 12 degrees

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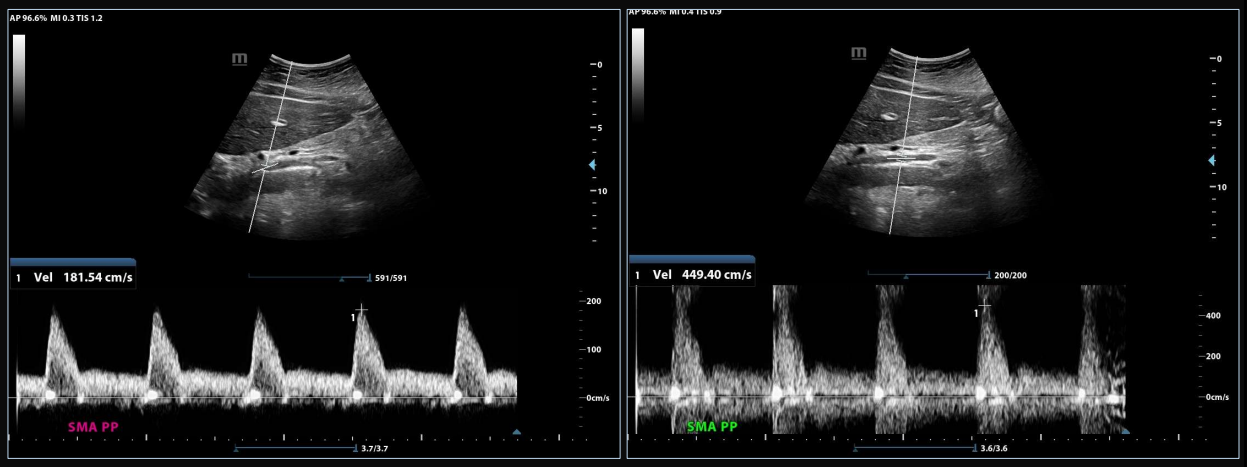
Let's look at the SMA



Angle: 55 degrees

Angle: 88 degrees

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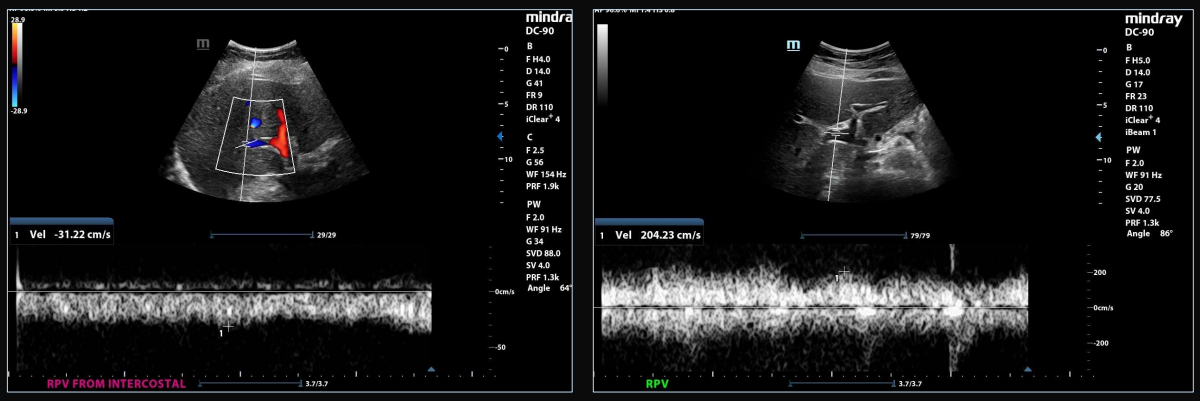
Let's apply to the portal vein



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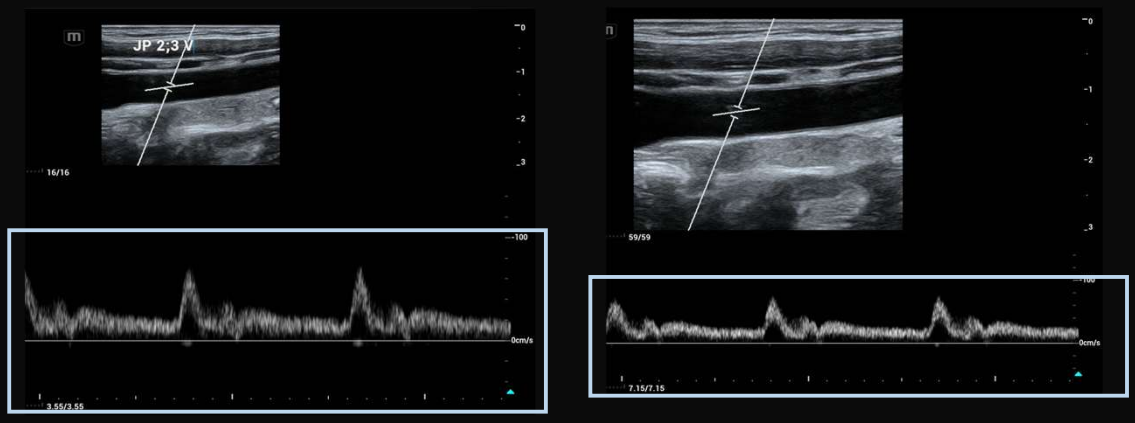
2D : Spectral Ratio



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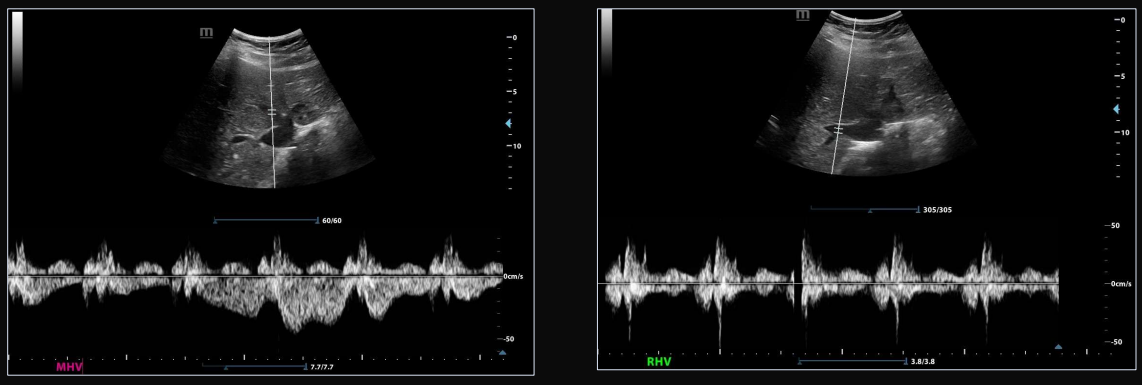
Let’s apply to the hepatic vein



