TIPS – All that Non-interventional Radiologists Should Know

e-Poster: EE-170

Congress: ESGAR 2013

Type: Educational Exhibit

Topic: Interventional / Other - TIPS

Authors: L. Andrade[1], R.M. Amaral[2], J.F. Costa[1], L. Curvo-Semedo[1], F. Caseiro-Alves[1]; [1]Coimbra/PT, [2] Ponta Delgada/PT

1. Learning Objectives

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Learning Objectives

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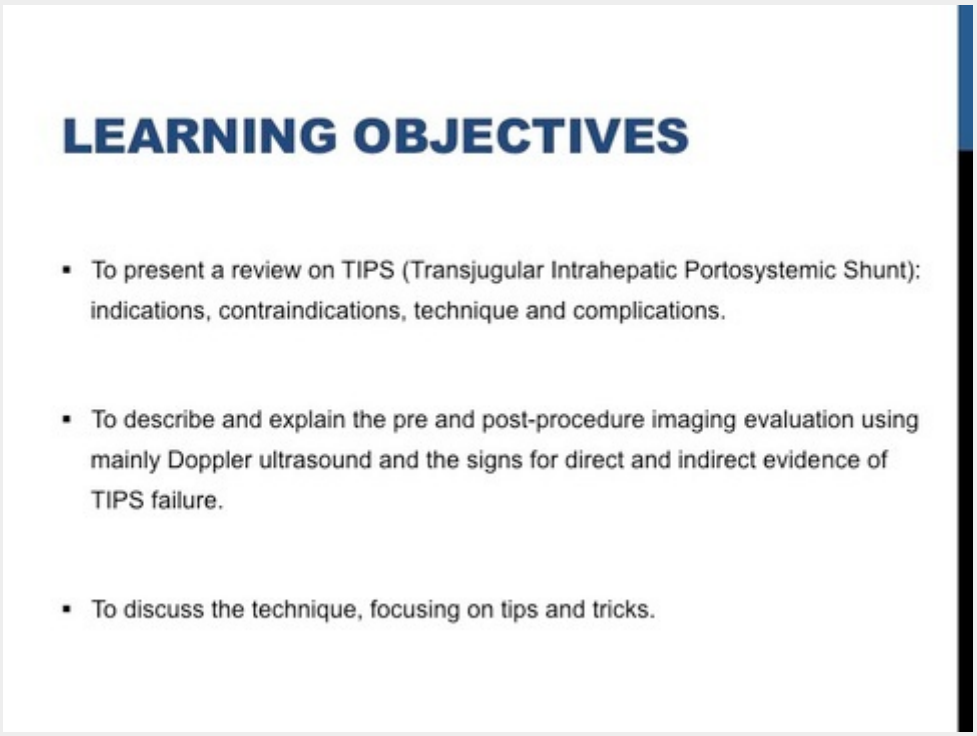

2. Background

Background

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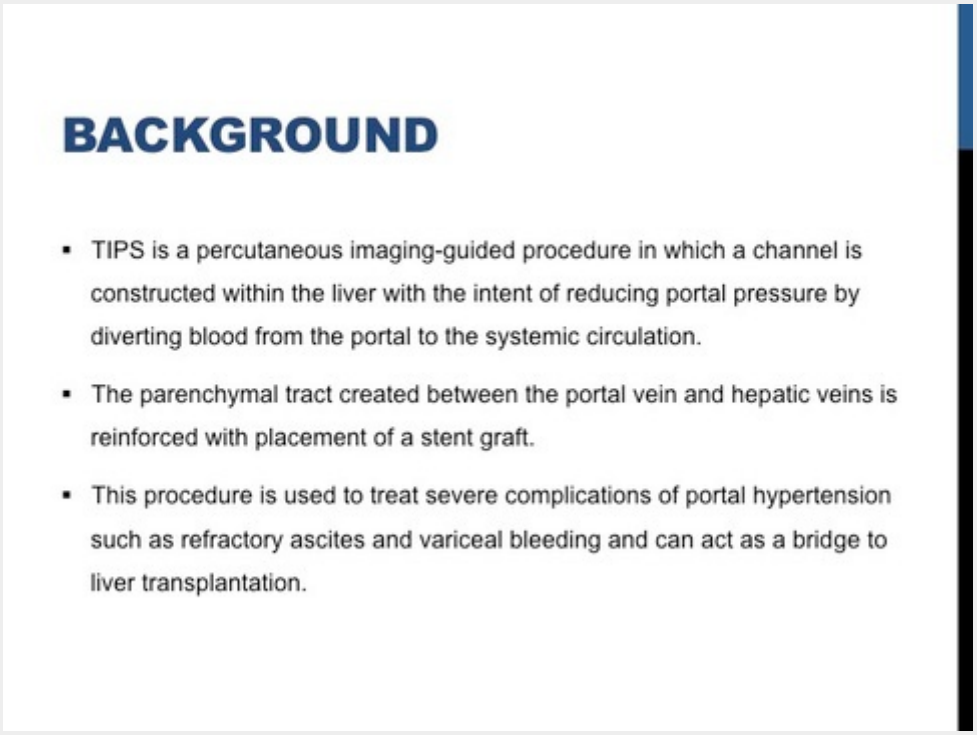

3. Imaging Findings/Procedure Details

Imaging Findings

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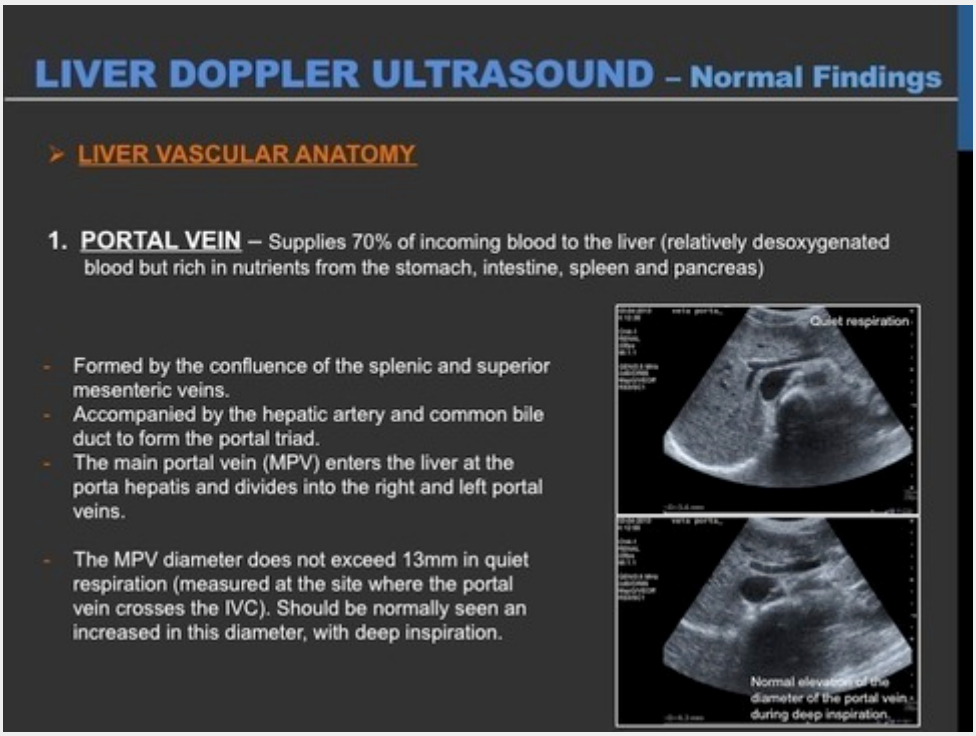

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LIVER DOPPLER ULTRASOUND – Normal Findings

➢ LIVER VASCULAR ANATOMY

2. **HEPATIC ARTERY** – Supplies 30% of incoming blood to the liver (oxygenated blood)

- The common hepatic artery originates in the majority of patients from the celiac artery.
- After the origin of the gastroduodenal artery it is called the proper hepatic artery.
- It enters the liver alongside and anterior to the portal vein, where is divides into left and right hepatic arteries.
- There are numerous variants of hepatic artery anatomy.

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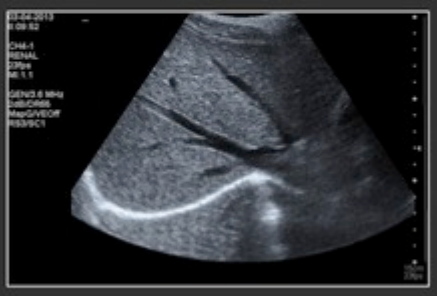
LIVER DOPPLER ULTRASOUND – Normal Findings

➢ LIVER VASCULAR ANATOMY

3. **HEPATIC VEINS** – hepatic venous drainage into inferior vena cava (IVC)



- They converge into IVC approximately 1cm below its confluence with the right atrium.
- In most people the right, middle and left hepatic veins enter the IVC in a "crows foot" configuration (transverse plane).
- 30% of individuals have additional hepatic veins.
- The walls of the hepatic veins are relatively hypoechoic, which helps to differentiate them from the portal veins in the more echogenic portal triads.

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LIVER DOPPLER ULTRASOUND – Normal Findings

- The right hepatic vein (RHV) is the largest of hepatic veins and courses between the anterior and posterior segments of the right lobe and drains into the right postero-lateral aspect of the IVC.
- The middle hepatic vein (MHV) courses along the major lobar fissure and drains the anterior right lobe segments (V, VIII) and segment IVb. In 85% of people the MHV forms a common trunk with the left hepatic vein (LHV), which then drains into the left antero-lateral aspect of the IVC.
- The LHV is the smallest of the hepatic veins and drains the lateral segments of the left lobe (II e III) and segment IVa.
- The venous drainage from the central portion of the liver (including caudate lobe) empties directly into the IVC (and cannot be perceived by color Doppler).

