DUPLEX ULTRASOUND EVALUATION OF THE PORTAL – HEPATIC SYSTEM

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Vascular Sonography Education
THE MESENTERIC STUDY

Arterial

- Celiac - Hepatic - Splenic
- Superior Mesenteric Artery
- Inferior Mesenteric Artery

Venous

- Mesenteric system
- Porto - hepatic system
- Inferior Vena Cava
Hemodynamics of the Liver

- Normal Inflow
  - Hepatic Artery
  - Portal Vein

Approximately 25% of cardiac output
(1.5 L/min)
Portal Vein and Hepatic Artery should have same flow direction.
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Hemodynamics of the Liver

- Normal Outflow
  - Hepatic Veins
  - IVC
Hemodynamics of the Liver

- Hepatic Artery
  - Sharp systolic upstroke
  - RI ~ 0.6 – 0.7
  - EDV ≤ 20 cm/s
Hemodynamics of the Liver

- Hepatic Artery

The Artery supplies the disease process
Portal Venous Hemodynamics

- Normal
  - Confluence of Splenic / SMV
  - Two-thirds of hepatic blood flow
  - Only 10% of hepatic oxygen supply
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Portal Venous Hemodynamics

Portal Vein flow typically with subtle phasicity, \( \leq 20 \text{ cm/sec} \) (fasting patient)
Portal Venous Hemodynamics

Liver Vascular Index: Portal vein velocity approx. equal to hepatic artery EDV
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Liver Vascular Index

Initially thought to be sensitive and specific for HCC

Many other causes

(Iwao, Am J Gastroenterol 1997)
Normal portal vein flow is hepato – petal (not hepato – pedal)

Reversed portal vein flow is hepato – fugal

(Centripetal vs Centrifugal)
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Portal Venous Hemodynamics

Transition from hepato-petal to hepato-fugal flow is through no-flow (or nearly so) stasis

May be mis-diagnosed as portal vein thrombosis

CDI with low scale, high gain

Spectral Doppler at slow sweep speed
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Portal Venous Hemodynamics

Valsalva: Flips PV flow direction
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Pulsatile Portal Venous Flow

Hyperdynamic hepatic arterial inflow:
A-V fistula
Capillary leak

...
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Pulsatile Portal Venous Flow

Increased peripheral venous pressure:

NORMAL PRESSURES
in mm Hg

-2 - +5

0 - +6
Pulsatile Portal Venous Flow

Increased peripheral venous pressure:
- Elevated right heart pressure transmitted via IVC
- Tricuspid insufficiency
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CHF

Tricuspid Insufficiency
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Hepatic Veins – Right, Middle, Left
Hepatic Veins – Periodic flow waveform
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Hepatic Veins – Periodic flow waveform

Pulsatility

Periodicity

Phasicity
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Hepatic Veins – Periodic flow waveform
Portal Hypertension: Pathophysiology

- Increased pressure gradient between the portal vein and the IVC above 6 mmHg
- $>6 \text{ mmHg} < 12 \text{ mmHg}$ (clinically silent)
- $>12 \text{ mmHg}$ (clinically evident)
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Portal Hypertension: Pathophysiology

Pre-sinusoidal

Sinusoidal

Post-sinusoidal
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Portal Hypertension: Pathophysiology

Pre-sinusoidal – Extrahepatic
Portal vein obstruction
Arterial-portal fistula

Intrahepatic
Fibrosis
Wilson disease
Sarcoid
Parasitic
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Portal Hypertension: Pathophysiology

- Sinusoidal – Cirrhosis
- Hepatitis
- Sclerosing cholangitis
Portal Hypertension: Pathophysiology

Post-sinusoidal – Budd-Chiari Syndrome

Hepatic vein thrombosis

Hepatic vein outflow obstruction

IVC

Cardiac

Pulmonary
Portal Hypertension: Pathophysicsiology

Hepato-cellular disease – Elevated liver enzymes (depends on severity)
Ultrasound first
Doppler essential; gray scale may not be diagnostic
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Portal Hypertension: Pathophysiology

Hepato-cellular disease –
Portal vein flow decreases
Hepatic artery flow increases (early in disease process)
Portal Hypertension: Pathophysiology

Hepato-cellular disease –
Hepatic artery flow resistance increases with disease severity; path of least resistance becomes portal system
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Portal Hypertension:
Clinical Manifestations

Cirrhosis – Elevated liver enzymes
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Portal Hypertension: Sonographic Findings

Splenomegaly (> 13 cm)
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Portal Hypertension: Sonographic Findings

Ascites
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Portal Hypertension: Sonographic Findings

Severe ascites with extrinsic compression of Portal Vein
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Portal Hypertension: Sonographic Findings

Dilated Portal Vein (> 13mm)
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Portal Hypertension: Sonographic Findings

Hepatofugal flow
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Portal Hypertension: Sonographic Findings