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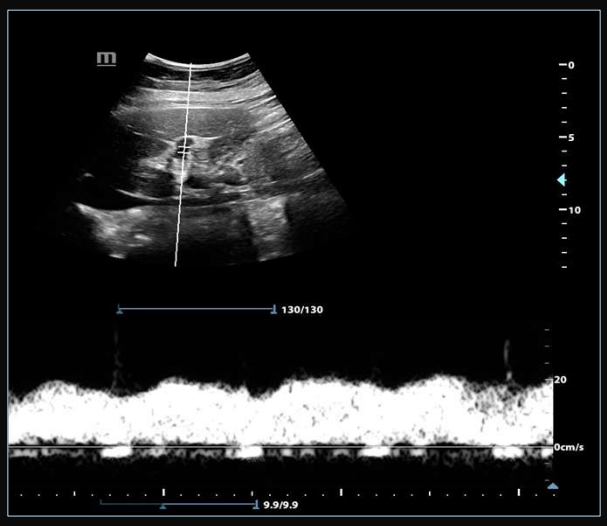
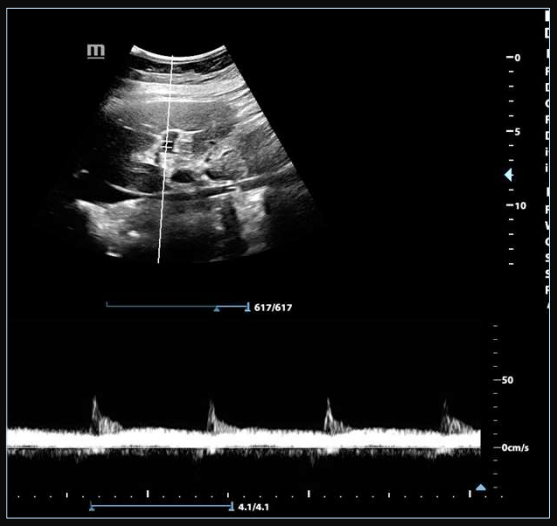
Scale/PRF Effect





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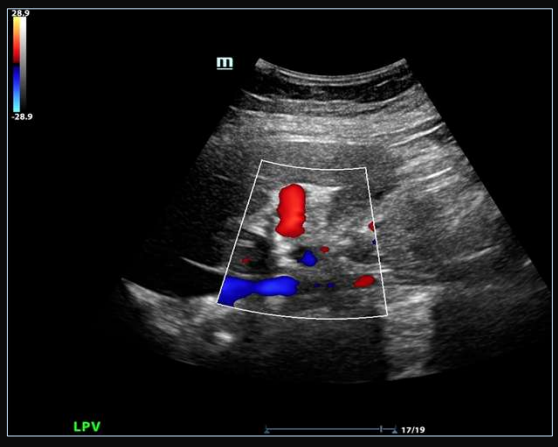
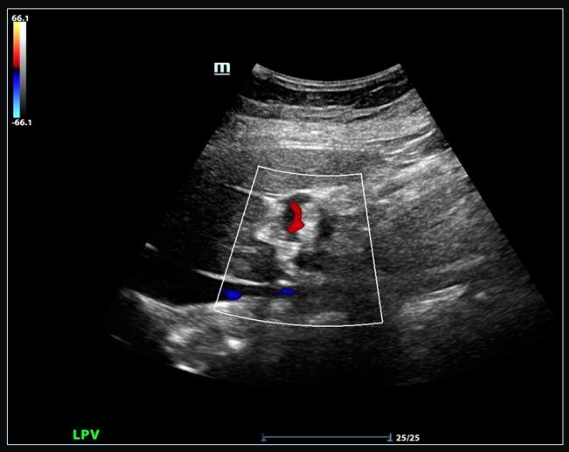
Color Scale/PRF





Images: Goss Personal File

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Directionality of Flow

- It is important to understand directionality of flow.
- Traditionally, arterial waveforms appear on the top of the baseline (can be positive shift or a negative shift on an inverted scale)
- Some protocols place all venous on the bottom of the baseline (negative or positive shift an inverted scale) , while other protocols keep the scale non-inverted.
- Most important is understanding, so that color Doppler and spectral scale are not inverted in error and the diagnosis of retrograde flow is missed.

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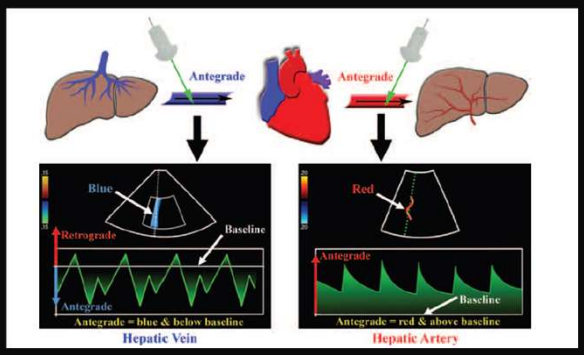
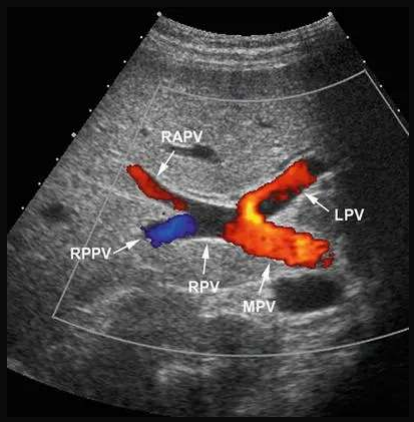
Antegrade Flow





Images: 1.McNaughton, D., et.al Doppler US of the Liver Made Simple.

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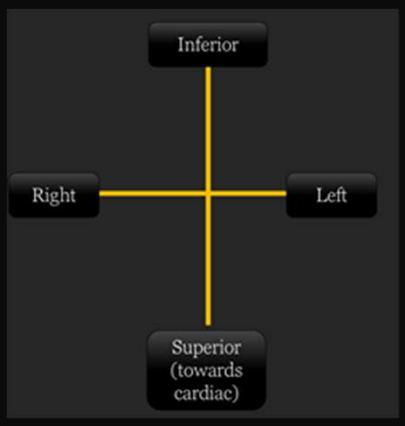
HV waveform for antegrade flow



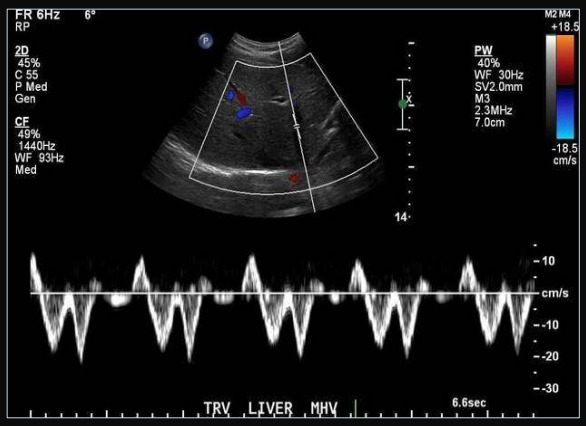


Image: 2. Iranpour, P., et.al. Altered Doppler flow patterns in cirrhosis patients: an overview.