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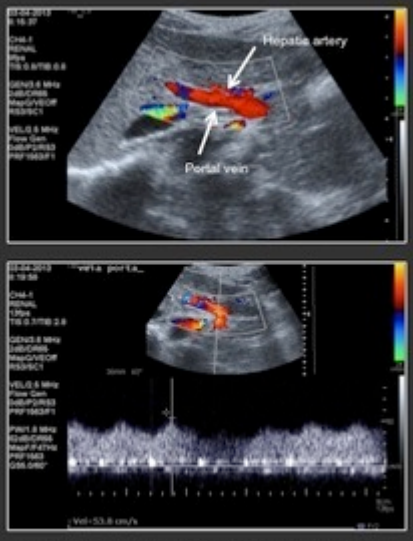
LIVER DOPPLER ULTRASOUND – Normal Findings

➢ **NORMAL FLOW PATTERNS**

1. PORTAL VEIN

- Antegrade flow (toward the transducer), therefore with a waveform that is above the baseline.
- Hepatopetal flow (towards the liver) throughout the entire cardiac cycle.
- Portal flow velocity varies with cardiac activity and respiration, giving the portal waveform an undulating appearance.
- Mean flow velocity relatively low (but >16cm/s)



Spectral Doppler tracing of portal vein flow. Hepatopetal portal vein flow, with a undulating appearance and a mean velocity > 16 cm/sec.

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LIVER DOPPLER ULTRASOUND – Normal Findings

➢ **NORMAL FLOW PATTERNS**

2. HEPATIC ARTERY

- Direction of flow: antegrade, which corresponds to a waveform above the baseline.
- Low-resistance: resistive index (RI) between 0,55 and 0,7.
- During systole, the velocity is approximately 30-60 cm/sec; while during diastole it normally slows down to 10-15 cm/sec (which is usually less than the velocity of the portal vein).
- The systolic acceleration time is brisk, typically less than 0,07s.

Spectral Doppler tracing of hepatic artery flow. Low-resistance profile of the hepatic artery waveform, with a resistance index of 0,67

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LIVER DOPPLER ULTRASOUND – Normal Findings

➢ **NORMAL FLOW PATTERNS**

3. HEPATIC VEINS

- The normal hepatic vein waveform is triphasic as a result of transmitted cardiac activity (waveform pattern similar to that of jugular vein).
- The majority of blood flow is antegrade (away from the liver and toward the heart), thus, it will also be away from the transducer and displayed below the baseline.
- The maximal retrograde hepatic venous flow - the *a wave* – corresponds to the auricular contraction.
- During ultrasound examinations the sonographer ask sometimes do the patient to do a forced inspiration – in this situation, with increased intrathoracic pressure, the *s* and *d-waves* become more proeminent, while the *a* and *v*-waves are less pronounced and may actually not manifest as reversed flow.

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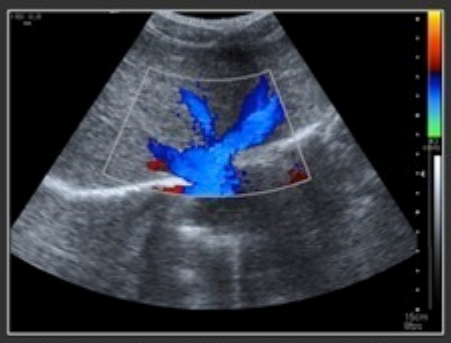
LIVER DOPPLER ULTRASOUND – Normal Findings



Color Doppler of the liver. Normal convergence of the hepatic veins

Spectral Doppler tracing of hepatic vein flow. Normal waveform of the hepatic vein with a triphasic profile ("W" appearance).

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PORTAL HYPERTENSION

- Portal hypertension accompanies cirrhosis of the liver in over 90% of the cases.
- Cirrhosis disrupts the normal hepatic sinusoidal pattern, impairing venous drainage and leading to increase in portal vein pressure.
- Portal hypertension is the increased in porto-systemic pressure gradient in any portion of the portal venous system.

Porto-Systemic Pressure Gradient:

- This gradient is assessed by measuring the wedge hepatic venous pressure (a measure of sinusoidal hepatic pressure) and subtracting the free hepatic venous pressure (systemic pressure) thus obtaining the hepatic venous pressure gradient (HVPG).

- Normal: HVPG = 2-5mmHg.
- Sub-clinically Portal Hypertension: HVPG > 6mmHg

- Clinically significant Portal Hypertension: **HVPG > 10-12 mmHg** (predicts clinical course in patients with cirrhosis including development of varices, variceal hemorrhage and encephalopathy, decompensation or death after liver resection, and hepatocellular carcinoma).

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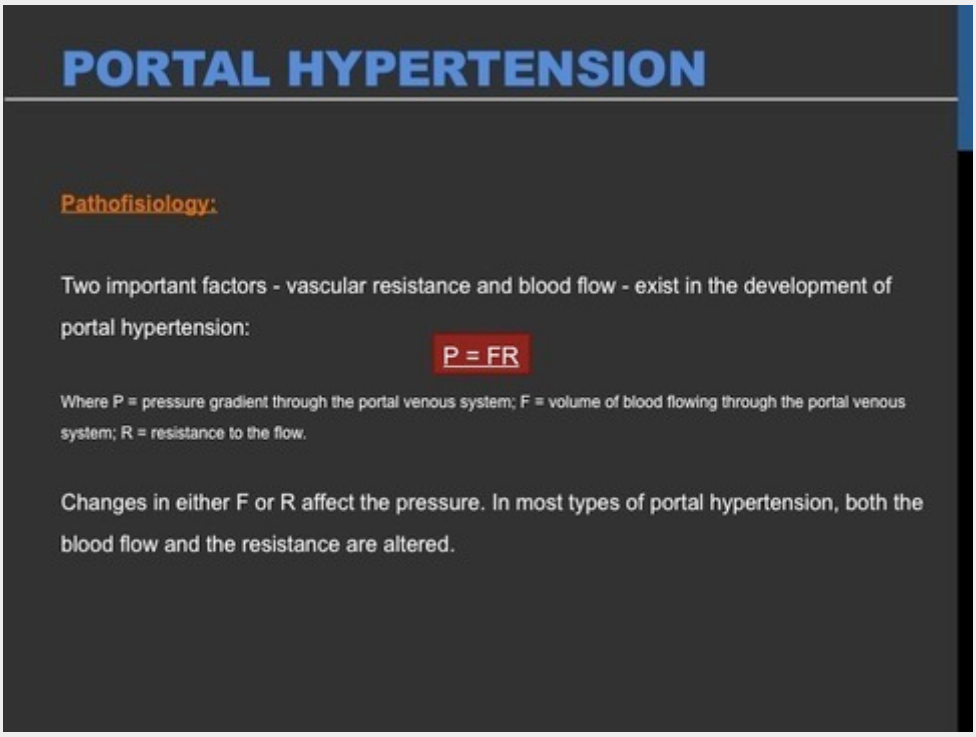

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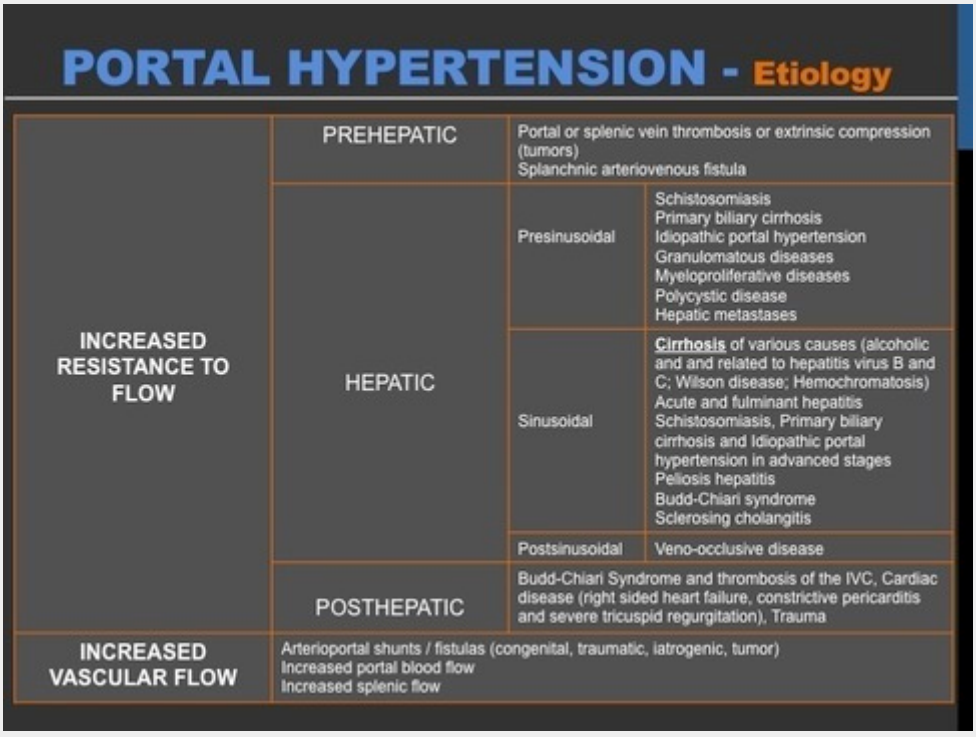

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Doppler Ultrasound – Cirrhosis and Portal Hypertension

In patients with cirrhosis and indication to TIPS the radiologist should evaluate the following parameters:

1. **Hepatic size and morphology:**

- In patients with advanced cirrhosis the liver is small with relative enlargement of caudate lobe and left lobe relatively to the right lobe (in early stages of cirrhosis the liver is enlarged or could appear absolutely normal).