Portosystemic collaterals -
Gastroesplenic (short gastric)
Left gastroesplenic
Recanalized umbilical vein
Splenorenal
Mesenteric
Retroperitoneal
Hemorrhoidal
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Portal Hypertension: Sonographic Findings

Portosystemic collaterals

Recanalized Umbilical Vn
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Portal Hypertension: Sonographic Findings

Portosystemic collaterals – Recanalized Umbilical Vein

Caput Medusa
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Portal Hypertension:
Sonographic Findings

Portosystemic collaterals

Dilated Coronary Vein (> 7mm)
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Portal Hypertension:
Sonographic Findings

Portosystemic collaterals

Abnormal flow direction
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Portal Hypertension:
Sonographic Findings

Identification and mapping of varices –

helps avoid surgical complications
helps in transplant planning
helps in TIPS placement
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Portal Hypertension:
Sonographic Findings

Varices

Superficial Varices off recanalized Umbilical Vn
Portal Hypertension: Sonographic Findings

Varices: Gastric Gallbladder
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Portal Hypertension: Sonographic Findings

Portal Vein Thrombosis
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Portal Hypertension: Sonographic Findings

Cavernous Transformation: Peri-portal collaterals
Portal Hypertension: Conclusions

Variceal pathways can occur virtually anywhere.
An unsuspected varix can cause severe complications.
Caput Medusa is present in only a small percentage of patients with recanalized paraumbilical vein.
If it looks like a cystic mass – turn Doppler on!!
TIPS, DIPS and other Shunts

Shunt - Portal hypertension

Cirrhosis of the Liver: > 600,000

Alcoholic cirrhosis
Hepatitis B and C
Hepatitis C: 4 – 5,000,000
Budd-Chiari Syndrome
Portal Hypertension: Complications

- Ascites
- Splenomegaly
- Liver failure
  - Platelet / WBC abnormalities
  - Encephalopathy
- Varices
  - Variceal bleeding
TIPS, DIPS and other Shunts

Portal Hypertension:
Child’s-Pugh Classification System

<table>
<thead>
<tr>
<th>Parameter</th>
<th>One point</th>
<th>Two points</th>
<th>Three points</th>
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</thead>
<tbody>
<tr>
<td>Bilirubin (mg/dl)</td>
<td>&lt; 2.0</td>
<td>2.0–3.0</td>
<td>&gt; 3.0</td>
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<tr>
<td>Albumin (g/dl)</td>
<td>&gt; 3.5</td>
<td>2.8–3.5</td>
<td>&lt; 2.8</td>
</tr>
<tr>
<td>Prothrombin time (elevated secs)</td>
<td>1–3</td>
<td>4–6</td>
<td>&gt; 6</td>
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<tr>
<td>Ascites</td>
<td>None</td>
<td>Slight</td>
<td>Moderate</td>
</tr>
<tr>
<td>Encephalopathy</td>
<td>None</td>
<td>1–2 (mild)</td>
<td>3–4 (severe)</td>
</tr>
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Grades: A, 5 to 6 points; B, 7 to 9 points; C, 10 to 15 points.
Portal Hypertension: Management

Concept of surgically shunting portal vein blood flow to relieve hypertension is over 100 years old.

First porto-caval shunt in human in 1903
TIPS, DIPS and other Shunts

Portal Hypertension: Management

Porto-systemic shunting reintroduced by Whipple in 1945

## Portal Hypertension: Management

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<table>
<thead>
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<tbody>
<tr>
<td>1.</td>
<td>Bleeding is controlled in 90% of patients after operative shunts.</td>
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<tr>
<td>2.</td>
<td>Rate of encephalopathy is determined by amount of portal flow diverted</td>
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<td>Distal splenorenal shunts – 10% to 15%</td>
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<tr>
<td></td>
<td>Partial shunts – 10% to 20%</td>
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<tr>
<td></td>
<td>Total shunts – 30% to 40%</td>
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<td>3.</td>
<td>Survival rates are similar in all type of operative shunts.</td>
</tr>
</tbody>
</table>
TIPS, DIPS and other Shunts

Portal Hypertension: Management

Porto-systemic shunting

Total portal systemic shunt

End-to-side
TIPS, DIPS and other Shunts

Portal Hypertension: Management

Porto-systemic shunting

Total portal systemic shunt

Side-to-side
TIPS, DIPS and other Shunts

Portal Hypertension: Management

Porto-systemic shunting

Partial portal systemic shunt

Side-to-side
TIPS, DIPS and other Shunts

Portal Hypertension: Management

Porto-systemic shunting

Partial shunt

Splenoportal

Splenoportal (end-to-side) shunt
TIPS, DIPS and other Shunts

Portal Hypertension: Management

Porto-systemic shunting

Partial shunt

Mesocaval
TIPS, DIPS and other Shunts

Portal Hypertension: Management

Selective distal spleno-renal shunting

popularized by Warren

TIPS, DIPS and other Shunts

Portal Hypertension: Management

Selective distal splenorenal shunt

(Warren shunt)
TIPS, DIPS and other Shunts

Portal Hypertension: Management

Surgical shunting

All of these are effective
All of these involve a major operation
All of these have significant associated morbidity / mortality
TIPS, DIPS and other Shunts