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Hepatoportal Waveform Morphology

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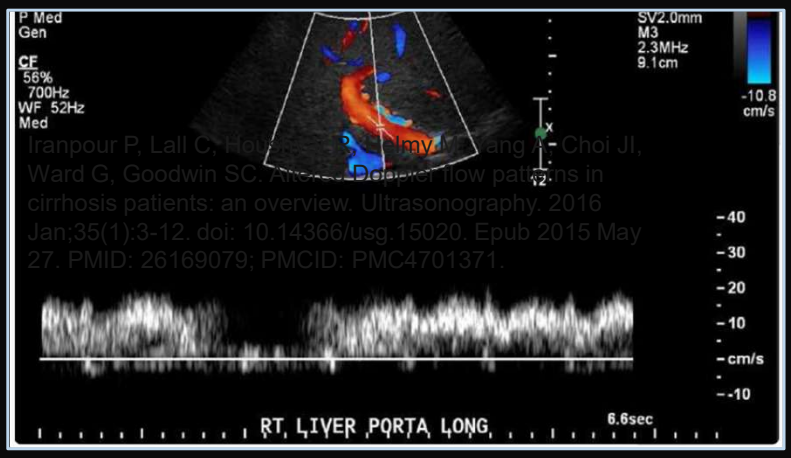
Portal vein waveform characteristics



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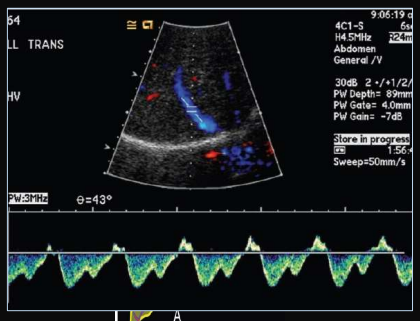

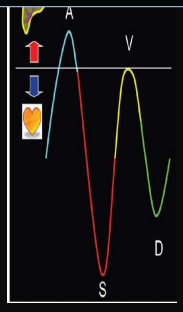

Hepatic Vein Hemodynamics

- The HV waveform aligns with the hemodynamics of the right atrium.
- **A** is the atrial 'kick' when the atria is contracting to finalize the blood flow through the TV. Some flow is pushed back very momentarily creating a momentary reverse flow. Normal is on the opposite side of baseline or may be close but not on opposite side.
- **S** is ventricular systole (atria is filling), **V** is when the RA fills (says, hold up a minute) and places a minimal resistance to flow coming in from IVC (and HV) and SVC, **D** is ventricular diastole when the TV is open allowing flow out of the RA into the RV.
- Have patient breath normal – holding one's breath will alter appearance of the waveform.

3. Scheinfeld, M. et.al (2009) Understanding the spectral doppler waveforms of the hepatic veins in health and disease.

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Cardiac Influence of HV Waveform

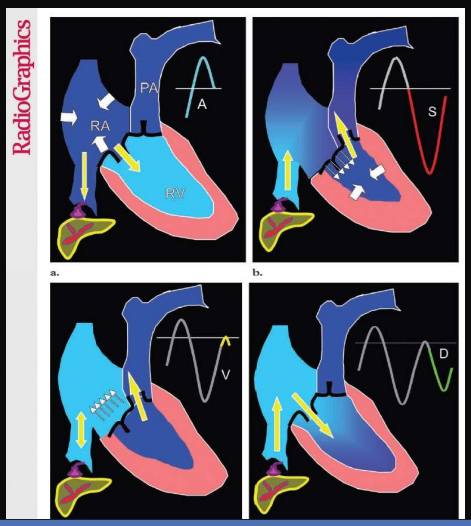

Image 3. Scheinfeld, M. et.al (2009) Understanding the spectral doppler waveforms of the hepatic veins in health and disease.

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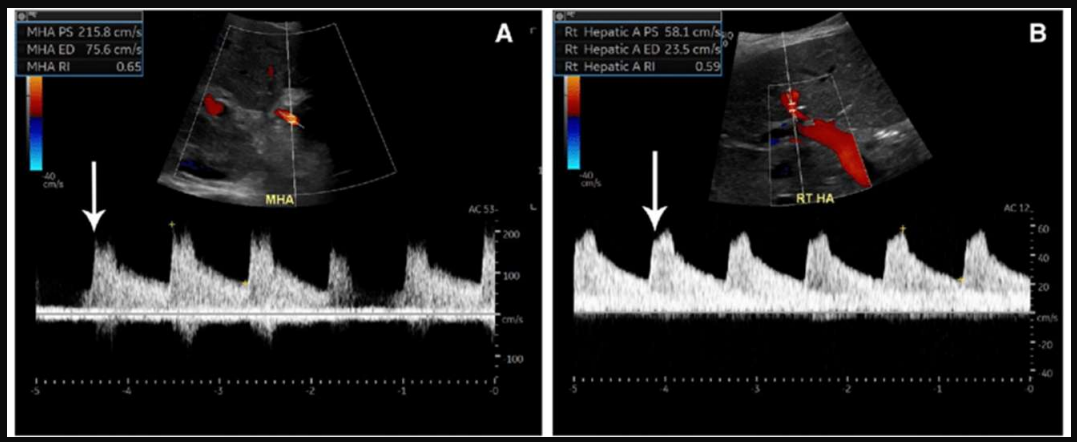
Hepatic Artery Waveform



Images: 4. Craig, Elizabeth & Heller, Matthew. (2021). Complications of liver transplant. Abdominal Radiology. 46. 10.1007/s00261-019-02340-5.

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Portal Vein and Hepatic Artery

- From the intercostal space, the ability at time to place the sample gate over both the portal vein and hepatic artery allow for evaluation of the PSV of the portal vein and the EDV of the HA.
- In normal hemodynamics, they should be similar.
- This indicates that is no increased resistance of the liver placed upon the HA or portal vein.

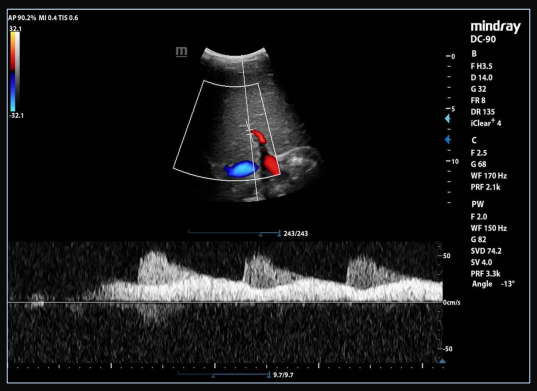

Image: Goss Personal File

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Abnormal Waveforms

- Refresher
  - For venous flow
  - Important to evaluate for phasicity; therefore, avoid having the patient hold their breath
  - Pulsatility may be a sign of increased right sided heart pressure.
  - If evaluating for liver congestion, look at the IVC for dilation or decrease in response to respiration.

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Portal Vein

- What is occurring with this waveform?