US demonstrates a dysmorphic liver with coarse appearance and irregular borders.
This patient has cirrhosis and portal hypertension complicated with ascites.

2. **Liver echogenicity and texture:**

- Echogenicity could be increased in cirrhotic livers with fat infiltration.
- Irregular borders and nodular surface (in relation to the presence of regenerating nodules and fibrosis).
- Exclude the presence of definable nodules (dysplastic nodules – portal venous supply vs. HCC – arterial hepatic venous supply).
- Exclude the presence of multiple cysts (polycystic liver disease precludes the TIPS technique).

Cirrhotic liver. The hiperechoic nodule proved to be a small hepatocarcinoma.

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Doppler Ultrasound – Cirrhosis and Portal Hypertension

In cirrhosis, most of the normal liver architecture is replaced by distorted vascular channels that provide increased resistance to portal venous blood flow and obstruction to hepatic venous outflow.

3. **Portal vein:**

- **Diameter:**

- Although the caliber of the portal vein initially may be increased (>13mm) in PH, with the development of porto-systemic shunts, the portal vein caliber will decreased.
- Evaluate the response to respiratory manoeuvers: if the diameter of portal vein does not increase at least 20% from quiet respiration to deep inspiration the patient has probably PH.

B mode US shows dilatation of the portal vein (A) and normal portal vein diameter (B) after the development of varices.

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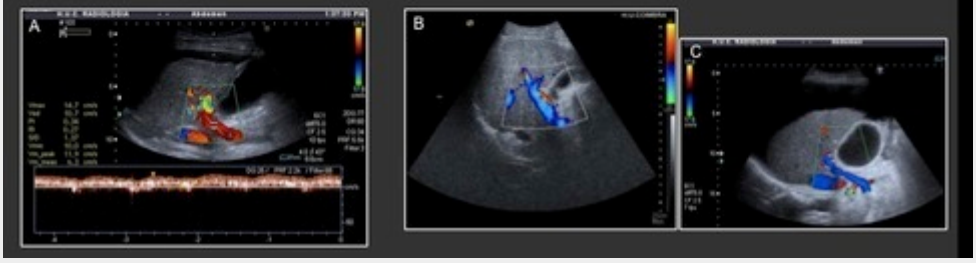
Doppler Ultrasound – Cirrhosis and Portal Hypertension

- **Permeability, flow direction and velocity:**

- In severe cirrhosis portal venous flow may become continuous (without undulating appearance) or pulsatile due to arteriovenous shunting;
- Portal flow velocity decreases (< 16cm/s) (A);
- Flow may become to and fro (bidireccional) or hepatofugal (retrograde) (B and C). As with slow flow, this finding is diagnostic for portal hypertension from whatever cause.
- A narrow portal vein and a prominent hepatic artery are commonly associated findings when flow is hepatofugal in the main portal vein.

However, we should always kept in mind that, the flow direction in the portal vein is a variable finding in PH and depends on the development of collaterals.



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Doppler Ultrasound – Cirrhosis and Portal Hypertension

- Absent (aphasic) portal venous flow may be due to stagnant flow (portal hypertension) or occlusive disease, usually caused by bland or malignant thrombosis.
- In the setting of subacute/chronic occlusive portal vein thrombosis could be development of collateral vessels in or around the occluded portal vein (*cavernous transformation of portal vein).*

(A). Absent flow in the portal vein (RPV) that is markedly dilated due to malignant portal vein thrombosis.
(B) Spectral Doppler of the "thrombus" show an arterial waveform in a hepatofugal direction.

A normal portal vein could not be visualised. Instead there is a plexus of small vessels - anechoic serpiginous structures (arrow). After portal vein thrombosis this web of small vessels reconstitutes portal flow to the liver and is known as cavernomatous transformation of the portal vein.

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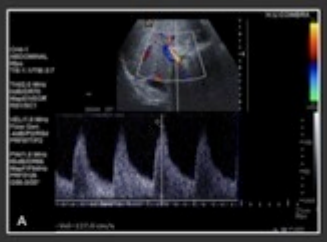
Doppler Ultrasound – Cirrhosis and Portal Hypertension

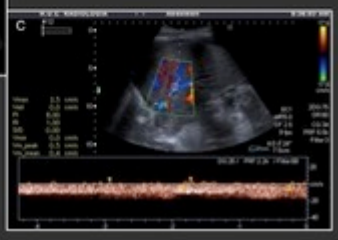
4. **Hepatic Artery:** (A)

- In patients with PH and decreased portal flow velocity, the hepatic artery appears enlarged with increased flow to compensate for the diminished portal vein flow.
- In patients with cirrhosis the resistive index in the hepatic artery is elevated (>0,7); with development of portal hypertension and arteriovenous/arterioportal shunts the RI decreases (<0,55).



5. **Hepatic Veins:**

- These veins became compressed and narrowed in cirrhotic patients (B).
- With PH they loss the classic pulsatility and turn into a biphasic or monophasic waveform (C).



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Doppler Ultrasound – Cirrhosis and Portal Hypertension

6. **Spleen**

- Access spleen greatest dimension – in the setting of PH there could be mild to moderate splenomegaly (>13cm).
- Reversed flow in the splenic vein (towards the spleen). Indirect sign of splenogastric or splenorenal collaterals, and thus PH.

7. **Presence / absence of ascites and volume quantification**

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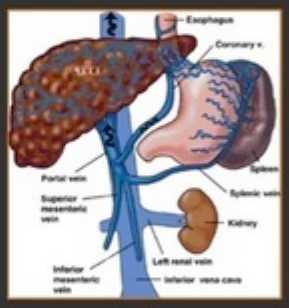
Doppler Ultrasound – Cirrhosis and Portal Hypertension

8. **Porto-systemic venous collaterals** – shunting of blood from the portal to the systemic circulation.

- **Short gastric varices:** courses between the spleen and the greater curvature of the stomach.
- **Left gastric varices (coronary varices):** curses from the splenic or portal veins to the lesser curvature of the stomach. Dilatation of the coronary vein (>7mm) is associated with severe PH (HVPG > 10mmHg).

These veins communicate with systemic esophageal veins and are known as gastroesophageal varices.



- **Paraumbilical veins:** originates from the left portal vein and runs inferiorly through the falciform ligament towards the anterior abdominal wall where it connects with the systemic epigastric veins or with the subcutaneous veins originating the *caput medusae*.
- **Splenorenal-mesenteric collaterals:** courses between the splenic hilum and the left renal vein.

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Doppler Ultrasound – Cirrhosis and Portal Hypertension

US scan of the spleen. Tangle of vessels are seen at the upper pole of the spleen, corresponding to short gastric varices.

Color Doppler image shows a recanalized paraumbilical vein that carries blood towards the umbilicus.

Longitudinal US image shows a tortuous left gastric varix coursing from the region of celiac axis towards the gastro-esophageal junction

(D) US scan of the spleen revealed anechoic tubular structures adjacent to the lower pole of the spleen, communicating to the left renal vein (not shown).

(E) A large varix occupies the space between the splenic hilum (s) and the left kidney (k)

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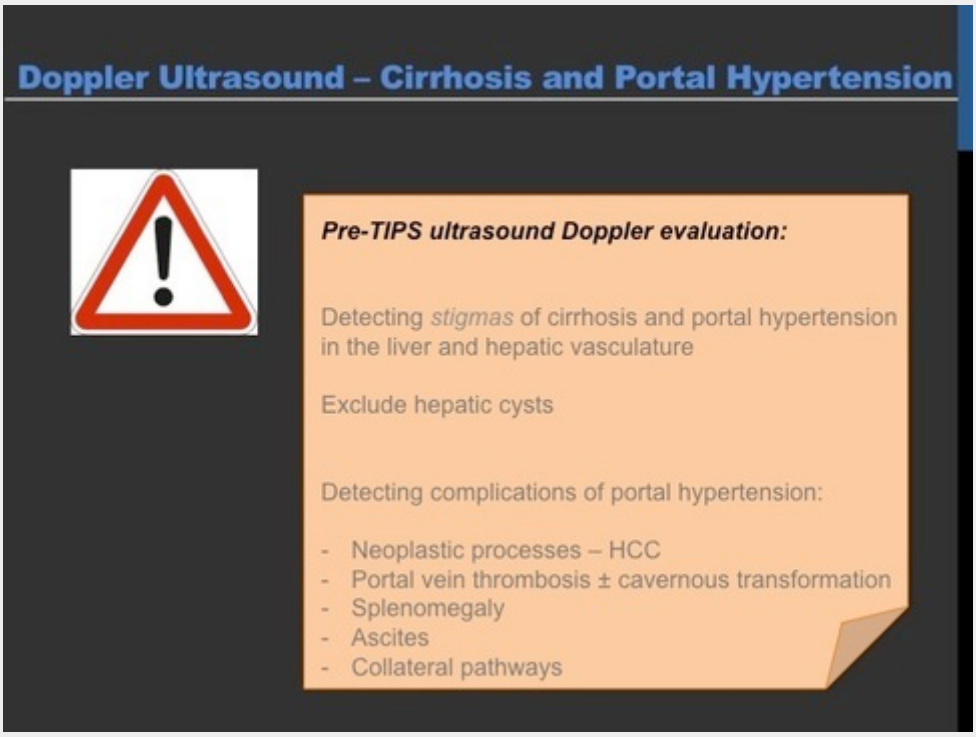

