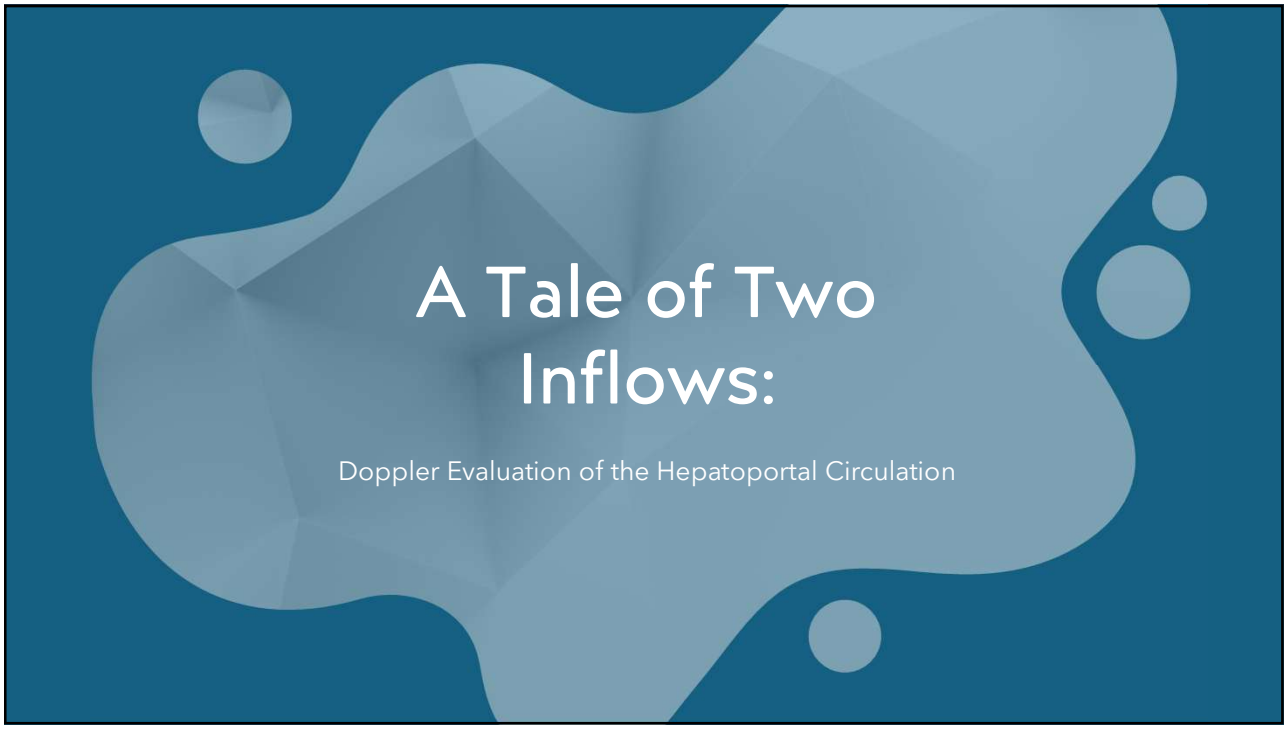
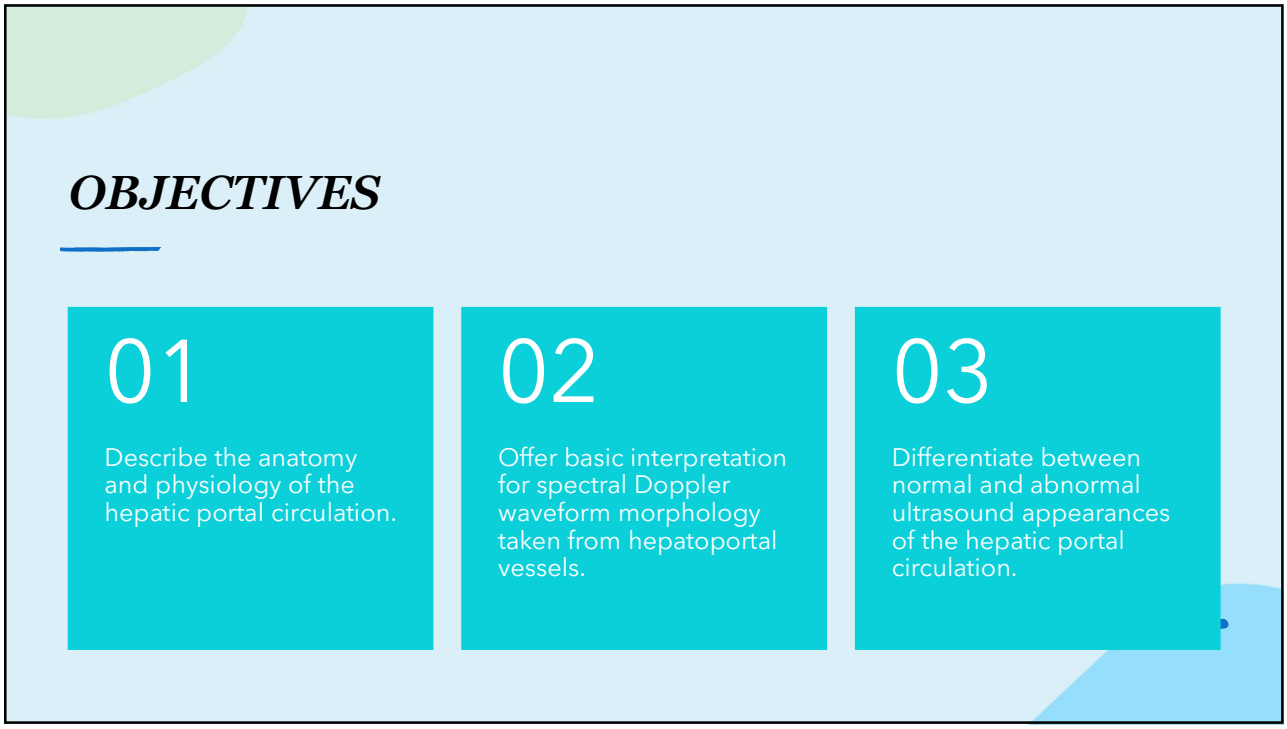


1



2

Hepatoportal Circulation

Anatomy & Physiology

3

Hepatic Arterial Supply

Hepatic Artery

Branch of the celiac axis

Branches of the HA:

- Gastrodudodenal artery
- Right gastric artery
- Cystic artery[1]

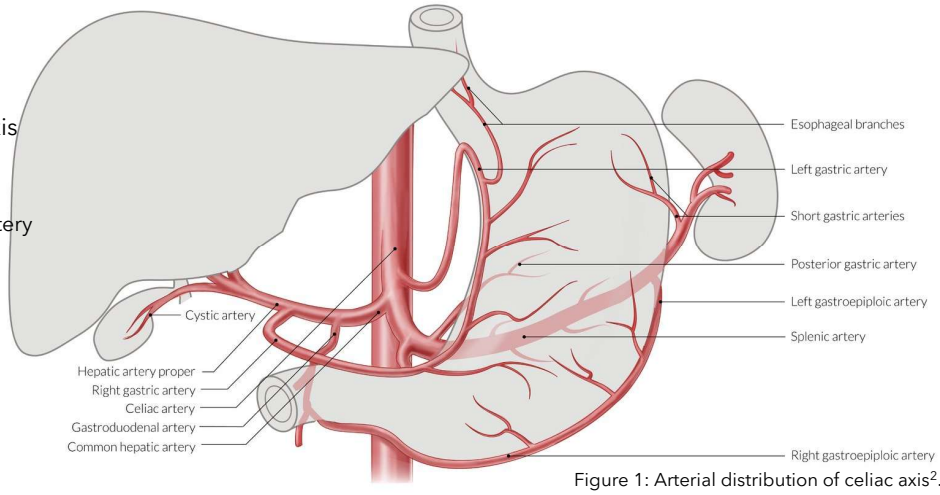


Figure 1: Arterial distribution of celiac axis[2].