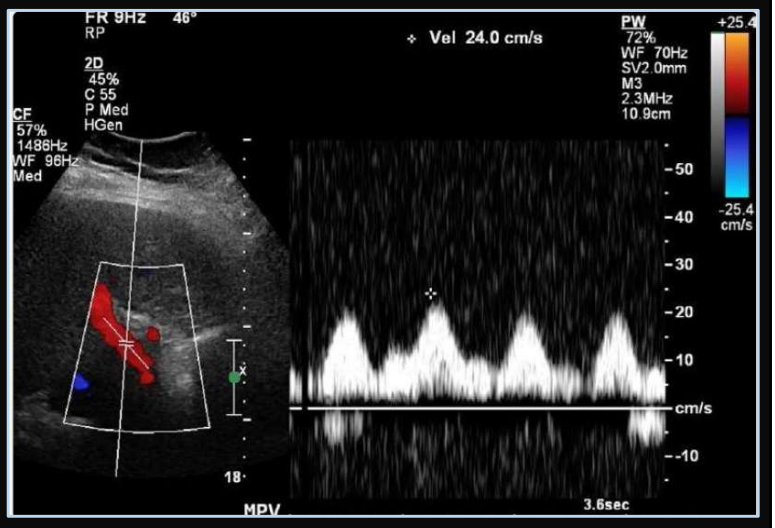

Image:2. Iranpour, P., et.al. Altered Doppler flow patterns in cirrhosis patients: an overview

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Portal Vein

- Normal velocity is between 20 and 40 cms/sec.
- Diameter of the PV at the level of the IVC should be less than 13 mm (1.3 cms)
- If the diameter is increased, the PSV will decrease with less undulations being seen.
- Intrahepatic fibrosis of the sinusoids seen with cirrhosis or other hepatocellular diseases, can increase resistance to the PV and create alternate patterns in the waveforms.

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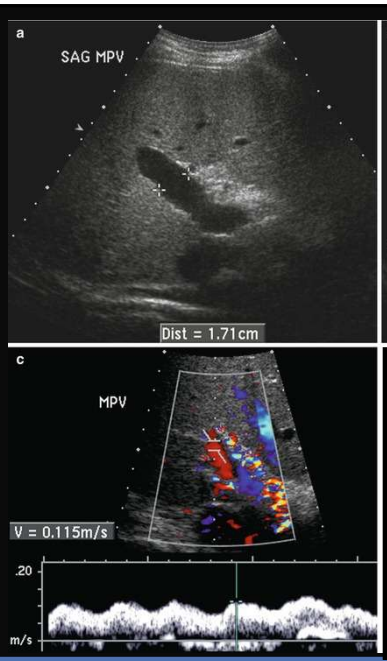
Portal Hypertension



Criteria:

- PV diameter > 13 mm
- Decreased PV velocity
- Can be antegrade, bidirectional or retrograde (hepatofugal)
- Often ascites is present

Image: 5. Benson, C. B. Ultrasound of the Hepatoportal Circulation

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Alternating Flow (to-fro)

- This can be seen with portal hypertension, most often due to cirrhosis.
- This is different from the image earlier illustrating pulsatility.

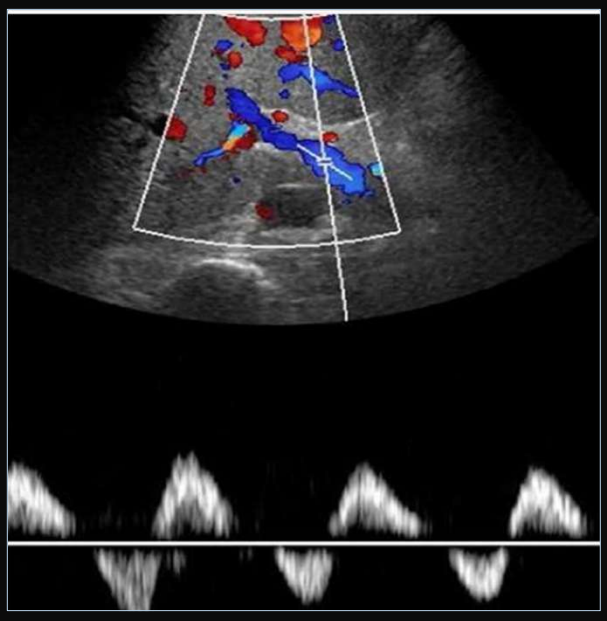

Image: 2. Iranpour, P., et.al. Altered Doppler flow patterns in cirrhosis patients: an overview

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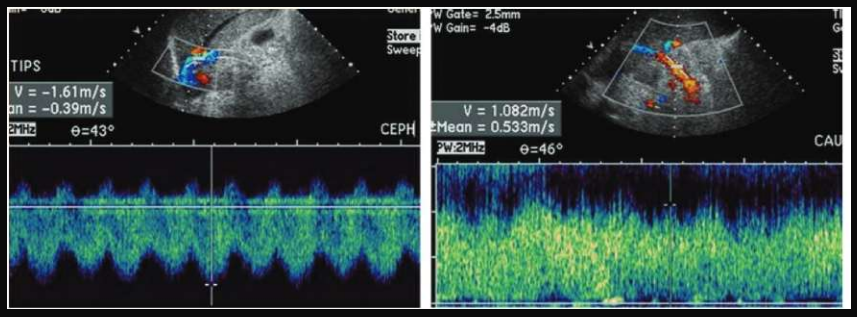
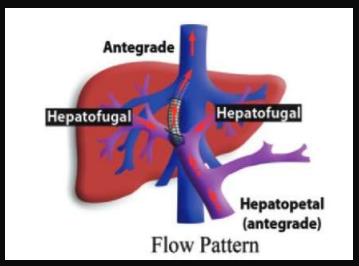
TIPS

- Normal velocities for the shunt are 90-190 cms/sec





Images: 1. McNaughton, A. and Abu-Yousef, M. Doppler US of the liver made simple

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Signs of TIPS Malfunction

Direct evidence
Shunt velocity <90 cm/sec or ≥190 cm/sec
Temporal increase or decrease in shunt velocity >50 cm/sec
Indirect evidence
Main portal venous velocity <30 cm/sec
Collateral vessels (recurrent, new, or increased)
Ascites (recurrent, new, or increased)
Right-left portal venous flow reversal (ie, hepatofugal to hepatopetal)

1. McNaughton, A. and Abu-Yousef, M. Doppler US of the liver made simple

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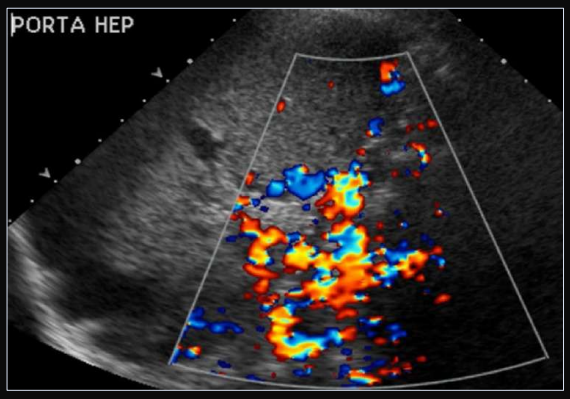
Portal Vein Thrombosis



Images:2. Iranpour, P., et.al, Altered Doppler flow patterns in cirrhosis patients: an overview.