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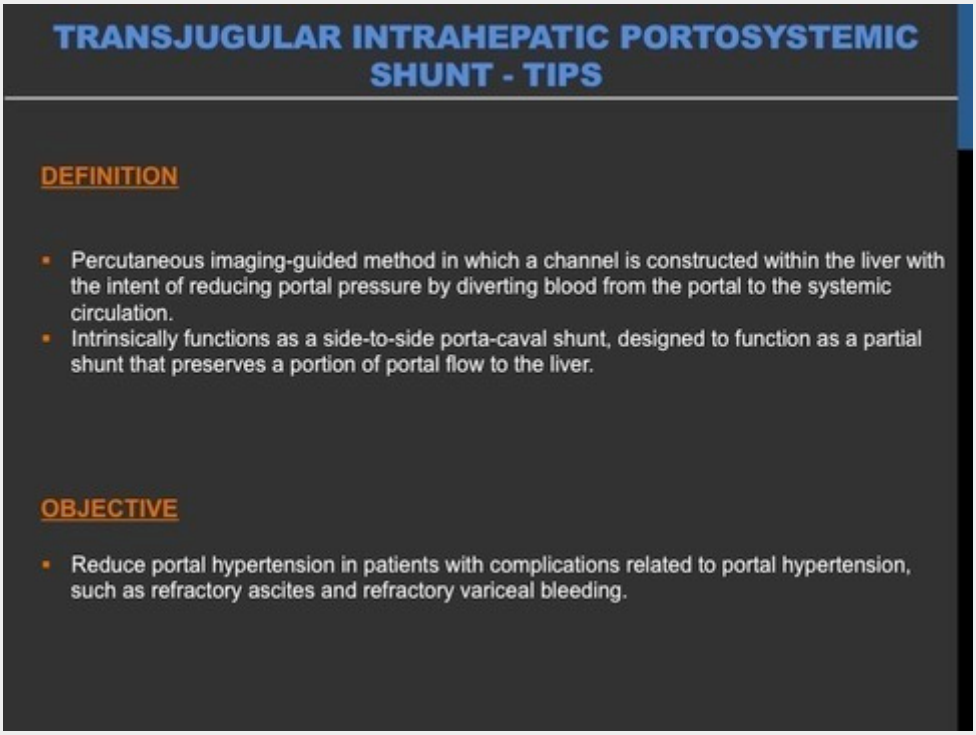

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TIPS - Indications

- **Refractory ascites** (the most frequent indication for TIPS)
- **Secondary prevention of variceal bleeding** (second-line therapy after failure of medical and endoscopic therapy)

- Refractory acute variceal bleeding
- Portal hypertensive gastropathy
- Hepatorrenal syndromes
- Bleeding gastric / ectopic varices
- Refractory hepatic hydrothorax
- Budd-Chiari syndrome
- Hepatic veno-occlusive disease
- Hepatopulmonary syndrome

- In centers with extensive experience TIPS should be considered in patients with portal vein thrombosis with or without cavernomatous transformation, when intrahepatic portal venous branches are patent.

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TIPS – Patient Selection

- Patients with a Child-Pugh score of >12 are in high risk of post-procedural death.

- MELD scores of >15-18 or a bilirrubin level of >3.5mg/dl have poor prognosis and TIPS should only be performed in the absence of any other treatment possibilities.

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TIPS – Contra-Indications

Absolute
- Unproved portal hypertension
- Primary prevention of variceal bleeding
- Congestive heart failure
- Polycystic liver disease
- Uncontrolled systemic infection or sepsis
- Unrelieved biliary obstruction
- Severe pulmonary hypertension
- Severe tricuspid regurgitation

Relative:
- Hepatocarcinoma large and central
- Hepatic venous obstruction
- Portal vein thrombosis
- Severe coagulopathy (INR>5)
- Thrombocytopenia (<20 000)
- Moderate pulmonary hypertension
- Hepatic encephalopathy poorly controled

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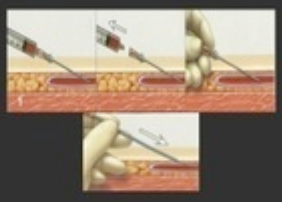
TIPS – Technique

1. Jugular access (right internal jugular vein) – Seldinger technique



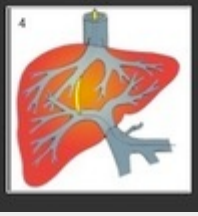
2. A catheter is placed and guided through the superior vena cava, right atrium and inferior vena cava into a hepatic vein. (Because of large size and consistent and predictable relation to the portal veins, the right hepatic vein is the preferred hepatic vein branch for the creation of a TIPS shunt).

3. Selective catheterization of a suitable branch of the RHV

(Pressure measurements are preformed at this point, including central venous pressures, at the level of right atrium and IVC and free and wedged hepatic venous pressures).

4. A needle inserted through the catheter is then used to puncture the liver from a central portion of the hepatic vein and enter the main portal branch (usually the right portal vein).

The puncture could be navigated with ultrasound.



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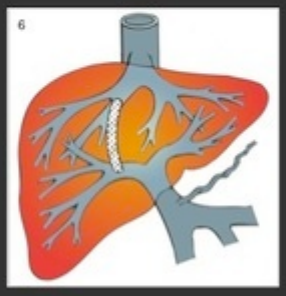
TIPS – Technique

5. Dilatation of the needle tract by a balloon catheter – establishing of a connection between the portal and systemic circulation directly inside the liver parenchyma.

6. Insertion of a TIPS stent graft



7. The final step of the TIPS procedure is placement of a pigtail catheter over the portal vein guide wire for follow up portography and pressure measurements.

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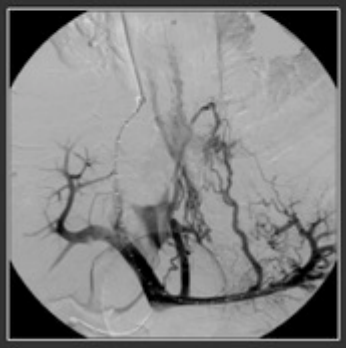
TIPS – Technique

Suprahepatic flebography

Advance of needle into the portal vein



Transhepatic portogram shows colateral circulation – left gastric vein varices

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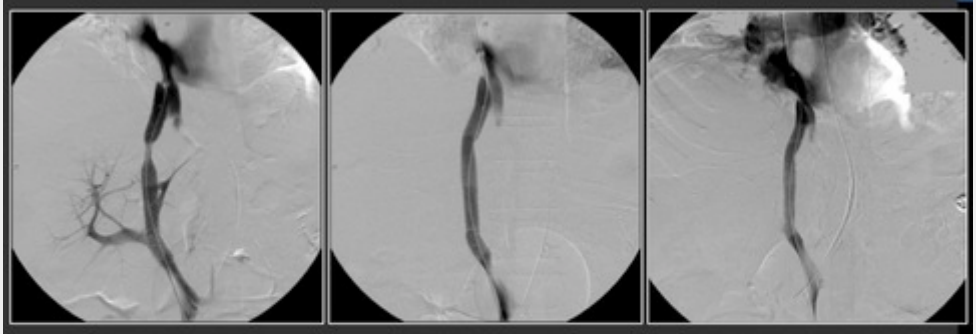
TIPS – Technique



Tract dilatation using a 10mm angioplasty balloon catheter. The narrowed part of the balloon is in the intraparenchymal part of the tract.

TIPS made with covered stent between portal and middle hepatic veins

Portal venogram obtained after TIPS insertion shows flow through covered stent. Peripheral portal vein branches are no longer opacified because of reversal of flow

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TIPS – Complications

Complications	Frequency (%)
TIPS Dysfunction *1 - Occlusion / Stenosis - Thrombosis	 18-78 10-15
Encephalopathy - New/worse - Chronic	 10-44 5-20
Transcapsular puncture	33
Stent migration or non-optimal placement	10-20
Hemolysis	10-15
Sepsis	2-10
Hemobilia	<5
Intraperitoneal bleeding	1-2
Hepatic infarction	1
Fistulae and endotipsitis	rare

*1 When TIPS were created with bare metal stents, the loss of primary patency was around 50% at one year follow-up. In this era, with use of expanded polytetrafluoro-ethylene (ePTFE)– covered stent-graft, the patency has vastly improved and stenosis occurs in just 8-20% of TIPS.