4

Hepatic Arterial Supply

Inflow #1: Arterial

HEPATIC ARTERY

- Carries **30% of liver's blood supply**
- Source of oxygenated blood into the liver
- Enters the liver at the level of the porta hepatis
- One of three structures making up the portal triad[1]

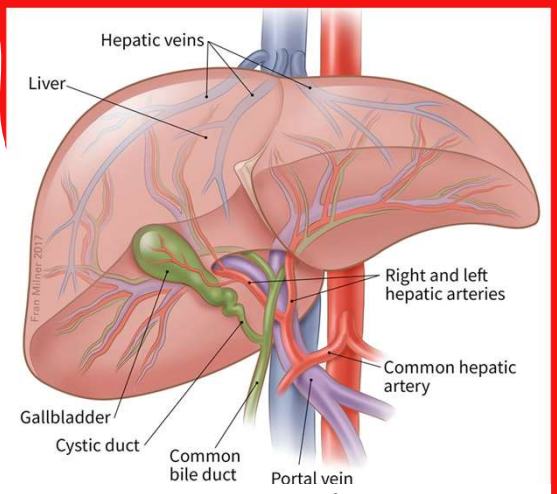
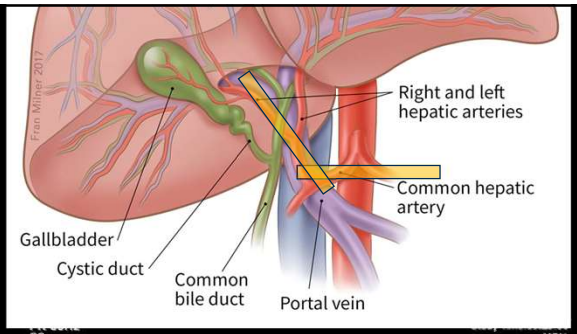


Figure 2: Hepatic circulation.[3]

5

Hepatic Artery – Sonographic Appearance



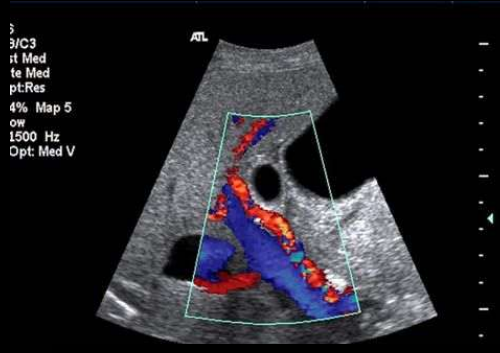


Figure 3: Hepatic circulation (a) and associated sonographic appearance, including the celiac axis, hepatic artery, splenic artery (b) and main portal vein (c) .[1,]

6

HA BLOOD STREAM IS OXYGEN RICH.

The source is the abdominal aorta.[1]

7

Hepatoportal Veins

Drain the stomach, spleen, small and large intestines, and pancreatic head **INTO THE LIVER.**

Esophageal veins

Gastric veins

Splenic vein

Inferior mesenteric vein

Superior mesenteric vein[4]

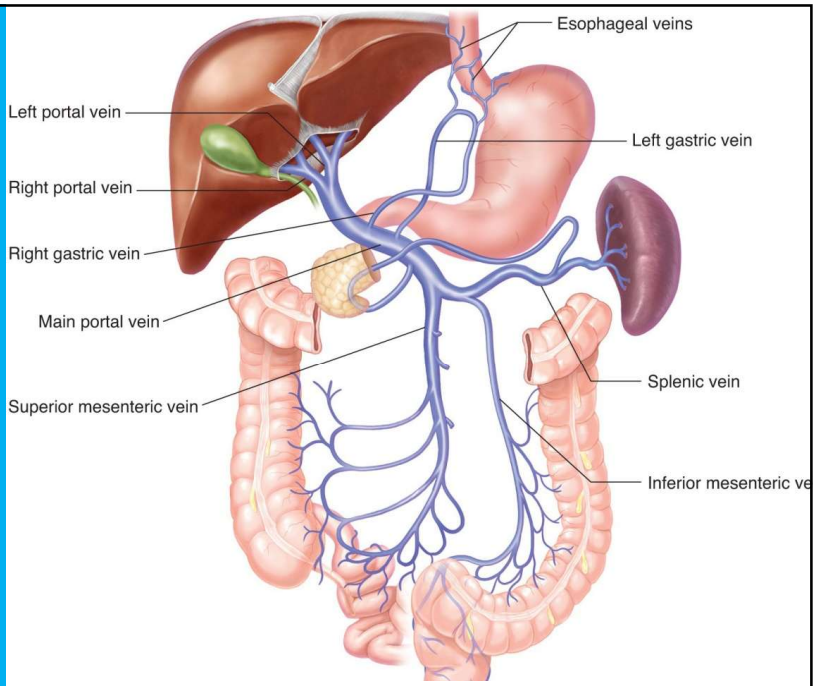
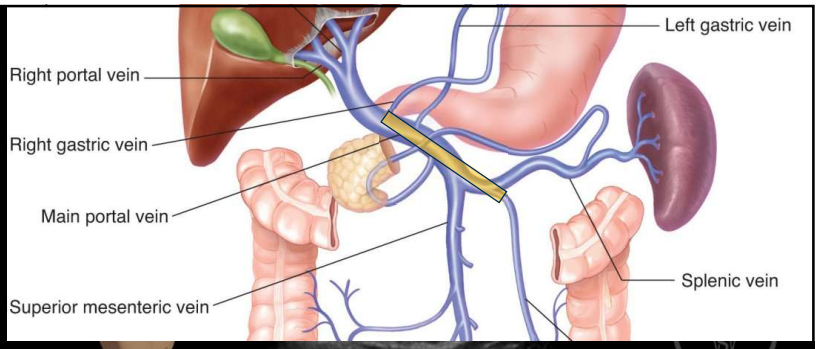


Figure 4: Portal venous inflow vessels.[5]

8

8

Portal-Splenic Confluence: Sonographic Appearance



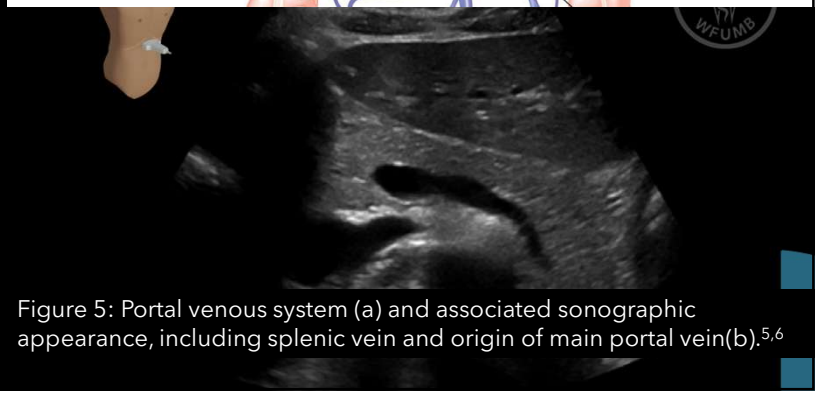
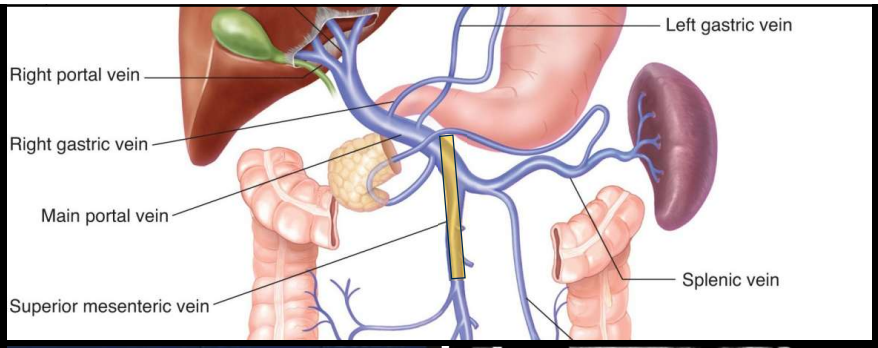


Figure 5: Portal venous system (a) and associated sonographic appearance, including splenic vein and origin of main portal vein(b).[5,6]

9

Superior Mesenteric Vein: Sonographic Appearance



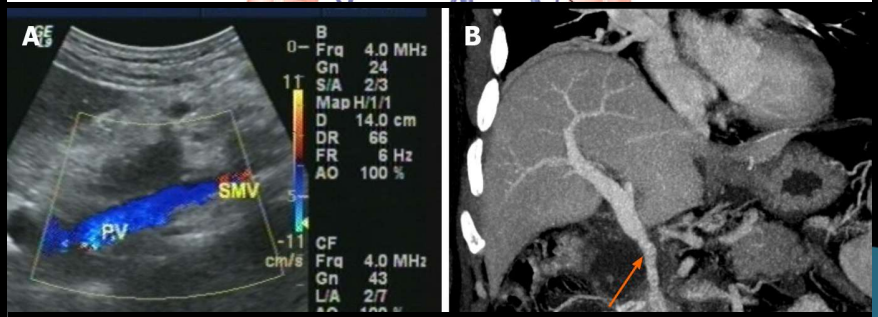


Figure 6: Portal venous system (a) associated sonographic appearance (b) and CT (c), including superior mesenteric vein and origin of main portal