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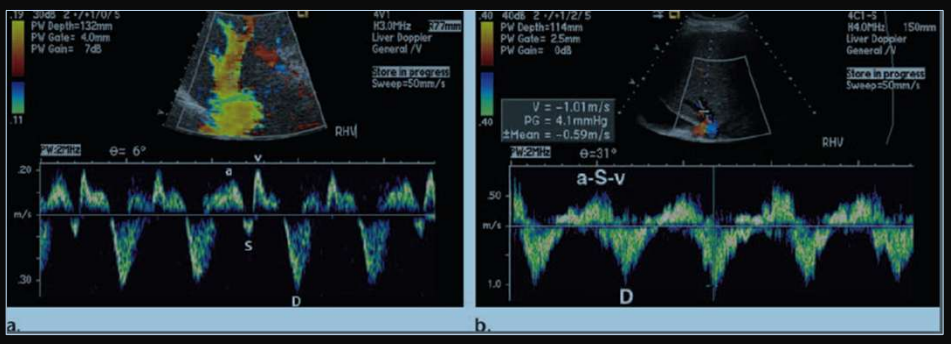
Hepatic Vein



- Hepatic vein abnormal pattern due to increased right heart pressure and tricuspid regurgitation

1. McNaughton, A. and Abu-Yousef, M. Doppler US of the liver made simple

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Effects of Tricuspid Regurgitation

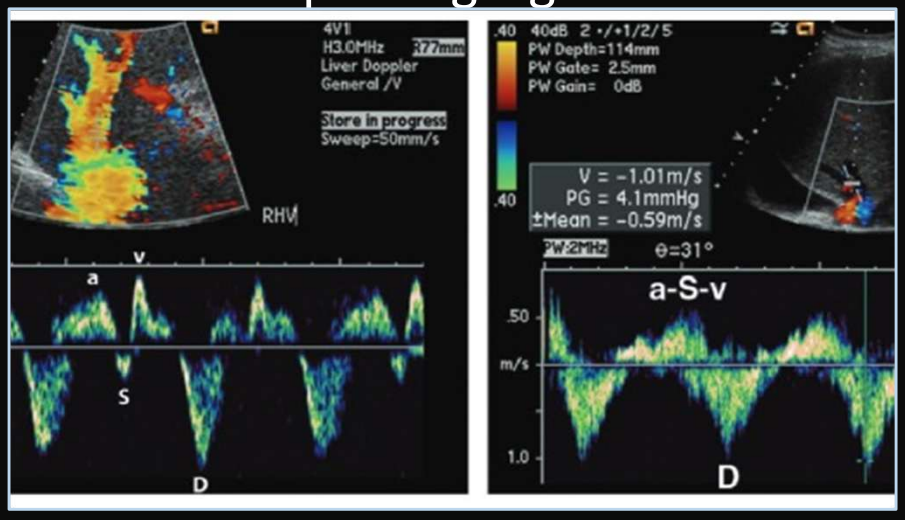

Image 1. McNaughton, A. and Abu-Yousef, M.(2011)

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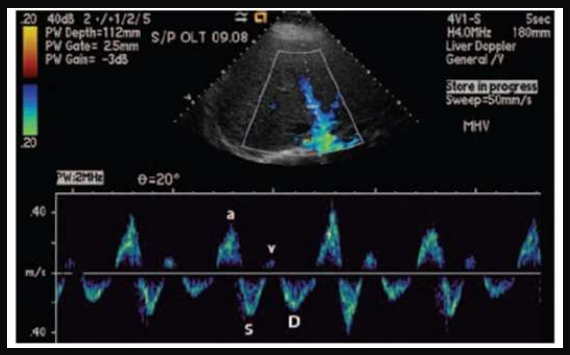
Hepatic Vein Waveform



Causes of Decreased Hepatic Venous Phasicity
Cirrhosis
Hepatic vein thrombosis (Budd-Chiari syndrome)
Hepatic veno-occlusive disease
Hepatic venous outflow obstruction from any cause

CHF without tricuspid regurgitation

1. McNaughton, A. and Abu-Yousef, M. Doppler US of the liver made simple1.

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Stages of HV Phasicity

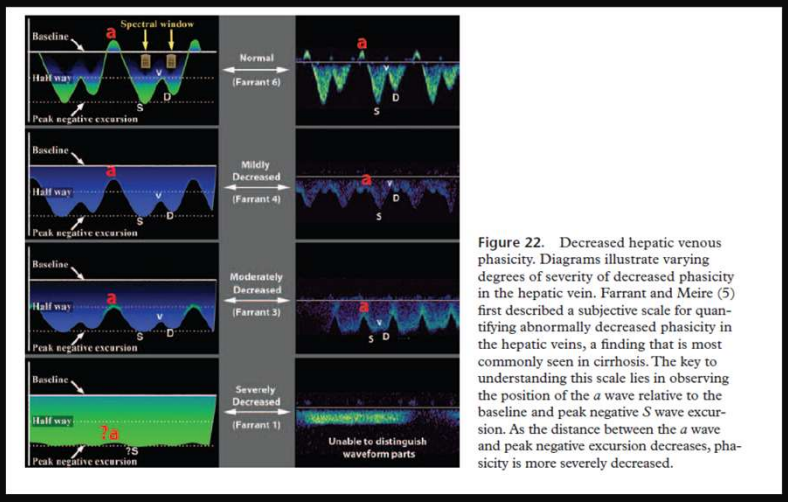

Figure 22. Decreased hepatic venous phasicity. Diagrams illustrate varying degrees of severity of decreased phasicity in the hepatic vein. Farrant and Meire (5) first described a subjective scale for quantifying abnormally decreased phasicity in the hepatic veins, a finding that is most commonly seen in cirrhosis. The key to understanding this scale lies in observing the position of the *a* wave relative to the baseline and peak negative *S* wave excursion. As the distance between the *a* wave and peak negative excursion decreases, phasicity is more severely decreased.

Image 1. McNaughton, A. and Abu-Yousef, M. Doppler US of the liver made simple

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Abnormal Arterial Waveforms

Refresher

For arterial decrease in diastolic flow, look downstream or distal to the sample gate.

Tardus parvus waveform (increased acceleration rise time), look at inflow or proximal to the sample gate

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Hepatic Artery

- The hepatic artery is normally a low-resistance vessel, meaning it should have an RI ranging from 0.55 to 0.7.
- Normal PSV is ~ 100 cms/sec
- High resistance is a nonspecific finding that may be seen in the postprandial state, patients of advanced age, and diffuse peripheral microvascular (arteriolar) compression or disease, as seen in chronic hepatocellular disease (including cirrhosis), hepatic venous congestion, cold ischemia (posttransplantation), and any stage of transplant rejection.