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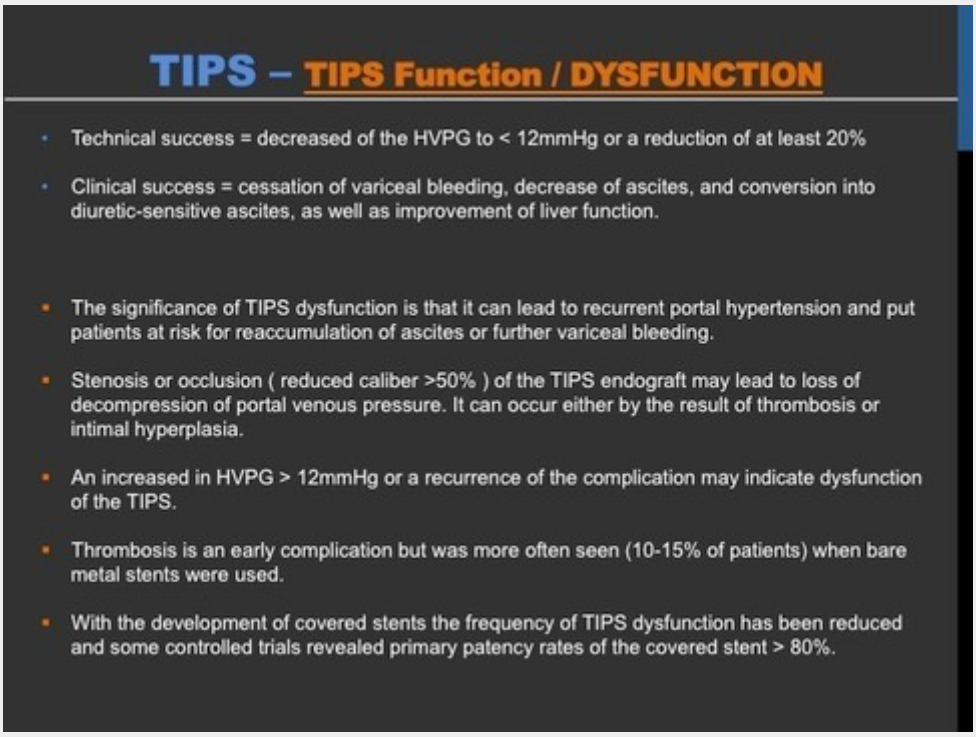

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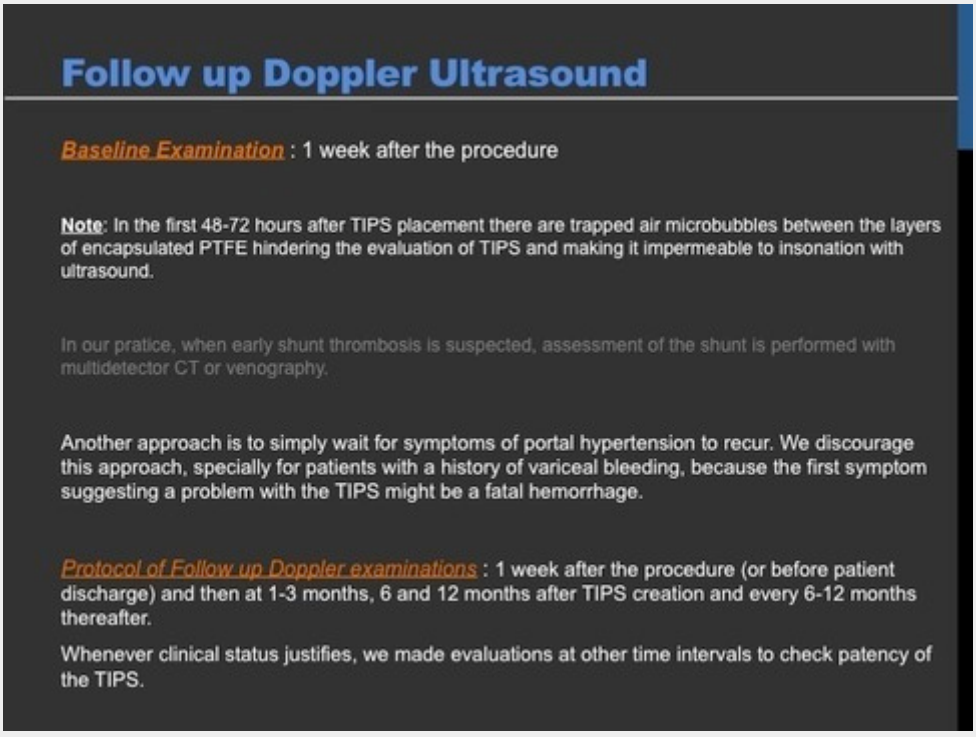

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Follow up Doppler Ultrasound – What evaluate ?

- Despite reports of variable success rates, ultrasound has remained an integral part of TIPS surveillance because it is non-invasive, inexpensive, and widely available.

1. **Liver morphology and focal liver lesions**

2. **Vascular evaluation:**

- Assessment and study of the permeability and flow direction in:

- *Portal vein and its branches*
- *Hepatic veins and* any hepatic vein segment between the cephalic portion of the TIPS and the IVC _The hepatic vein with the shunt, usually the right, is checked in both proximal to and just beyond its junction with the stent.
- Inferior vena cava
- Splenic vein

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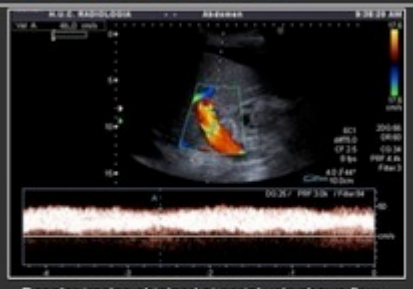
Follow up Doppler Ultrasound

Portal Vein

- Main portal vein velocity after TIPS is typically higher than its pre-TIPS value
- MPV velocity: > 30cm/s
- With shunt dysfunction, the flow in the portal vein leading up to the TIPS is diminished and the MPV velocity drops often below 30cm/s.



Doppler tracing obtained at portal vein shows flow direction towards the portal vein end of the TIPS (hepatopetal) and velocity of 46cm/s.

- Flow direction in the portal system is towards the portal vein end of the stent:
  - MPV and splenic vein = hepatopetal flow
  - Right and left portal veins = hepatofugal flow (towards the inflow of the shunt). If the patient has patent paraumbilical vein collaterals, the flow within the left portal vein will continued to be hepatopetal.

Left portal vein with hepatofugal flow - flowing out of the diseased liver and towards the inflow of the shunt

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Follow up Doppler Ultrasound

3. **Evaluation of TIPS**

- Position of the stent: the cephalic end of the shunt is most commonly located immediate to the connection of the right hepatic vein with the IVC, and the caudal end is located in the right portal vein.
- Lumen of TIPS : anechoic lumen without wall thickening

Two cases of baseline examination following TIPS placement. Grey-scale image of the right lobe of the liver. The TIPS is seen coursing from the porta hepatis region to the junction of the right hepatic vein with inferior vena cava. The mesh like appearance of the shunt is due to the echo reflection of the individual wire elements of the stent

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Follow up Doppler Ultrasound

- Check permeability and flow direction : the lumen should be completely filled by the turbulent, periodic flow and the direction of flow should be from the portal vein to the hepatic vein.

Color Doppler image of the TIPS. The entire lumen is saturated with color indicating patency. Note the non-uniforming of color encoding.

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Follow up Doppler Ultrasound

- Measure the flow velocity, with angle correction, in proximal, middle and distal portion of the TIPS.
- Thresholds velocities that are too high (> 200-250 cm/s – jet-effect zone beyond the stenosis) or too low (< 50 cm/s) are associated with high specificity and sensitivity for shunt dysfunction.
- **Normal flow velocity**: 90-190 cm/s
- Changes in the peak flow velocity ± 50cm/s within TIPS, in relation with the baseline examination also suggests TIPS dysfunction and should also prompt shunt venography and portosystemic pressure measurements.
- Velocities can also be variable through the shunt itself in a normal situation – usually velocities increased from the portal venous end to the hepatic venous end of the shunt.
- The flow is also more turbulent when multiple stents components are used and when overrinding stents cause a relative narrowing of the shunt lumen.

Spectral Doppler of the TIPS show an appropriately functioning TIPS.

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Follow up Doppler Ultrasound – *Signs of TIPS Dysfunction*

- Shunt malfunction is the result of narrowing or occlusion caused by intimal hyperplasia or in situ thrombosis.
- Can occur anywhere within the stent but is most commonly in the cephalic portion of the TIPS or in the hepatic vein between the stent and the IVC.

Occlusion

- Absent flow at color Doppler US (you can use *Power Doppler* and low filters to identify low flow conditions and differentiate them from true occlusion).
- Aphasic spectral waveform.
- When flow velocity and direction in the portal veins is the same as it was prior to TIPS placement.

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Follow up Doppler Ultrasound – *Signs of TIPS Dysfunction*

Stenosis

- Continuous waveform of the flow within the stent
- Abnormally high (>190 cm/sec) or abnormally low (<90 cm/sec) velocity within the shunt.
- Abnormal change in velocity (increase or decrease >50 cm/sec) compared with the prior examination.

Abnormally low velocity within distal end of the TIPS

slide43.jpg

Follow up Doppler Ultrasound – *Signs of TIPS Dysfunction*

- Intrahepatic portal venous flow (right and left portal veins) that was hepatofugal on the prior examination and has changed to hepatopetal flow (in the absence of a recanalized paraumbilical vein).
- Hepatofugal or to-and-fro flow in the main portal vein and/or splenic vein.
- Low velocity (<30 cm/sec) in the main portal vein.
- Development or recurrence of collateral vessels such as a recanalized umbilical vein.
- New, recurrent or worsening ascites.