10

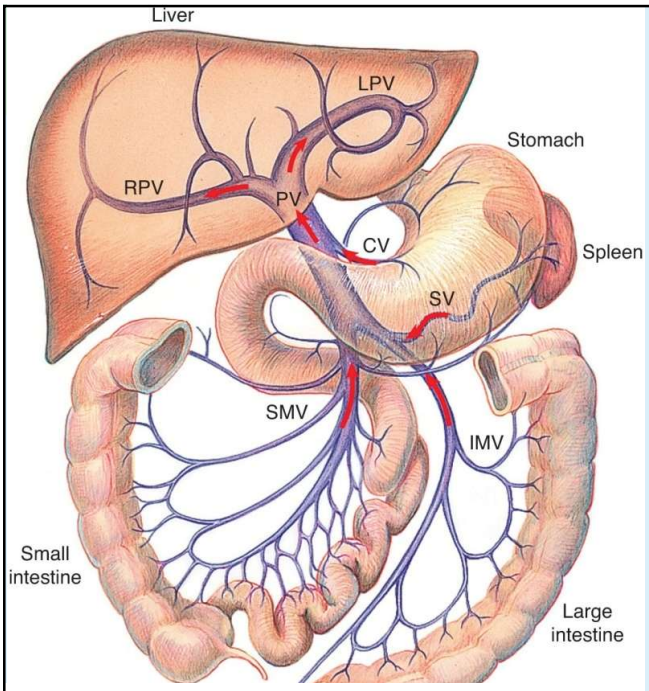


Figure 7: Portal venous inflow vessels and flow direction.

Hepatoportal Veins

Inflow #2: Venous

PORTAL-SPLENIC CONFLUENCE:

Inferior mesenteric vein

Superior mesenteric veins

Splenic vein

MAIN PORTAL VEIN

carries **70% of liver's blood supply**[4]

11

11

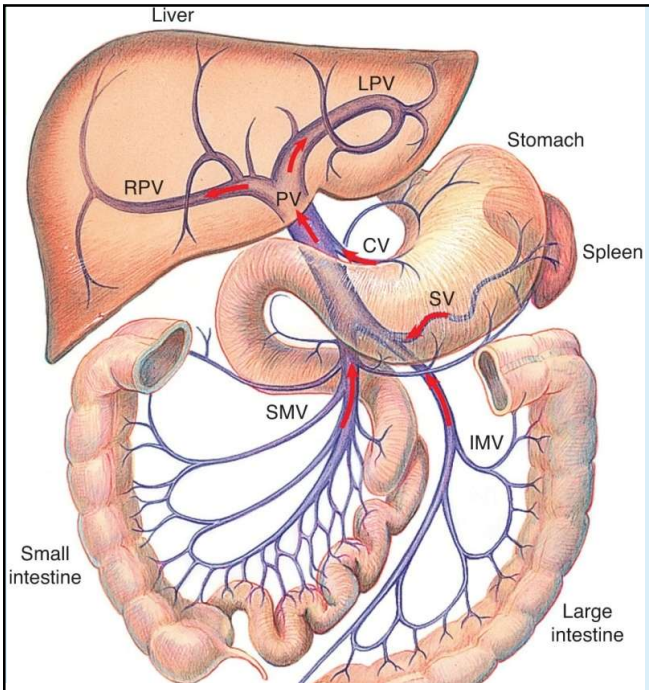


Figure 7: Portal venous inflow vessels and flow direction.

Hepatoportal Veins

MAIN PORTAL VEIN:

Begins posterior to the neck of the pancreas and anterior to the IVC

Enters the liver at the level of the porta hepatis.

Two of three structures in the portal triad.

Branches into right portal vein (anterior/posterior branches) and left portal vein[4]

12

12

MPV BLOOD STREAM IS NUTRIENT RICH.

The source is the esophagus, stomach, small and large intestines, pancreas, and the spleen.[4]

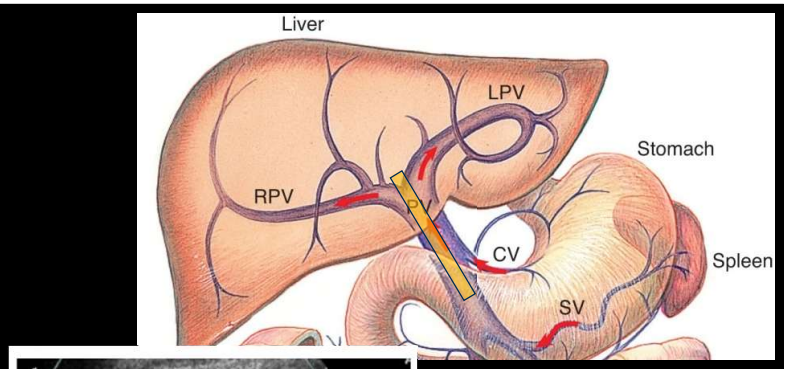
13

Anatomy: Portal Venous System

- Portal veins contain no valves
- Bright, echogenic walls due to thick collagenous tissue
- Course within the liver segments (intrasegmental)[1]

14

Main Portal Vein: Sonographic Appearance



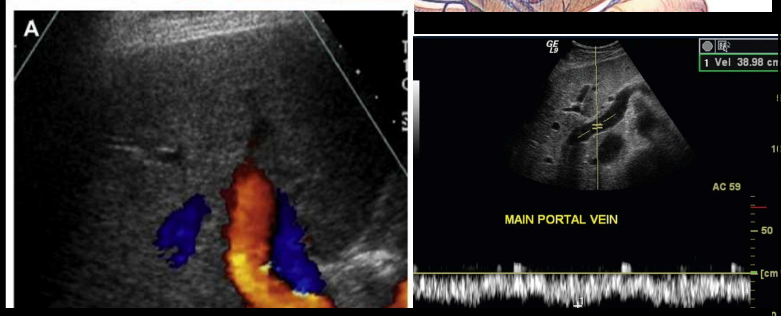


Figure 8: Main portal vein(a) and associated sonographic appearance, including splenic vein and origin of main portal vein(b).

15

Anatomy: Hepatic Sinusoids

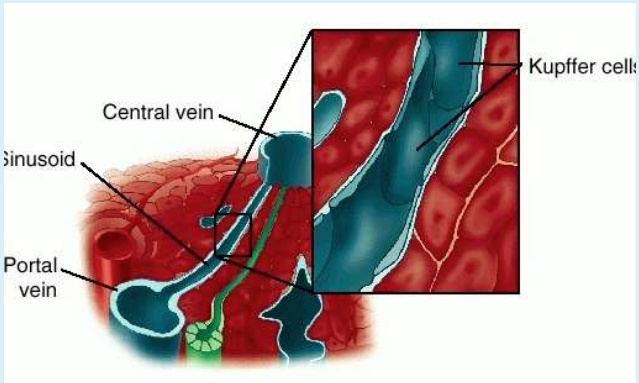


Figure 9: Hepatic sinusoids.

The portal veins terminate at the ***hepatic sinusoids***.

After Kupffer cells perform detoxification and metabolic activities, the blood is drained to the hepatic veins[1]

16

The bile ducts are the third structure in the portal triad.

(**Outflow #1: Bile**)[1]

17

Physiology: Function of the Liver[1]

- Bile production and excretion
- Excretion of bilirubin, cholesterol, hormones, and drugs
- Metabolism of fats, proteins, and carbohydrates
- Enzyme activation
- Storage of glycogen, vitamins, and minerals
- Synthesis of plasma proteins, such as albumin, and clotting factors
- Blood detoxification and purification