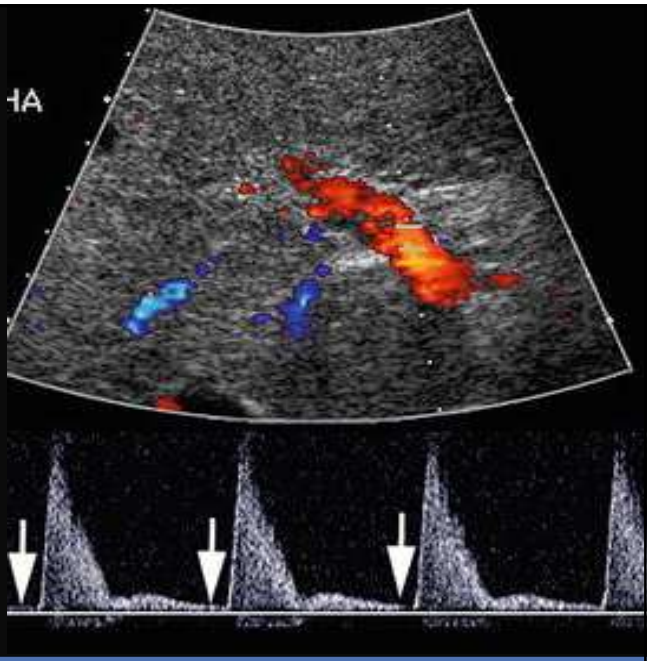

Image: 6. Color duplex scanning of the hepatoportal circulation

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Hepatic Artery with Portal Hypertension

- Decreased resistance of the hepatic artery.
- Increased PSV and EDV due to the hepatofugal flow in the PV.
- This is compensatory hepatic artery flow.

Images:2. Iranpour, P., et.al, Altered Doppler flow patterns in cirrhosis patients: an overview

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Alterations with Hepatic Artery

Table 4
Causes of Elevated Hepatic Arterial Resistance (RI >0.7)

Pathologic (microvascular compression or disease)
Chronic hepatocellular disease (including cirrhosis)
Hepatic venous congestion
Acute congestion → diffuse peripheral vasoconstriction
Chronic congestion → fibrosis with diffuse peripheral compression (cardiac cirrhosis)
Transplant rejection (any stage)
Any other disease that causes diffuse compression or narrowing of peripheral arterioles
Physiologic
Postprandial state
Advanced patient age

Table 5
Causes of Decreased Hepatic Arterial Resistance (RI <0.55)

Proximal arterial narrowing
Transplant stenosis (anastomosis)
Atherosclerotic disease (celiac or hepatic)
Arcuate ligament syndrome (relatively less common than transplant stenosis or atherosclerotic disease)
Distal (peripheral) vascular shunts (arteriovenous or arterioportal fistulas)
Cirrhosis with portal hypertension
Posttraumatic or iatrogenic causes
Hereditary hemorrhagic telangiectasia (Osler-Weber-Rendu syndrome)

1. McNaughton, A. and Abu-Yousef, M. Doppler US of the liver made simple

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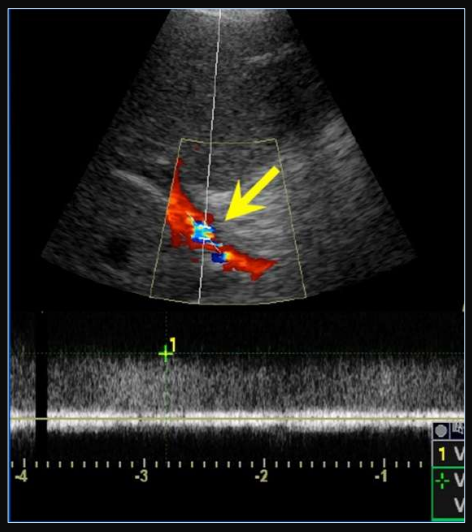
HA Stenosis Post Liver Transplant

- Increase in velocity 3-4 x normal
- Lack of pulsatility
- Usually occurs at the end-to-end anastomosis
- Be careful – if immediate post-operative – can be a pseudostenosis and may resolve within the short post-transplant phase.



1. McNaughton, A. and Abu-Yousef, M. Doppler US of the liver made simple

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Mesenteric Vessels

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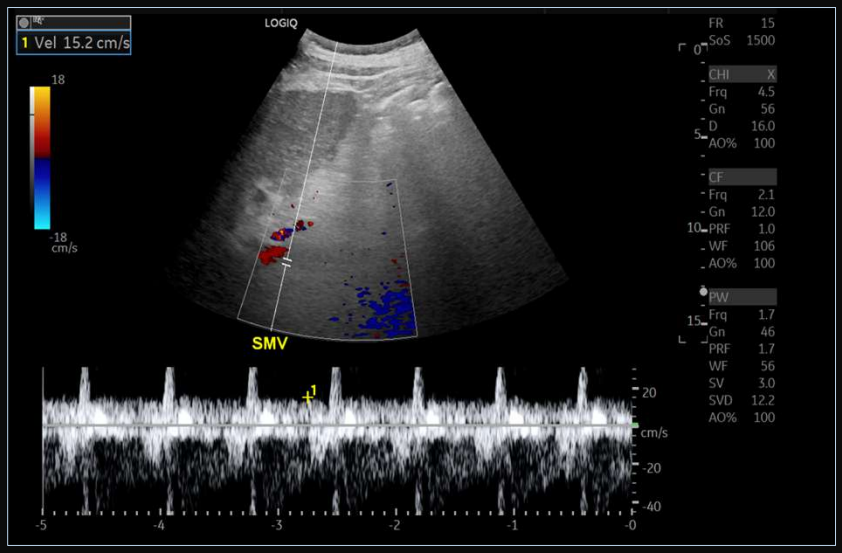
SMV Critique image



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SMV Critique image

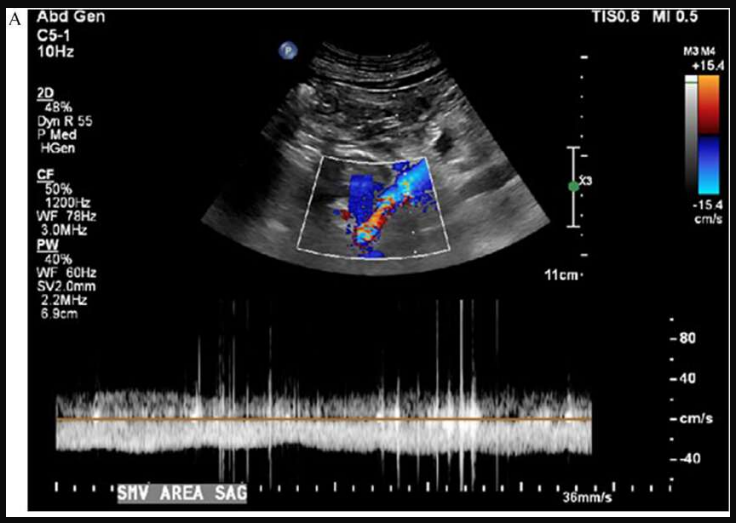

Image: 7. Smith, Z. et.al. (2022)

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Sagittal Aorta and Celiac Axis