Indirect signs of TIPS dysfunction – hepatofugal flow in the main portal vein and low velocity

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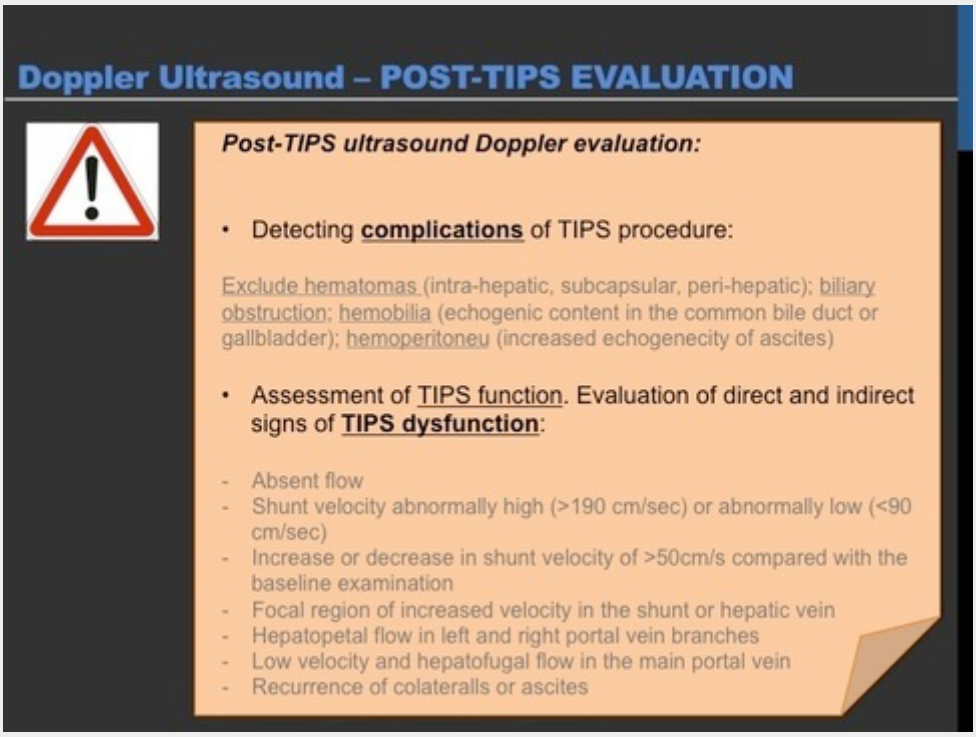

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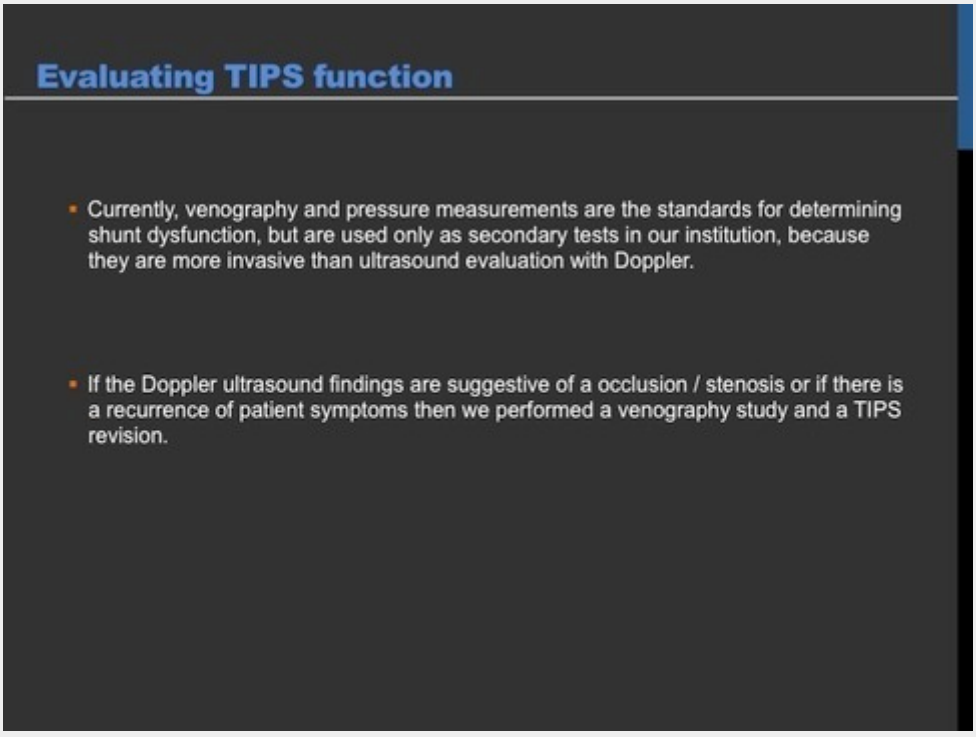

4. Conclusion

Conclusion

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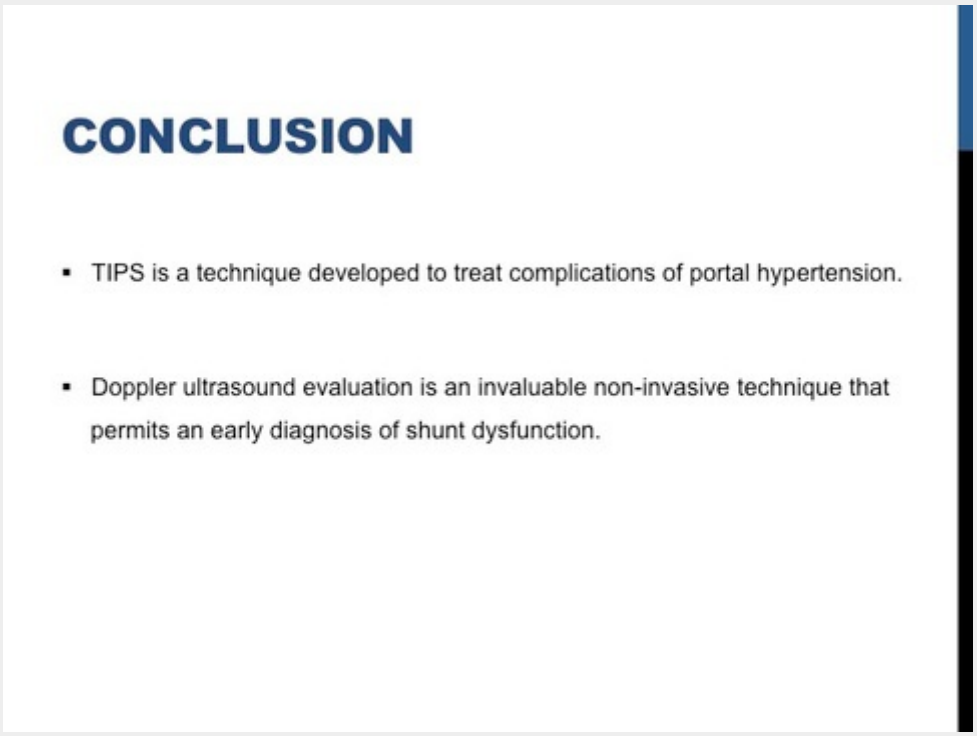

5. References

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6. Author Information

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7. Mediafiles

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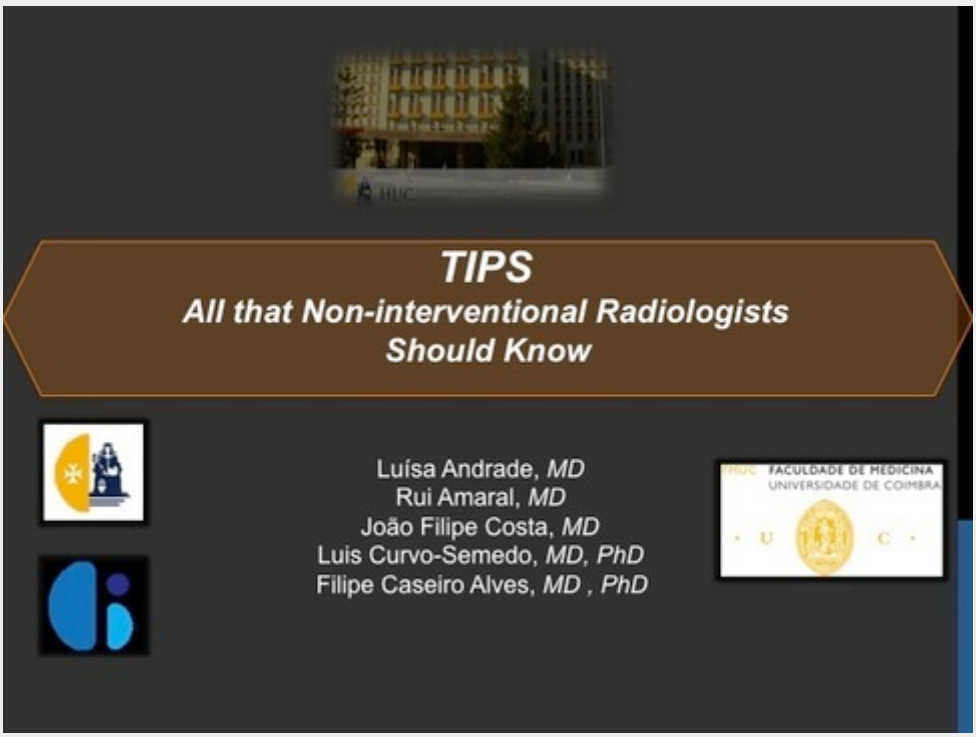