18

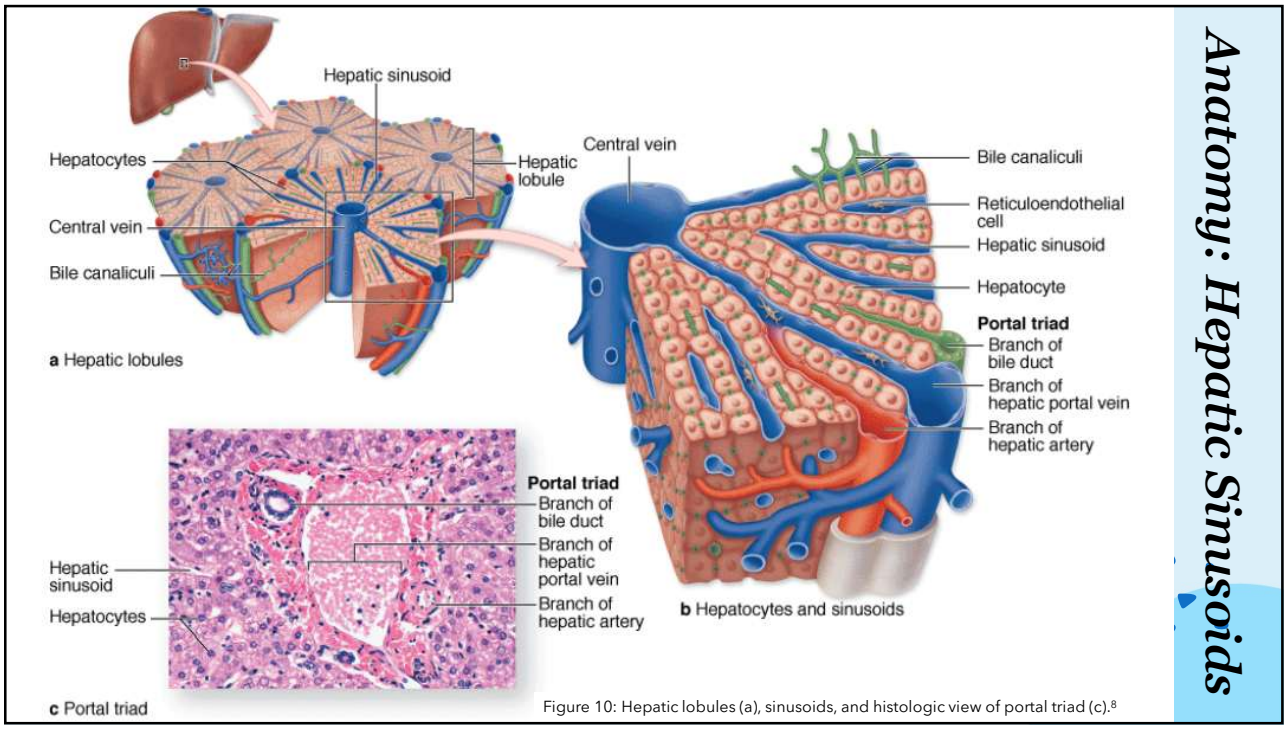


Figure 10: Hepatic lobules (a), sinusoids, and histologic view of portal triad (c).[8]

Anatomy: Hepatic Sinusoids

19

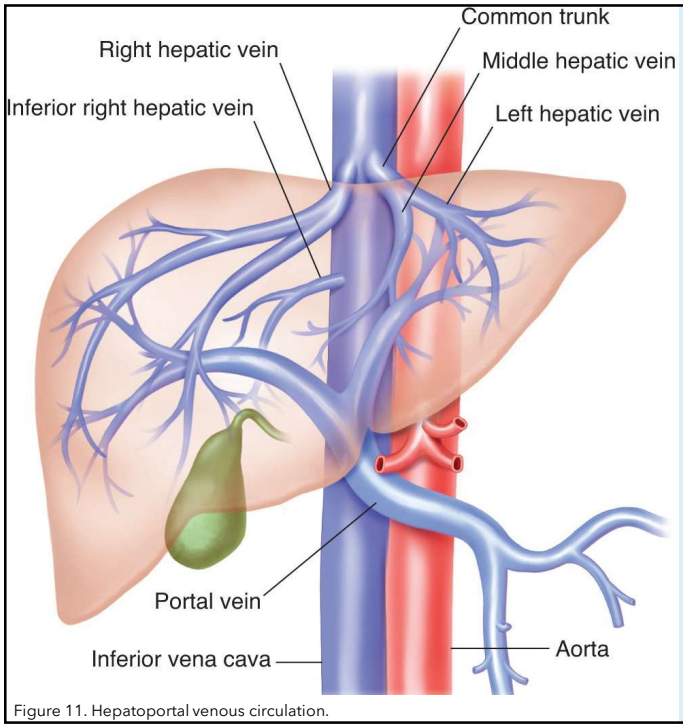


Figure 11. Hepatoportal venous circulation.

Hepatoportal Veins

Central veins in liver sinusoids are beginnings of hepatic venous system

Outflow #2: Venous

HEPATIC VEINS

(right, middle, and left) drain into inferior vena cava

Typically, the middle and left hepatic veins form common trunk before entering IVC

Caudate lobe (caudate vein) drains directly into IVC[1]

20

20

Anatomy: Hepatic Veins

- Anatomically separate from portal venous system
- Thin-walled and run between lobes of liver (intersegmental)
- Increase in size as they approach the diaphragm[1]

21

Hemodynamics 101

Basic of how blood flows through vessels.

22

Vascular Physiology & Hemodynamics

The purpose of the hepatoportal circulation is to perfuse and drain liver tissue with blood, to support cellular metabolism.

Proper function is dependent on healthy blood flow, and vice versa.

The most direct assessment of healthy blood flow is waveform acquisition and analysis.[9]

23

Vascular Physiology & Hemodynamics

Rather than answer the question, '*How do I scan this?*' or, '*Is this a normal 2D or 3D structure?,*' we must ask the question:

"IS FLOW NORMAL?'

To assess flow, we need to not only examine stationary structures in 2 and 3 dimensions, to looking at the 4th dimension: time. Vascular testing seeks to answer the question:

"HOW IS BLOOD MOVING OVER TIME?"[9]

24

Waveform Morphology 101

Y-Axis = Velocity

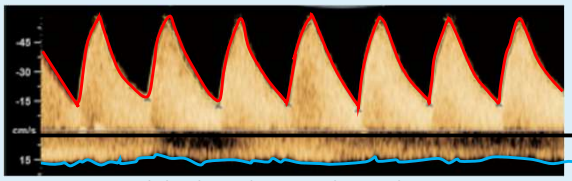


Figure 11: Umbilical Cord Spectral Doppler Tracing.

X-Axis = time

Baseline = Flow direction relative to **TRANSDUCER POSITION.**

Above = towards transducer

Below = away from transducer

25

Ohm's Law

"All flow characteristics are derived from the interplay of pressure and resistance, with flow morphology and velocity profiles of arterial and venous vessels reflecting both pressure from the source of flow, and resistance at its destination[9]"

26

Ohm's Law

$$Q = \frac{\Delta P}{r}$$

$Q = Flow$

$\Delta P = Pressure\ gradient$

$r = Resistance$

27

Hepatic Pressure Sources

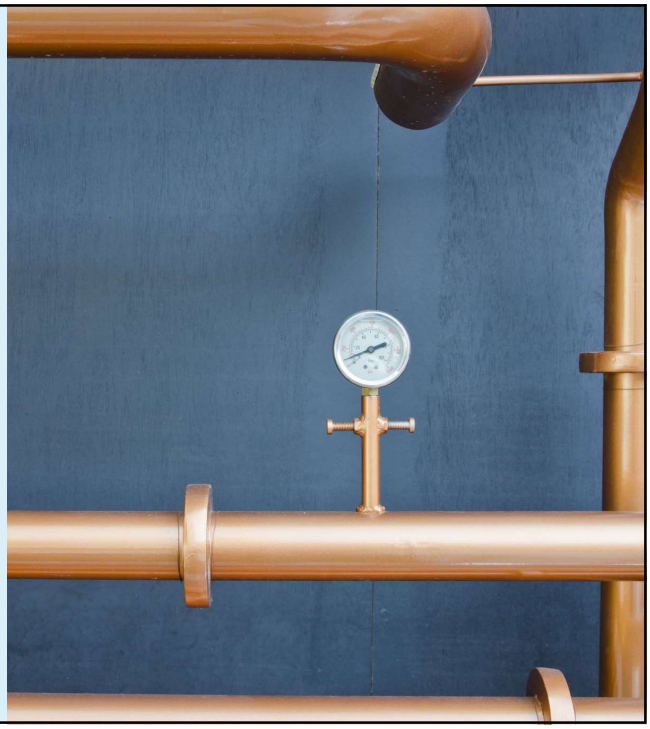
Created at the blood's SOURCE

Hepatic artery = left ventricle of the heart

Portal veins = confluence of blood from mesentery, spleen, stomach, esophagus

Hepatic veins = confluence from hepatic sinusoids

When pressure gradient is high, flow is high.[9]



28

Hepatic Resistance Sources

Created at the blood's DESTINATION

Hepatic artery = hepatic sinusoids

Portal veins = hepatic sinusoids

Hepatic veins = right atrium of the heart.

When resistance is high, flow is low.