- *Differentials?*

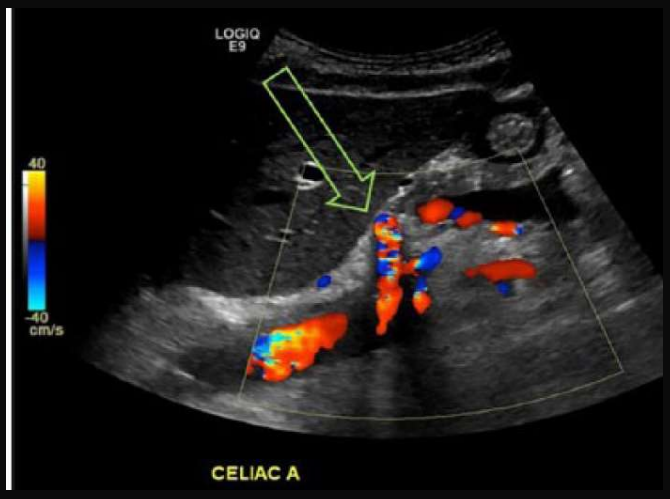

Image: 8. Wu E. (2019)

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Thoughts?

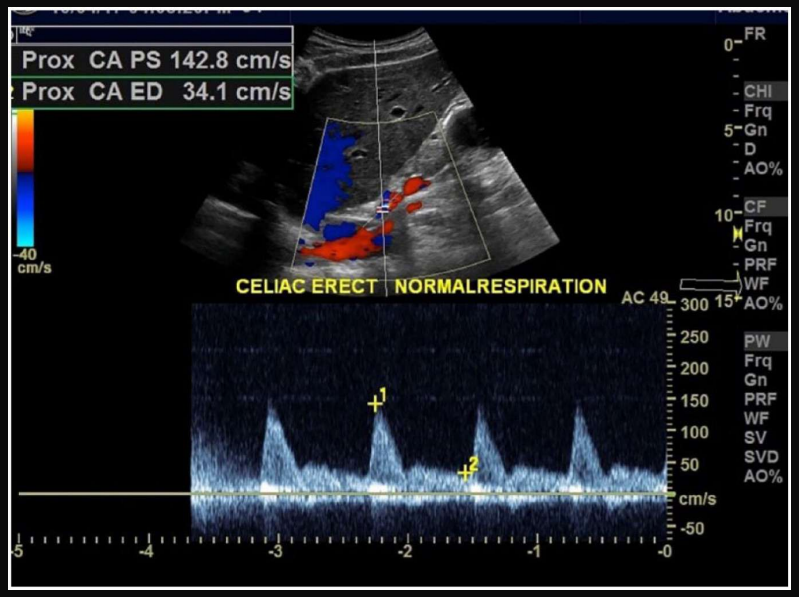

Image: 8. Wu E. (2019)

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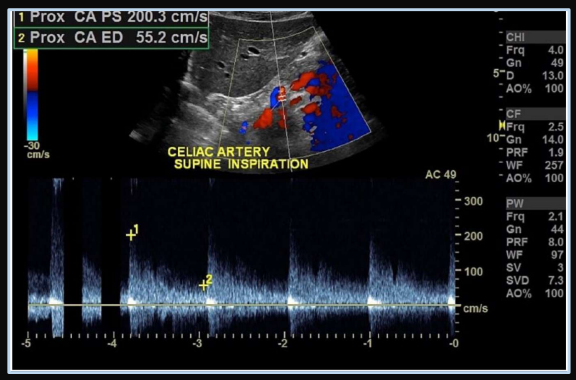
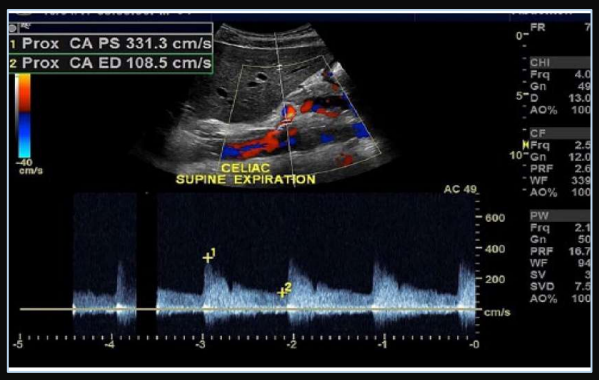
Special Maneuvers





Images: 8. Wu E., Median Arcuate Ligament Syndrome

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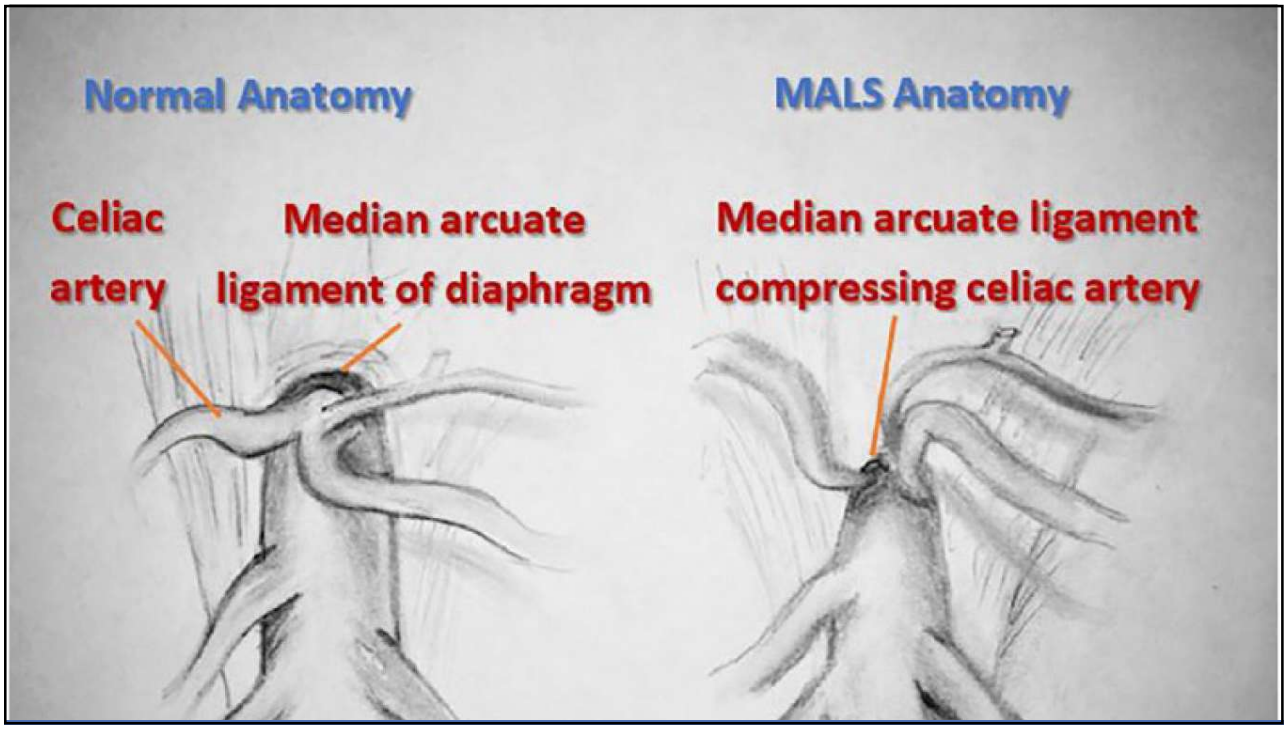