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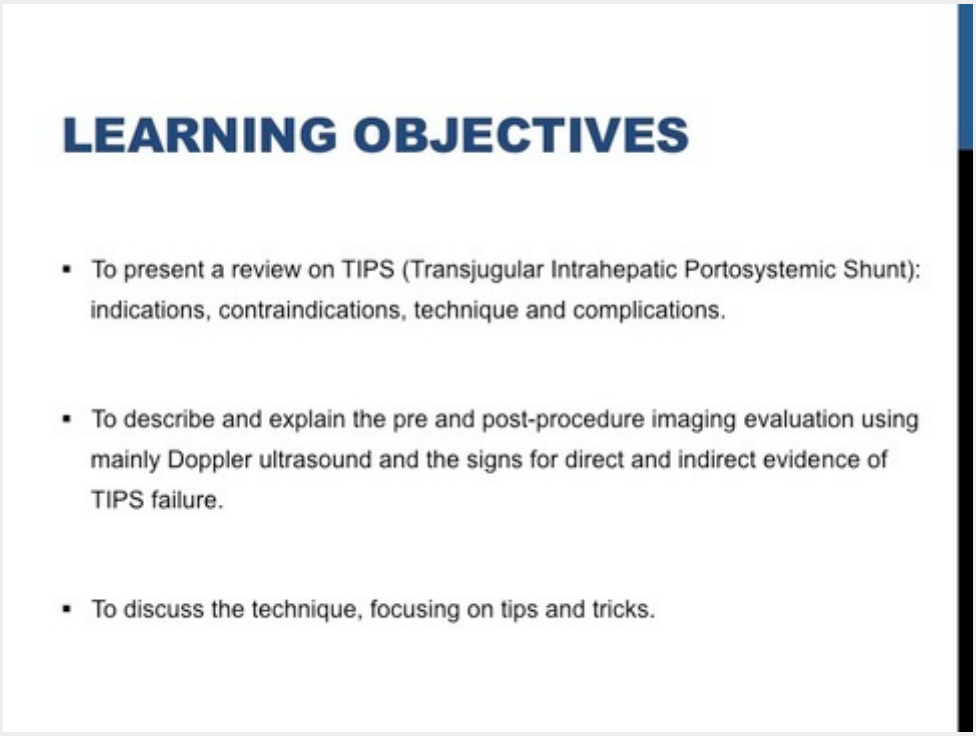

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BACKGROUND

- TIPS is a percutaneous imaging-guided procedure in which a channel is constructed within the liver with the intent of reducing portal pressure by diverting blood from the portal to the systemic circulation.
- The parenchymal tract created between the portal vein and hepatic veins is reinforced with placement of a stent graft.
- This procedure is used to treat severe complications of portal hypertension such as refractory ascites and variceal bleeding and can act as a bridge to liver transplantation.

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LIVER DOPPLER ULTRASOUND – Normal Findings

➢ LIVER VASCULAR ANATOMY

1. **PORTAL VEIN** – Supplies 70% of incoming blood to the liver (relatively desoxygenated blood but rich in nutrients from the stomach, intestine, spleen and pancreas)

- Formed by the confluence of the splenic and superior mesenteric veins.
- Accompanied by the hepatic artery and common bile duct to form the portal triad.
- The main portal vein (MPV) enters the liver at the porta hepatis and divides into the right and left portal veins.
- The MPV diameter does not exceed 13mm in quiet respiration (measured at the site where the portal vein crosses the IVC). Should be normally seen an increased in this diameter, with deep inspiration.

slide06.jpg

LIVER DOPPLER ULTRASOUND – Normal Findings

➢ LIVER VASCULAR ANATOMY

2. HEPATIC ARTERY – Supplies 30% of incoming blood to the liver (oxygenated blood)

- The common hepatic artery originates in the majority of patients from the celiac artery.
- After the origin of the gastroduodenal artery it is called the proper hepatic artery.
- It enters the liver alongside and anterior to the portal vein, where is divides into left and right hepatic arteries.
- There are numerous variants of hepatic artery anatomy.

slide07.jpg

LIVER DOPPLER ULTRASOUND – Normal Findings

➢ LIVER VASCULAR ANATOMY

3. HEPATIC VEINS – hepatic venous drainage into inferior vena cava (IVC)

- They converge into IVC approximately 1cm below its confluence with the right atrium.
- In most people the right, middle and left hepatic veins enter the IVC in a "crows foot" configuration (transverse plane).
- 30% of individuals have additional hepatic veins.
- The walls of the hepatic veins are relatively hypoechoic, which helps to differentiate them from the portal veins in the more echogenic portal triads.

slide08.jpg

LIVER DOPPLER ULTRASOUND – Normal Findings

- The right hepatic vein (RHV) is the largest of hepatic veins and courses between the anterior and posterior segments of the right lobe and drains into the right postero-lateral aspect of the IVC.
- The middle hepatic vein (MHV) courses along the major lobar fissure and drains the anterior right lobe segments (V, VIII) and segment IVb. In 85% of people the MHV forms a common trunk with the left hepatic vein (LHV), which then drains into the left antero-lateral aspect of the IVC.
- The LHV is the smallest of the hepatic veins and drains the lateral segments of the left lobe (II e III) and segment IVa.
- The venous drainage from the central portion of the liver (including caudate lobe) empties directly into the IVC (and cannot be perceived by color Doppler).

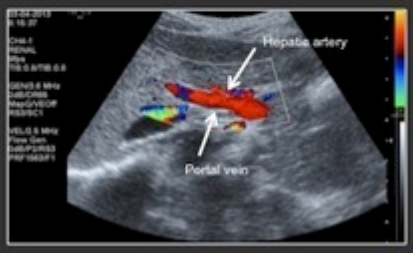
slide09.jpg

LIVER DOPPLER ULTRASOUND – Normal Findings

➢ **NORMAL FLOW PATTERNS**

1. PORTAL VEIN

- Antegrade flow (toward the transducer), therefore with a waveform that is above the baseline.
- Hepatopetal flow (towards the liver) throughout the entire cardiac cycle.
- Portal flow velocity varies with cardiac activity and respiration, giving the portal waveform an undulating appearance.
- Mean flow velocity relatively low (but >16cm/s)



Spectral Doppler tracing of portal vein flow. Hepatopetal portal vein flow, with a undulating appearance and a mean velocity > 16 cm/sec.

slide10.jpg

LIVER DOPPLER ULTRASOUND – Normal Findings

➢ NORMAL FLOW PATTERNS

2. HEPATIC ARTERY

- Direction of flow: antegrade, which corresponds to a waveform above the baseline.
- Low-resistance: resistive index (RI) between 0,55 and 0,7.
- During systole, the velocity is approximately 30-60 cm/sec; while during diastole it normally slows down to 10-15 cm/sec (which is usually less than the velocity of the portal vein).
- The systolic acceleration time is brisk, typically less than 0,07s.

Color Doppler of hepatic artery (*)

Spectral Doppler tracing of hepatic artery flow. Low-resistance profile of the hepatic artery waveform, with a resistance index of 0,67

slide11.jpg

LIVER DOPPLER ULTRASOUND – Normal Findings

➢ NORMAL FLOW PATTERNS

3. HEPATIC VEINS

- The normal hepatic vein waveform is triphasic as a result of transmitted cardiac activity (waveform pattern similar to that of jugular vein).
- The majority of blood flow is antegrade (away from the liver and toward the heart), thus, it will also be away from the transducer and displayed below the baseline.
- The maximal retrograde hepatic venous flow - the *a wave* – corresponds to the auricular contraction.
- During ultrasound examinations the sonographer ask sometimes do the patient to do a forced inspiration – in this situation, with increased intrathoracic pressure, the *s* and *d-waves* become more proeminent, while the *a* and *v*-waves are less pronounced and may actually not manifest as reversed flow.

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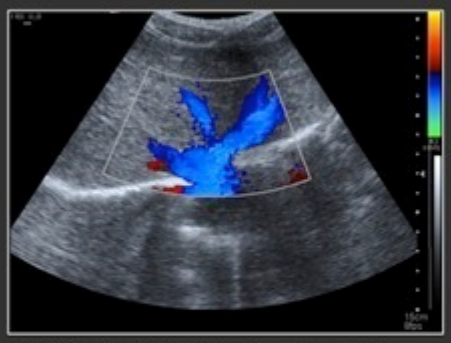
LIVER DOPPLER ULTRASOUND – Normal Findings



Color Doppler of the liver. Normal convergence of the hepatic veins

Spectral Doppler tracing of hepatic vein flow. Normal waveform of the hepatic vein with a triphasic profile ("W" appearance).

slide13.jpg

PORTAL HYPERTENSION

- Portal hypertension accompanies cirrhosis of the liver in over 90% of the cases.
- Cirrhosis disrupts the normal hepatic sinusoidal pattern, impairing venous drainage and leading to increase in portal vein pressure.
- Portal hypertension is the increased in porto-systemic pressure gradient in any portion of the portal venous system.

Porto-Systemic Pressure Gradient:

- This gradient is assessed by measuring the wedge hepatic venous pressure (a measure of sinusoidal hepatic pressure) and subtracting the free hepatic venous pressure (systemic pressure) thus obtaining the hepatic venous pressure gradient (HVPG).

- Normal: HVPG = 2-5mmHg.
- Sub-clinically Portal Hypertension: HVPG > 6mmHg

- Clinically significant Portal Hypertension: **HVPG > 10-12 mmHg** (predicts clinical course in patients with cirrhosis including development of varices, variceal hemorrhage and encephalopathy, decompensation or death after liver resection, and hepatocellular carcinoma).