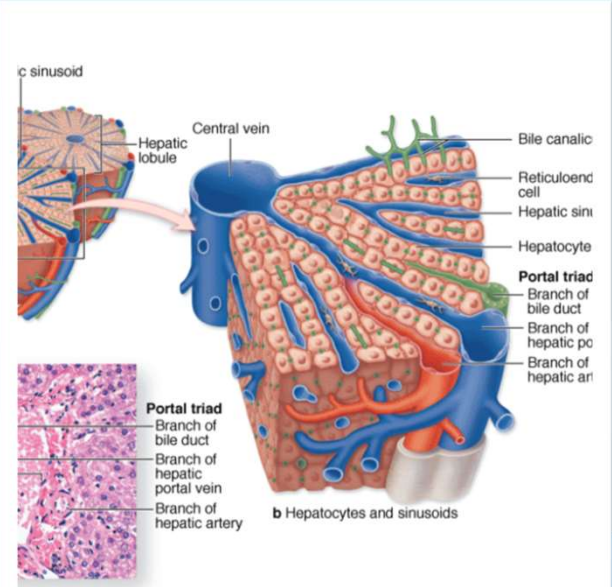


Figure 10: Hepatic lobules (a), sinusoids, and histologic view of portal triad (c).[8]

29

Hepatoportal Hemodynamics

30

Hepatoportal Waveforms

Flow toward the liver is termed **hepatopedal**

Flow away from the liver is termed **hepatofugal**[4]

31

Hepatic Artery Doppler

- **Source of pressure:** heart
- **Force of resistance:** hepatic sinusoids

WAVEFORM MORPHOLOGY
- Hepatopetal flow
- Sharp upstroke
- **Medium to high diastolic flow**
- **Low RI (0.55-0.7)**[7]

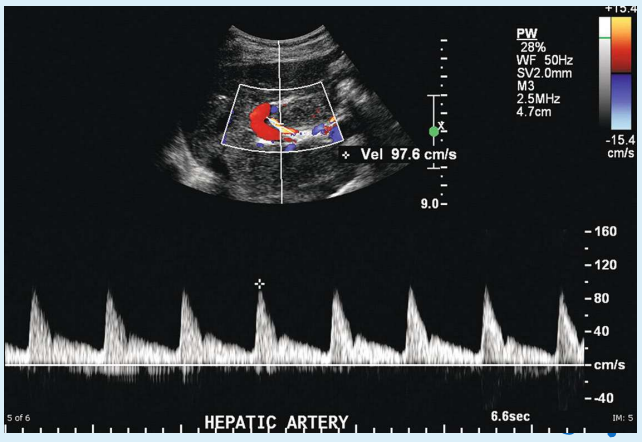


Figure 12: Normal arterial spectral Doppler waveform of the hepatic artery

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9/10/2025

Splenic Vein Doppler

Source of pressure: convergence of splenic capillary flow

Force of resistance: hepatic sinusoids

WAVEFORM MORPHOLOGY

- Hepatopetal flow
- Spontaneous
- Monophasic
- Respirophasic[1,7]

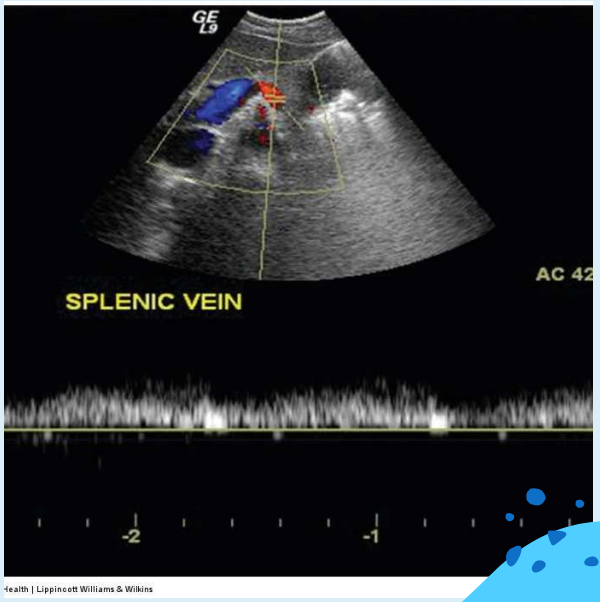

Figure 13: Normal spectral Doppler waveform of the splenic vein.

33

33

9/10/2025

Superior Mesenteric Vein Doppler

Source of pressure: convergence of mesenteric capillary flow

Force of resistance: hepatic sinusoids

WAVEFORM MORPHOLOGY

- Hepatopetal flow
- Spontaneous
- Monophasic
- Respirophasic
- Flow increases with expiration and ingestion of food[1,7]

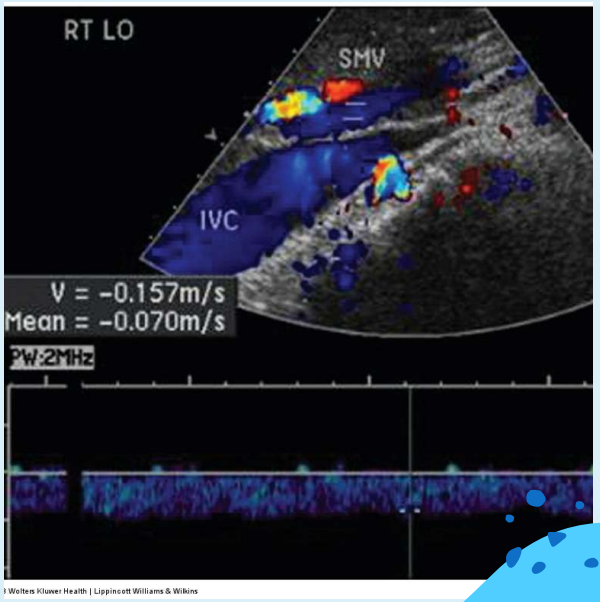

Figure 14: Normal spectral Doppler waveform of the superior mesenteric vein.

34

34

Main Portal Vein Doppler

Source of pressure: splenic, mesenteric, gastric, esophageal vein confluence

Force of resistance: hepatic sinusoids

WAVEFORM MORPHOLOGY

- Hepatopetal flow
- Spontaneous
- Monophasic
- Mild cardiac pulsatility[1,7]

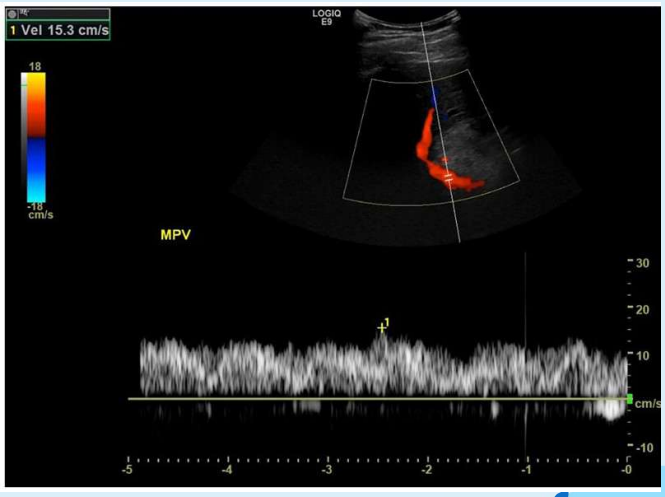

Figure 15: Normal spectral Doppler waveform of the main portal vein.

35

Main Portal Vein Doppler

Source of pressure: splenic, mesenteric, gastric, esophageal vein confluence

Force of resistance: hepatic sinusoids

WAVEFORM MORPHOLOGY

- **Respirophasic**
- Flow and velocity decrease with inspiration, exercise, and changes in posture
- Flow and velocity increase with expiration and ingestion of food
- Postprandially, flow velocity increases by 50%–100%[1,7]

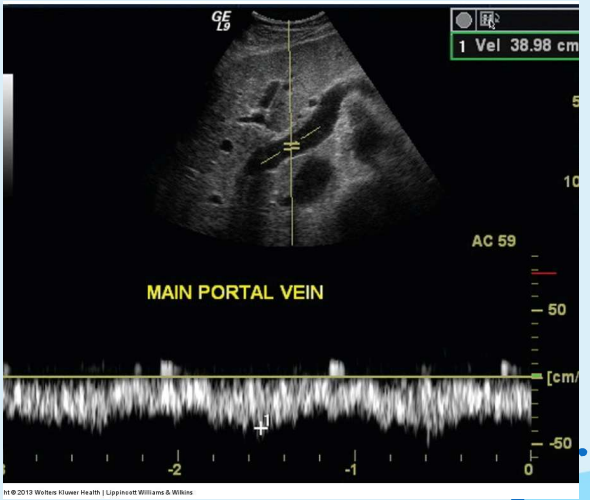

Figure 16: Normal spectral Doppler waveform of the main portal vein.