Portal Venous Hemodynamics

TIPS: Transjugular Intrahepatic Portosystemic Shunt
TIPS, DIPS and other Shunts

TIPS: Transjugular Intrahepatic Portosystemic Shunt

Clinical history –
Developed in canine model, 1969 (Rosch & Hanafee)
Used in humans, 1982 (Colapinto)
Unsuccessful until metallic stents, 1988 (Richter)
TIPS effective for variceal bleeding, 1995 (NIH)
Covered metallic stent, 2009
TIPS, DIPS and other Shunts

TIPS: Transjugular Intrahepatic Portosystemic Shunt

Indications:
Potential for variceal bleeding
Portal hypertension
End stage liver disease (bridge to transplant)
Refractory ascites
TIPS: Transjugular Intrahepatic Portosystemic Shunt

Contraindications:
- Congestive heart failure
- Tricuspid insufficiency
- Pulmonary hypertension (>45mmHg)
- Multiple hepatic cysts
- Systemic infection/sepsis
- Biliary obstruction
TIPS, DIPS and other Shunts

Hepatic Veins – Right, Middle, Left
TIPS, DIPS and other Shunts

Portal Venous Hemodynamics

**TIPS:**

Transjugular intrahepatic portosystemic shunt (TIPS)

- Hepatic vein
- Stent
- Liver
- Portal vein
TIPS, DIPS and other Shunts

Portal Venous Hemodynamics

TIPS:
TIPS, DIPS and other Shunts

TIPS: Transjugular Intrahepatic Portosystemic Shunt
Rt Hepatic Vn directly to Rt Portal Vn
TIPS, DIPS and other Shunts

TIPS: Transjugular Intrahepatic Portosystemic Shunt

Duplex Ultrasound Surveillance:
1-2 Days
1 Month
3 Months
6 Months
Every 6 Months
Following any revision
TIPS, DIPS and other Shunts

TIPS: Transjugular Intrahepatic Portosystemic Shunt

Normal Duplex Ultrasound Findings:
- Main portal vein – Hepato-petal flow
- Left portal vein – Hepato-fugal flow
- Stent velocity > 50 cm/sec
- Velocities relatively constant thru stent
- Velocities relatively constant over time
- Some cardiac periodicity
- Hep vn – Flow to heart
TIPS, DIPS and other Shunts

TIPS: Transjugular Intrahepatic Portosystemic Shunt

Normal Duplex Ultrasound Findings:
- Left portal vein – Hepato-fugal flow

Left PV flow may be hepato-petal if recanalized paraumbilical vein not embolized

Normal
“Blind” Rt. Hepatic Vein to Rt. Portal Vein (TIPS) has been replaced by a Direct Intrahepatic Portosystemic Shunt (DIPS) technique. Typically done using ultrasound guidance.
TIPS, DIPS and other Shunts
TIPS, DIPS and other Shunts

TIPS ➔ DIPS
TIPS, DIPS and other Shunts
TIPS, DIPS and other Shunts
TIPS, DIPS and other Shunts
TIPS, DIPS and other Shunts
TIPS, DIPS and other Shunts

Additional Doppler Msmts.
TIPS, DIPS and other Shunts

Additional Doppler Msmts.
TIPS, DIPS and other Shunts

Mechanisms of failure:
- Stent stenosis
  - Intimal hyperplasia
  - Ingrowth thru porous wall
  - Narrowing at hepatic vein outflow
  - Focal scarring
- Deployment short of IVC
- Stent thrombosis
Mechanisms of failure:
Stent stenosis
  Ingrowth thru porous wall

Covered stent eliminates this complication
Mechanisms of failure:
Narrowing at hepatic vein outflow
Stent torsion / torqueing
Inflammatory response
Incomplete stent expansion

TIPS, DIPS and other Shunts
Mechanisms of failure:
Narrowing at hepatic vein outflow

NB: The stenosis is beyond the end of the stent!!
TIPS, DIPS and other Shunts

Duplex Ultrasound Surveillance:
- Focal stenosis
- Stent velocity $< 50$ cm/sec
- Serial changes in velocity ($> 50$ cm/sec)
- Reversal of flow direction from baseline
Conclusions:

Ultrasound ideal for surveillance (Must educate referring physicians on need for routine followup)

Early identification of compromise allows salvage procedure; eliminates re-do

Base diagnosis on concordance of multiple findings
Conclusions: Concordant findings
Decreasing main PV flow
Reversal of flow direction in left PV
Evidence of focal stenosis in stent
Drop in stent velocities over time
Diminished cardiac periodicity in Doppler waveforms
Recurrent ascites
VASCULAR ULTRASOUND