Spectrum of the Portal Vein on Color and Spectral Doppler, and Contrast Enhanced Ultrasound in both Native and Transplanted Livers

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Learning Objectives

- Review range of normal Doppler findings in the portal vein
- Review pathologic appearance of the portal vein (PV) in native and transplanted livers with use of color Doppler, spectral Doppler, and contrast enhanced ultrasound

Topics to be discussed include:

- Monophasicity vs. increased pulsatility
- Flow direction: antegrade/bidirectional/reversed/helical
- Increased intraluminal echoes
  - PV Occlusions: Partial/Complete/Obliterated
  - Air/ Rouleaux (slow) flow
- Slow vs. high flow states (cardiac, pregnancy, shunting)
Normal Portal Vein

- Normal velocity range 20-40 cm/s
- Monophasic waveform with gentle undulations
- Antegrade flow
Increased Pulsatility

- Pulsatility is the variability of blood velocity in a vessel
- Increased pulsatility is usually seen in the setting of elevated right atrial pressure:
  - Right heart failure
  - Tricuspid regurgitation

Images of the MPV demonstrate increased pulsatility in the setting of right heart failure

Also note increased pulsatility in the middle hepatic vein and dilatation of the hepatic veins
Increased Pulsatility

- Do not mistake arterialized flow for increased venous pulsatility

**Teaching Point:** arterialized flow in portal vein is tumor thrombus, most commonly hepatocellular carcinoma, until proven otherwise

*Note the arterialized waveforms in the region of the portal vein in both images*
Variation in Flow Direction
Retrograde (hepatofugal) - Bidirectional

Main Causes: Cirrhosis, Portal Hypertension, Cardiac Disease

Two examples of spectral waveform of the portal vein with flow seen both above and below the baseline in these patients with liver disease.

Teaching point: Even small pressure changes related to inspiration and expiration can cause reversal of flow direction.
Retrograde – Bidirectional Flow

Still image from CINE loop demonstrating bidirectional (alternating red and blue color) flow in the main portal vein – Hyperlink for CINE hosted on web

Teaching point: This can be misinterpreted as unidirectional flow on still images only
Variations in Flow Direction
Helical flow

- Disruption in the normal laminar flow secondary to:
  - Vessel geometry
  - Irregularity of the vessel wall
  - Changes in flow direction and speed
- Doppler demonstrates alternating red and blue bands in a spiral
- Can be seen after liver transplant or TIPS patients as a normal finding
  - Abnormal if persistent
Variations in Flow Direction

**Helical flow**

- **Transplant**
  - Secondary to change in PV diameter between donor and native vessel, most prominent when discrepancy is >50%
  - Local turbulence

- **TIPS**
  - Changes in PV velocity, flow direction, and pulsatility
  - Reportedly as high as 28% of TIPS¹
Intraluminal Echoes
Portal Vein Air

Still image from CINE loop ([hyperlink](#)) demonstrating rapidly moving intraluminal echogenic foci in the portal system.

Spectral Doppler demonstrating characteristic “spike” like aberration in the portal vein waveform.

**Teaching point:** beware of pitfalls
- Rouleaux from slow flow
- True thrombus
- Misdiagnosis of pneumobilia
Intraluminal Echoes
Another example of Portal Vein Air

Still image from CINE loop (hyperlink) demonstrating numerous swirling internal reflectors within the main portal vein
Portal Vein Air

- CT may be confirmatory
- Unlike pneumobilia, generally considered a more ominous finding

Potential Causes
- Bowel Ischemia/infarction
- Bowel obstruction
- Pancreatitis
- Diverticulitis/Appendicitis
Complete PV Thrombus

Teaching point:
Need to optimize Doppler technique when evaluating for thrombus

- Use the appropriate depth
- Use the appropriate scale
  - High scale may miss lower velocities that are below threshold value

Intraluminal Echoes
Portal Vein Thrombosis

Partial Thrombus
Cavernous Transformation

- Sequelae of long standing portal vein thrombosis
- Thrombosed main portal vein may no longer be present
- Secondary signs of chronic thrombosis
  - Periportal collaterals with many flow directions
  - Small caliber or absent main PV
Intraluminal Echoes
Tumor Thrombus

Grayscale image demonstrates expanded main portal vein filled with intraluminal echoes

Color and spectral Doppler images demonstrate irregular vessels with arterialized waveforms in PV
Tumor Thrombus

Still image from CINE clip (hyperlink) demonstrating tumor thrombus in MPV
Role of CEUS
Bland versus Tumor Thrombus

- Contrast-enhanced ultrasound adds value in differentiating bland thrombus from tumor thrombus
- CEUS improves sensitivity and diagnostic accuracy\(^4,7\)

(Top Left) Gray scale images show intraluminal filling defect
(Bottom) CEUS dual screen CINE images (hyperlink): note enhancement in area of filling defect in left portal vein
**Slow flow**

- Normal MPV peak systolic velocity (PSV) measures between 20-40 cm/s
  - PSV of <16 cm/s and increased caliber of MPV are diagnostic features of portal hypertension

*(Top right) Images demonstrate slow, low amplitude bidirectional flow in the RPV*

*(Bottom right) Power Doppler demonstrating low amplitude flow in LPV*
Slow flow

“Rouleaux” flow

- Images demonstrating mobile low level echoes in the MPV (a.) and middle hepatic vein and IVC (b.) better appreciated on CINE
  - “Rouleaux” flow is due to red blood cell aggregation from sluggish flow
High flow

- High velocities
- Causes
  - Stenosis
    - Most commonly seen in post-transplant
  - Pregnancy
  - Pseudoaneurysm
  - Arteriovenous Fistula/AVM
    - Congenital (Osler Weber Rendu)
    - Acquired (post biopsy/trauma)

*Images from a liver transplant showing turbulent high flow (>50 cm/s) related to a hepatic artery-portal vein fistula*
PV in Liver Transplant

- **Stenosis**
  - Typically with end to end anastomosis
  - 3-4x increase in peak systolic velocity (PSV)
  - Associated findings
    - Aliasing
    - Elevated PSV
    - Spectral broadening

*Note aliasing and elevated velocities at site of PV anastamosis*

**Teaching point: beware of pitfalls**
- Pseudostenosis – can be a normal finding secondary to difference in vessel caliber between native and donor. Usually resolves in immediate postoperative period
Abdominal radiologists should be familiar with the spectrum of normal variants and pathology in the portal vein reflecting underlying pathologic states, including but not limited to, cardiac dysfunction, portal hypertension, stenosis, and thrombosis.
References


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CINE Loops Hosted on Web

- Slide 8 – Bidirectional Flow – https://vimeo.com/199039295
- Slide 17 – Tumor Thrombus - https://vimeo.com/198946303
- Slide 18 – CEUS Tumor Thrombus - https://vimeo.com/199041745