36

9/10/2025

Hepatic Vein Doppler

Source of pressure: Hepatic sinusoids

Force of resistance: Right atrium of heart

WAVEFORM MORPHOLOGY

- Hepatofugal flow
- Spontaneous
- Venous pulsatility[1,7]

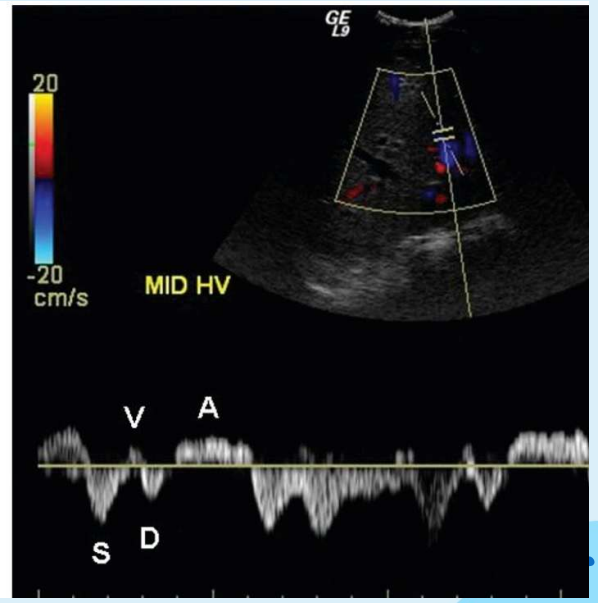

Figure 17: Normal spectral Doppler waveform of the middle hepatic vein.

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9/10/2025

Hepatic Vein Doppler

- Normal flow is triphasic with both antegrade and retrograde components
  - Corresponds to pressure changes in heart
  - S wave: ventricular systole/atrial filling, flow toward heart
  - V trough: right atrial overfilling before tricuspid valve opening, flow toward heart slows
  - D wave: Ventricular filling, flow directed toward heart
  - A wave: atrial systole, flow toward liver[1,7]

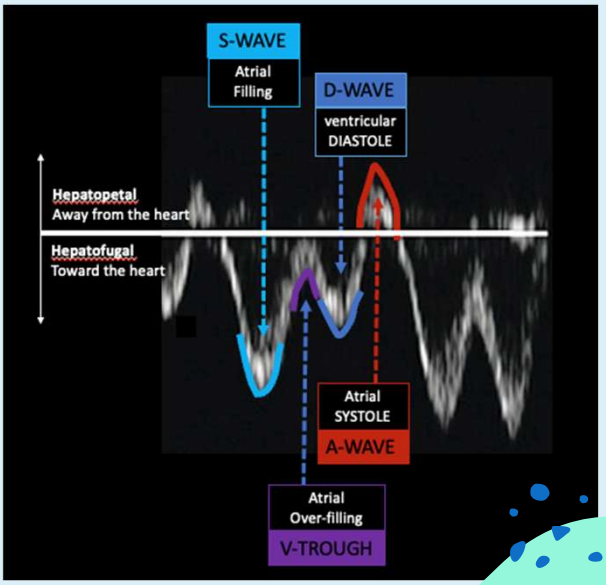


Figure 18: Normal spectral Doppler waveform of the middle hepatic vein.

38

Hepatoportal Pathophysiology

Diseases of the liver vasculature

39

PORTAL HYPERTENSION

Abnormal increase in portal venous pressure as a result of obstruction of blood flow through the liver[10]

40

Portal Hypertension

True portal pressure, or portal pressure gradient = portal vein pressure - IVC pressure

Normal pressure is between <5 mm Hg

Pressures above 10 mm Hg cause clinical significance[11]

41

Disorders: Portal Hypertension

Progressive condition:

- Vessels maximally dilate
- Venous flow slows
- Venous flow reverses on inspiration
- Venous flow completely reverses[4]

42

Portal Hypertension

- Flow is rerouted away from liver through collateral channels to lower pressure vessels
- Primary complication of portal hypertension are ruptured esophageal and gastric varices[4]

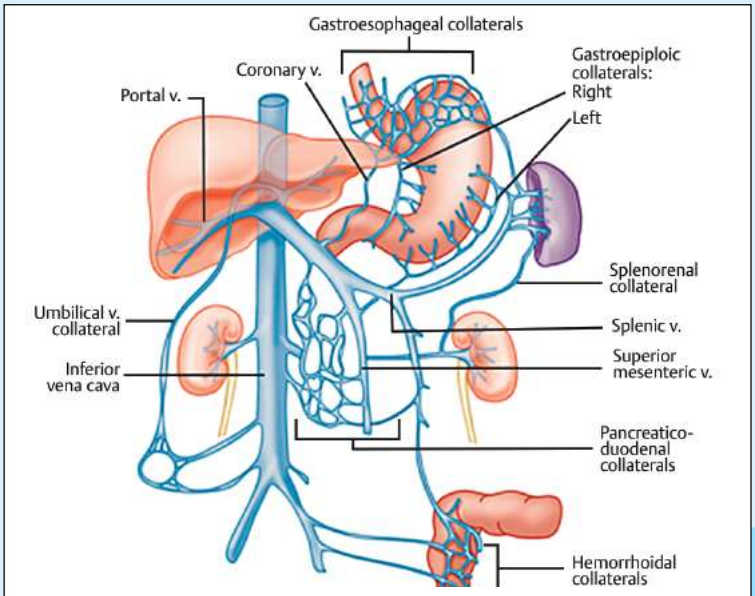


Figure 19: Hepatoportal circulation with active collateral pathways.

43

Sonographic Appearance: Esophageal Varices

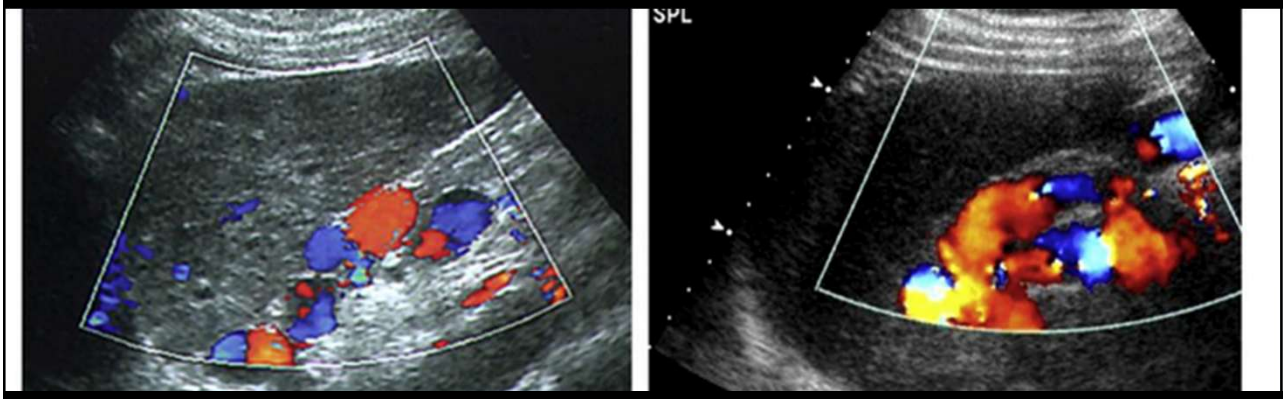


Figure 20: Color Doppler image of esophageal varices.

44

Sonographic Appearance: Gallbladder Varices

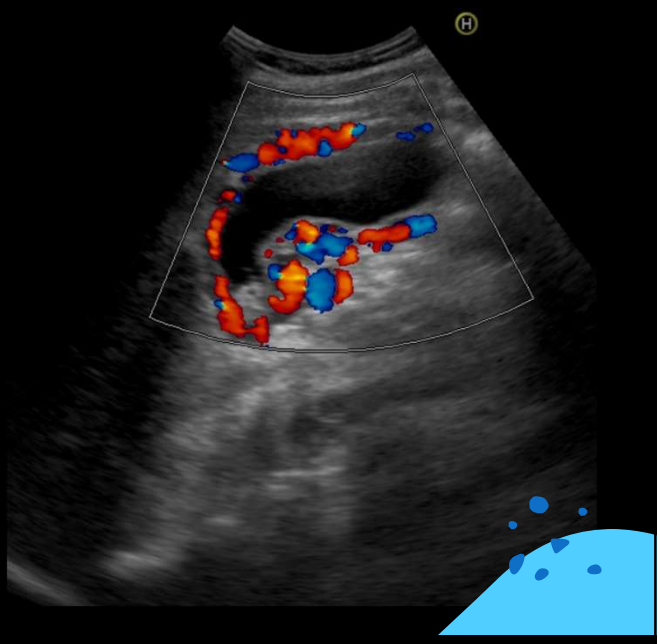


Figure 22: Color Doppler image of gallbladder.