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Median Arcurate Ligament Syndrome (MALS)

- Also known as:
  - Celiac artery compression syndrome
  - Celiac axis syndrome
  - Dunbar syndrome
- Symptoms
  - Variable
  - Asymptomatic
  - Abdomen pain
  - Bloating, nausea, or vomiting
  - Can be increased with exercise

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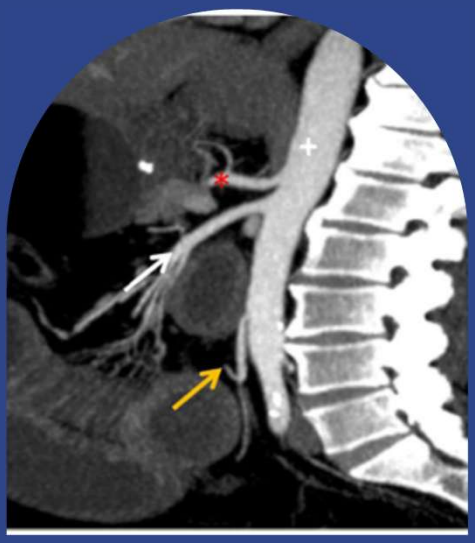
Mesenteric Ischemia

- Acute
  - Most common
  - Emboli (cardiac most common source)
    - 60-70% of cases
    - SMA more common due to sharp angle off the aorta
  - Non-occlusive
  - Mesenteric venous thrombosis
- Chronic
  - Accounts for about 10% of cases



9. Florim S,. Et. Al, Acute mesenteric ischaemia: a pictorial review.

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Mesenteric Duplex

Celiac

- Low resistive
- > 200 cm/sec is > 70% stenosis

SMA

- High resistive with fasting
- Sligh decrease in resistance (increase in the EDV) post prandial
- > 275 cm/sec is > 70% stenosis.

IMA

- High Resistive
- > 200 cm/sec is > 70% stenosis

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Abnormal SMA

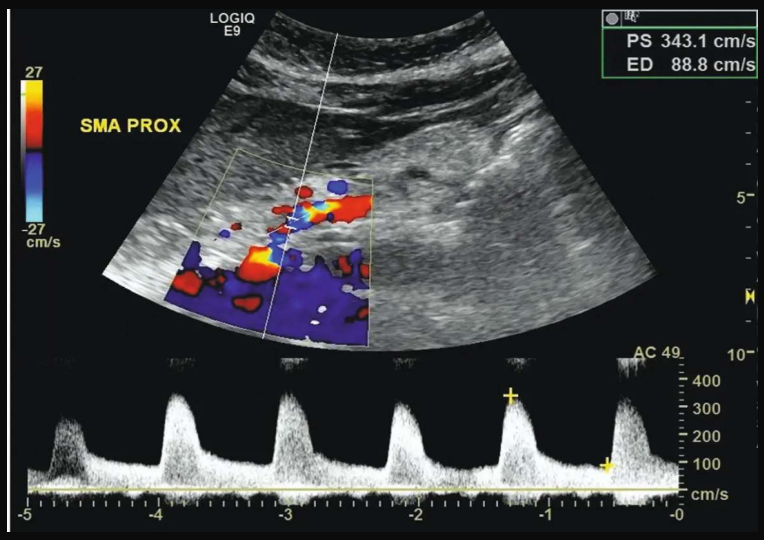

Image: 10. Parikh A. Doppler ultrasound of visceral arteries.

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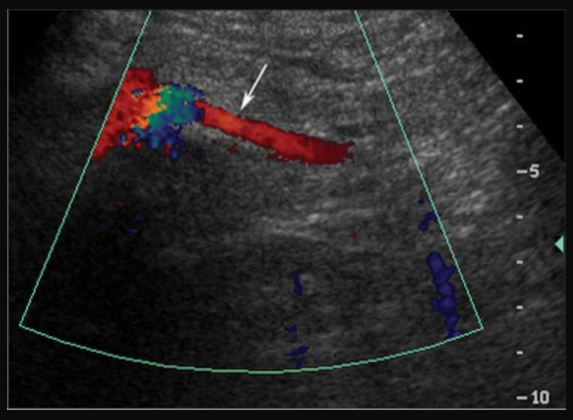
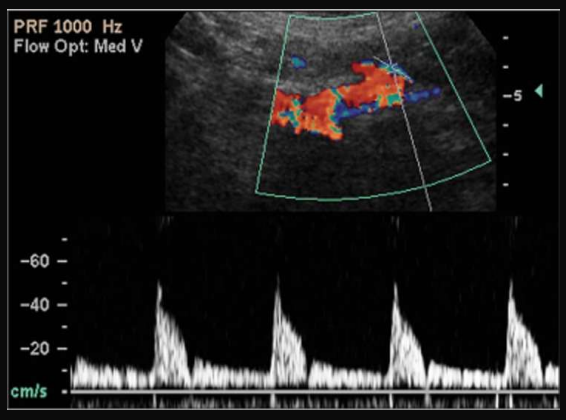
Normal IMA





Images:11. Pellerito JS, et.al. Doppler sonographic criteria for the diagnosis of inferior mesenteric artery stenosis.

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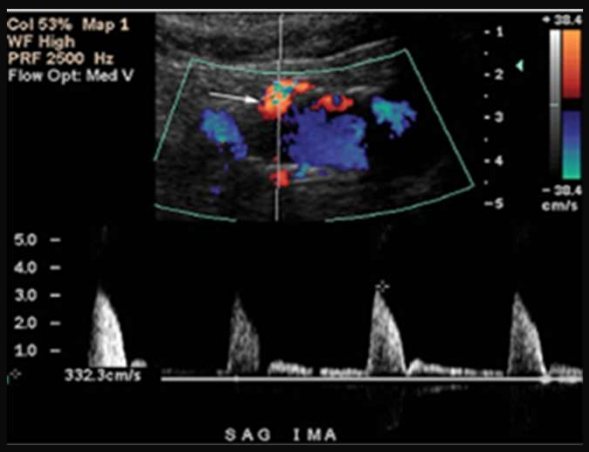
Abnormal IMA



Images:11. Pellerito JS, et.al. Doppler sonographic criteria for the diagnosis of inferior mesenteric artery stenosis.

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Summary

Learning never ends. Seek a mentor to expand your knowledge or skills.

Performing Doppler of the abdominal vessels is challenging for many reasons.

Variants of anatomical origins and duplication	*Acquiring proper angles*	*Body habitus*	*Overlying bowel gas*

It is critical to understand the physical principles of Doppler

It is critical to differentiate normal from abnormal

Is abnormal due to disease?	*Is abnormal due to technical inaccuracies?*

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