45

Sonographic Appearance: Splenorenal Collaterals

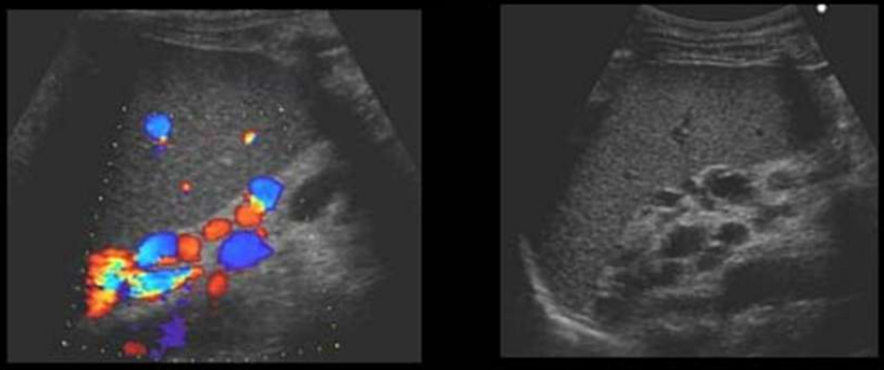


Figure 23: Color Doppler image of spenorenal collaterals.

46

Portal Hypertension

Atrophied paraumbilical veins course within ligamentum teres

Umbilical vein recanalization is a potential collateral pathway[1]

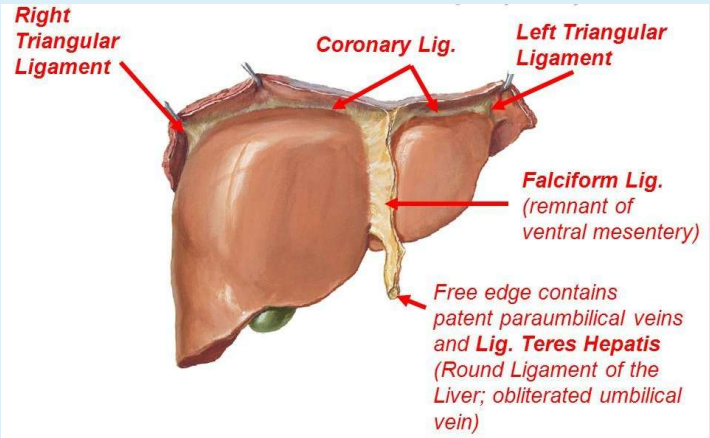
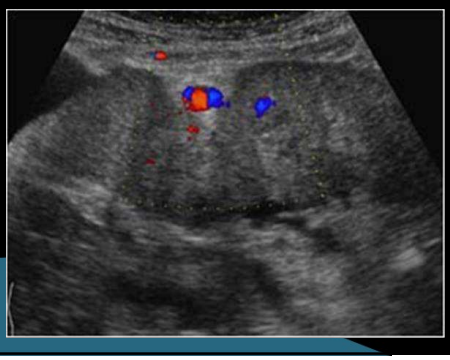


Figure 24: Suspensory ligaments of the liver.

47

Sonographic Appearance: Recanalized Umbilical Vein



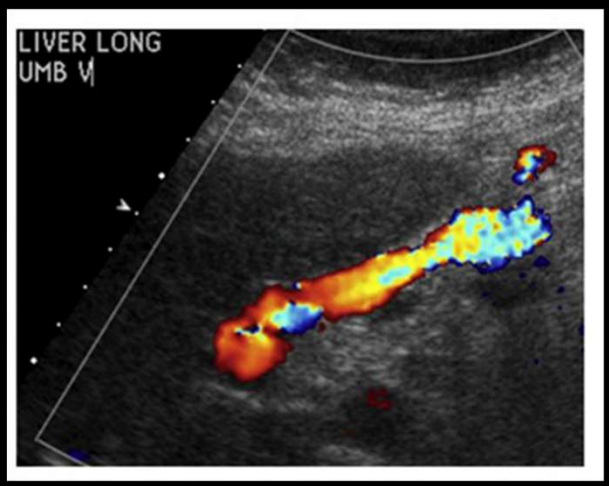


Figure 25: Color Doppler of recanalized umbilical vein in transverse (a) and longitudinal views (b).

48

Portal Hypertension

Hepatic Artery Arterialization

- Decreased portal vein flow results in increased hepatic artery flow
- Hepatic artery becomes enlarged, shows increased flow, and becomes tortuous (corkscrew appearance)[4]

49

Portal Hypertension: Symptoms[1]

- Hematemesis
- Blood in stool
- Bloating and weight gain
- Edema
- Confusion

50

Portal Hypertension[4]

Etiologies :

1. Prehepatic
2. Intrahepatic
3. Posthepatic

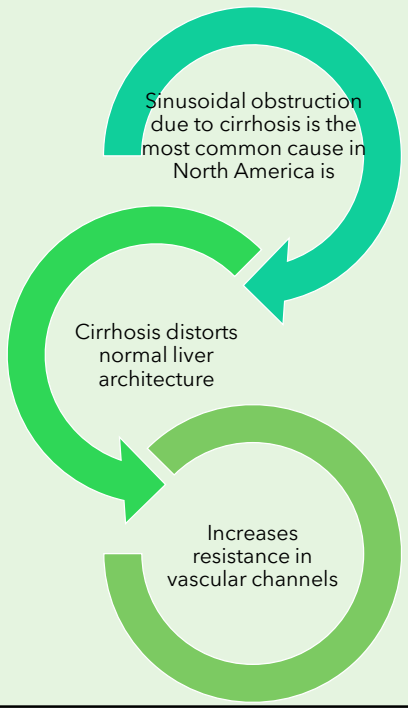
TABLE 22-2
Causes of Portal Hypertension

Prehepatic:
Portal/splenic vein thrombosis
Splanchnic arteriovenous fistula
Malignancy
Trauma
Sepsis
Pancreatitis
Hypercoagulable states
Intrahepatic:
Cirrhosis
Malignancy
Lymphoma
Schistosomiasis
Veno-occlusive disease
Budd-Chiari syndrome (hepatic vein occlusion)
Sarcoidosis
Posthepatic:
Congestive heart failure/constrictive pericarditis
IVC obstruction

Table 1: Causes of portal hypertension.[4]

51

Portal Hypertension[1]



52

Portal Hypertension

Other causes of cirrhosis and portal hypertension include

- Nonalcoholic fatty liver disease
- Hepatitis B
- Hepatitis C[1,4,11,12]

53

Hepatoportal Assessment:

Basic Interpretation

54

Portal Hypertension Diagnosis

Box 1
Sonographic features of portal hypertension

- Initially there is slow (<20 cm/s) hepatopetal flow in the MPV; stagnant and hepatofugal flow is seen with progression.
- Enlarged hepatic artery
- Enlarged portal vein greater than 1.3 cm
- Splenomegaly: greater than 12 cm longitudinal diameter or greater than 45 cm^2 maximum cross-sectional area
- Ascites
- Varices: gastroesophageal, splenic
- Portosystemic collaterals: recanalized umbilical vein, coronary vein
- Monophasic waveforms in the hepatic veins
- Increased resistive index in hepatic and splenic arteries

Figure 26: Sonographic features of portal hypertension.[4]

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Portal Hypertension

Remember that portal hypertension is a progressive disease. It starts out mild and gets more severe as the underlying condition progresses. This means that there are different findings for different stages:

1. Slow PV flow and increased PV diameter
2. To-fro-flow in the PV and increased PV diameter
3. Reversed PV flow, collateral formation and increased PV diameter.[4]

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Portal Hypertension

Progression of waveform morphology:

A: Normal

B. Abnormal – Increased cardiac pulsatility

C. Abnormal – Alternating flow, with hepatofugal elements[4]

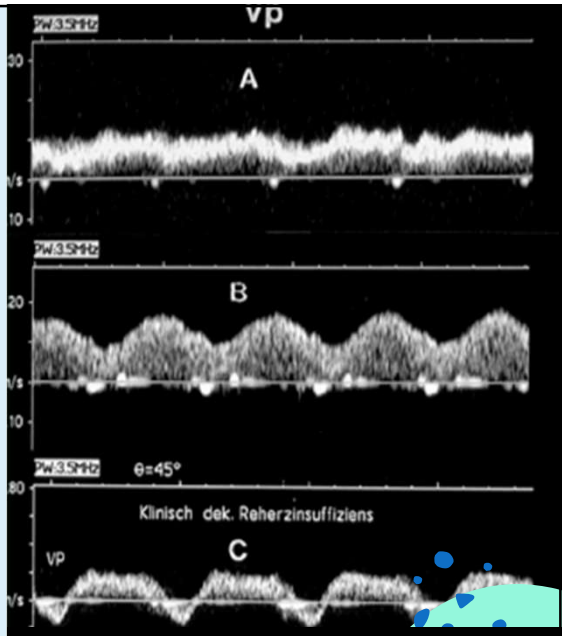

Figure 27: Spectral Doppler of main portal vein demonstrating normal (a), pulsatile (b) and biphasic flow (c).

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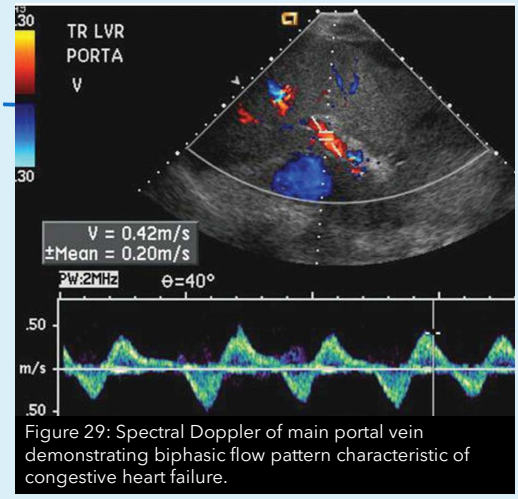

Figure 29: Spectral Doppler of main portal vein demonstrating biphasic flow pattern characteristic of congestive heart failure.

Portal Hypertension: Congestive Heart Failure

Causes edema of the liver secondary to vascular congestion

Increased right heart pressures will impact portal and hepatic waveforms

- Portal vein flow becomes markedly pulsatile
- Hepatic vein waveforms demonstrated highly pulsatile "W"-type pattern

IVC also becomes dilated[4]

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Portal Hypertension

Progression of ultrasound findings:

A: Visibly dilated MPV

B. Abnormal – VERY slow flow

C. Abnormal – Increased velocity hepatic artery[4]

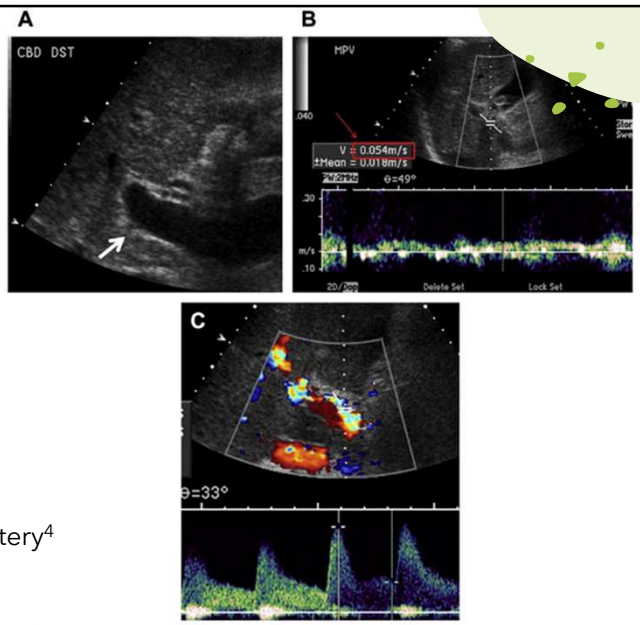

Figure 30: Ultrasound images of portal hypertensive patient demonstrating a dilated main portal vein (a), slow MPV flow (b), and increased hepatic artery flow (c).

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Portal Hypertension

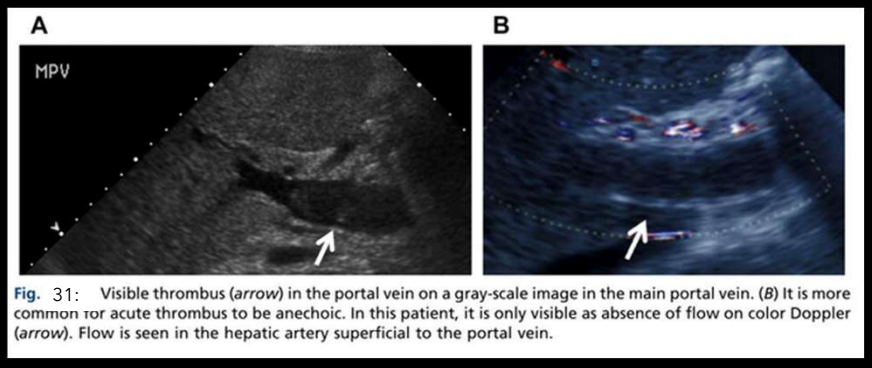

Fig. 31: Visible thrombus (*arrow*) in the portal vein on a gray-scale image in the main portal vein. (*B*) It is more common for acute thrombus to be anechoic. In this patient, it is only visible as absence of flow on color Doppler (*arrow*). Flow is seen in the hepatic artery superficial to the portal vein.

Portal Vein Thrombosis

May be caused by stagnant and/or slow flow

Color and spectral Doppler flow absent.[4]

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Portal Hypertension

Hepatofugal flow in the MPV evidenced by opposite direction flow of hepatic artery and MPV on color and spectral Doppler[4]

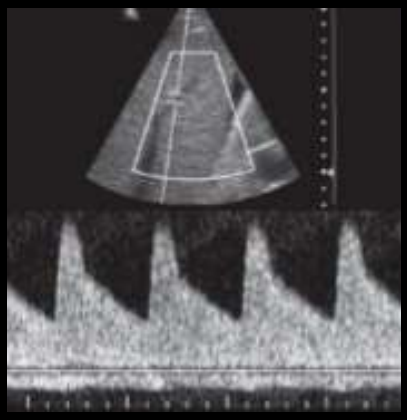

Figure 32: Color (a) and spectral Doppler (b) of main portal vein and hepatic artery demonstrating flow in opposite directions.

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Portal Hypertension: Hepatic Veins

Hepatic Portal Hypertension:

Loss of liver compliance results in blunted to monophasic hepatic vein waveforms.[4]

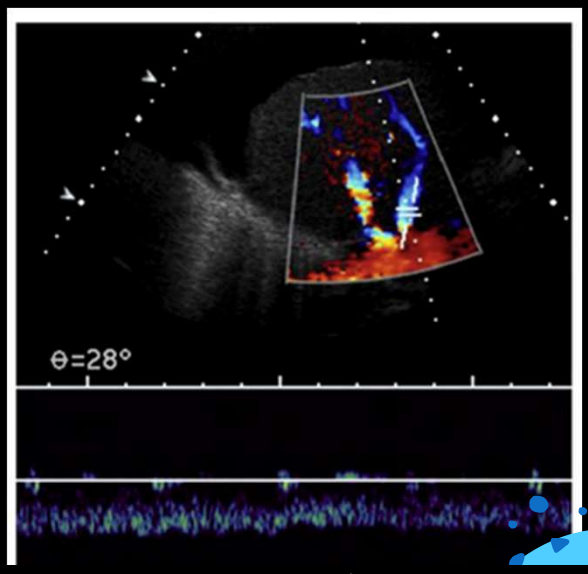

Figure 34: Color and spectral Doppler of hepatic vein demonstrating blunted flow.

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Portal Hypertension: Hepatic Veins

Post-hepatic Portal Hypertension:

Cardiac congestion will result in exaggerated hepatopetal flow

Characteristic "W" shaped waveform of CHF

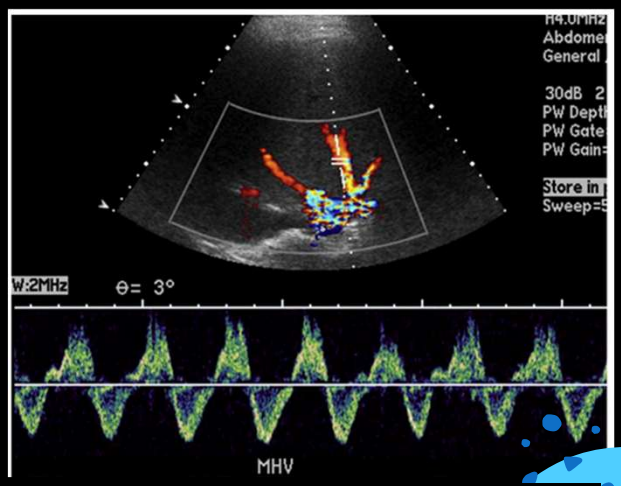

Figure 34: Color and spectral Doppler of hepatic vein abnormally pulsatile flow.

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