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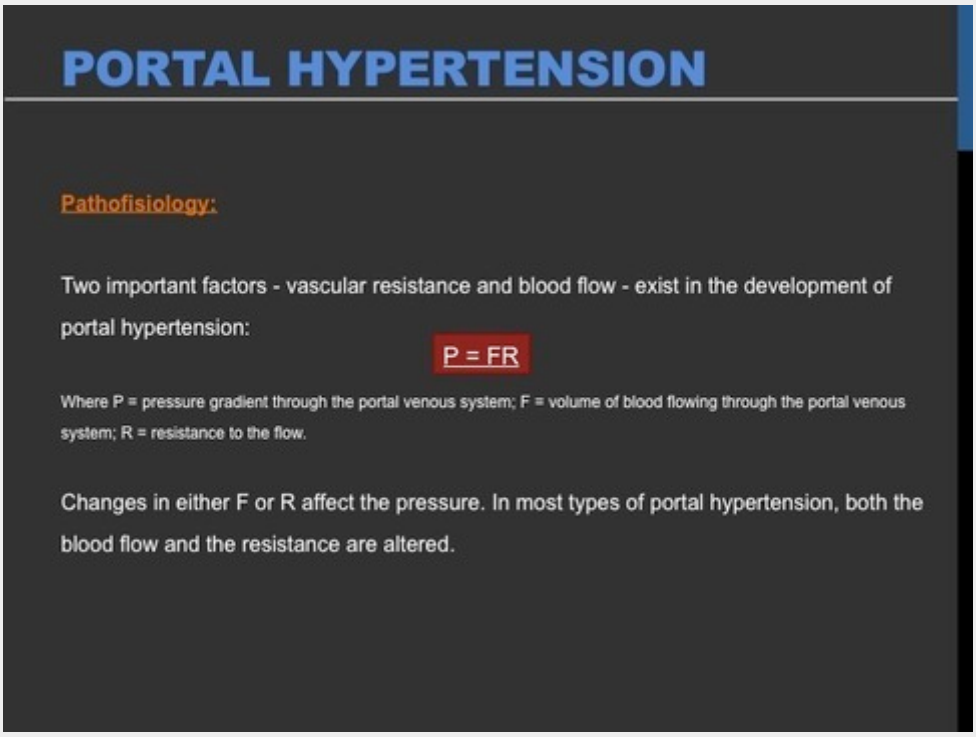

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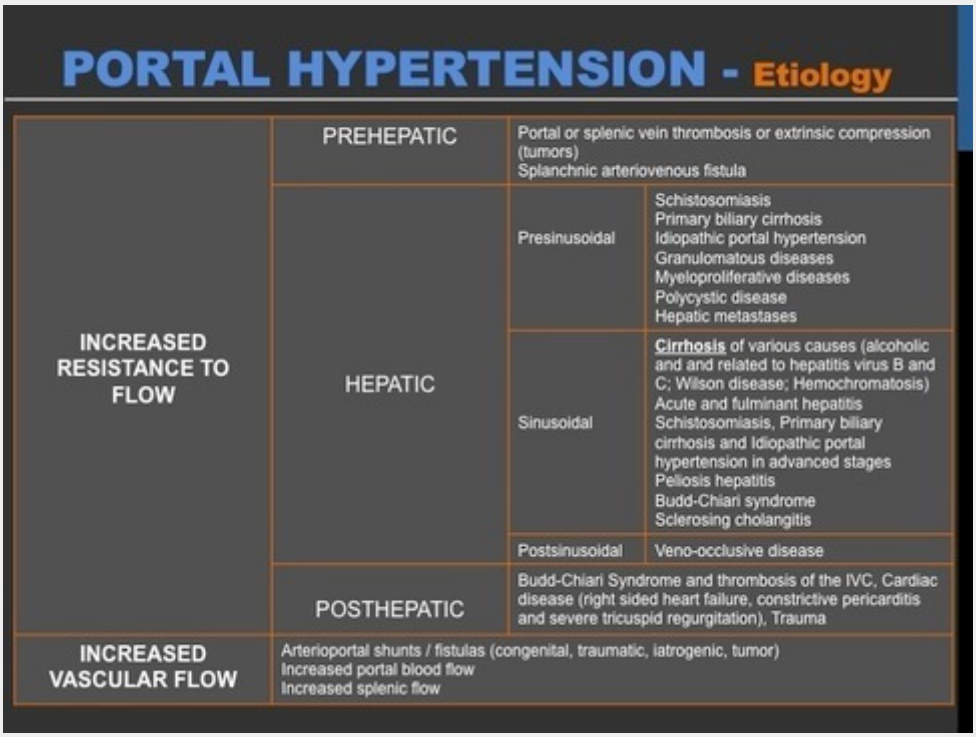

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Doppler Ultrasound – Cirrhosis and Portal Hypertension

In patients with cirrhosis and indication to TIPS the radiologist should evaluate the following parameters:

1. **Hepatic size and morphology:**

- In patients with advanced cirrhosis the liver is small with relative enlargement of caudate lobe and left lobe relatively to the right lobe (in early stages of cirrhosis the liver is enlarged or could appear absolutely normal).

US demonstrates a dysmorphic liver with coarse appearance and irregular borders.
This patient has cirrhosis and portal hypertension complicated with ascites.

2. **Liver echogenicity and texture:**

- Echogenicity could be increased in cirrhotic livers with fat infiltration.
- Irregular borders and nodular surface (in relation to the presence of regenerating nodules and fibrosis).
- Exclude the presence of definable nodules (dysplastic nodules – portal venous supply vs. HCC – arterial hepatic venous supply).
- Exclude the presence of multiple cysts (polycystic liver disease precludes the TIPS technique).

Cirrhotic liver. The hiperechoic nodule proved to be a small hepatocarcinoma.

slide17.jpg

Doppler Ultrasound – Cirrhosis and Portal Hypertension

In cirrhosis, most of the normal liver architecture is replaced by distorted vascular channels that provide increased resistance to portal venous blood flow and obstruction to hepatic venous outflow.

3. **Portal vein:**

- **Diameter:**

- Although the caliber of the portal vein initially may be increased (>13mm) in PH, with the development of porto-systemic shunts, the portal vein caliber will decreased.
- Evaluate the response to respiratory manoeuvers: if the diameter of portal vein does not increase at least 20% from quiet respiration to deep inspiration the patient has probably PH.

B mode US shows dilatation of the portal vein (A) and normal portal vein diameter (B) after the development of varices.

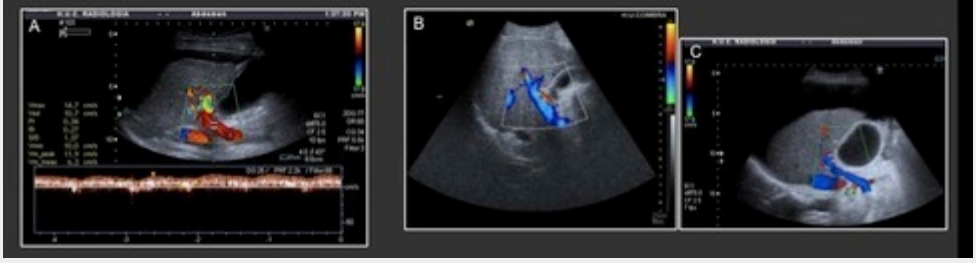
slide18.jpg

Doppler Ultrasound – Cirrhosis and Portal Hypertension

- **Permeability, flow direction and velocity:**

- In severe cirrhosis portal venous flow may become continuous (without undulating appearance) or pulsatile due to arteriovenous shunting;
- Portal flow velocity decreases (< 16cm/s) (A);
- Flow may become to and fro (bidireccional) or hepatofugal (retrograde) (B and C). As with slow flow, this finding is diagnostic for portal hypertension from whatever cause.
- A narrow portal vein and a prominent hepatic artery are commonly associated findings when flow is hepatofugal in the main portal vein.

However, we should always kept in mind that, the flow direction in the portal vein is a variable finding in PH and depends on the development of collaterals.



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Doppler Ultrasound – Cirrhosis and Portal Hypertension

- Absent (aphasic) portal venous flow may be due to stagnant flow (portal hypertension) or occlusive disease, usually caused by bland or malignant thrombosis.
- In the setting of subacute/chronic occlusive portal vein thrombosis could be development of collateral vessels in or around the occluded portal vein (*cavernous transformation of portal vein).*

(A). Absent flow in the portal vein (RPV) that is markedly dilated due to malignant portal vein thrombosis.
(B) Spectral Doppler of the "thrombus" show an arterial waveform in a hepatofugal direction.

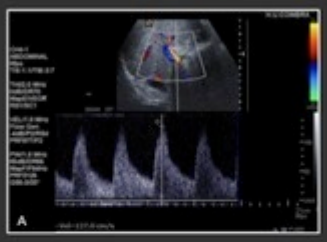
A normal portal vein could not be visualised. Instead there is a plexus of small vessels - anechoic serpiginous structures (arrow). After portal vein thrombosis this web of small vessels reconstitutes portal flow to the liver and is known as cavernomatous transformation of the portal vein.

slide20.jpg

Doppler Ultrasound – Cirrhosis and Portal Hypertension

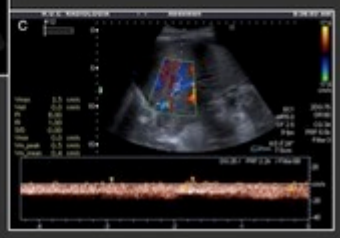
4. **Hepatic Artery:** (A)

- In patients with PH and decreased portal flow velocity, the hepatic artery appears enlarged with increased flow to compensate for the diminished portal vein flow.
- In patients with cirrhosis the resistive index in the hepatic artery is elevated (>0,7); with development of portal hypertension and arteriovenous/arterioportal shunts the RI decreases (<0,55).



5. **Hepatic Veins:**

- These veins became compressed and narrowed in cirrhotic patients (B).
- With PH they loss the classic pulsatility and turn into a biphasic or monophasic waveform (C).



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Doppler Ultrasound – Cirrhosis and Portal Hypertension

6. **Spleen**

- Access spleen greatest dimension – in the setting of PH there could be mild to moderate splenomegaly (>13cm).
- Reversed flow in the splenic vein (towards the spleen). Indirect sign of splenogastric or splenorenal collaterals, and thus PH.

7. **Presence / absence of ascites and volume quantification**

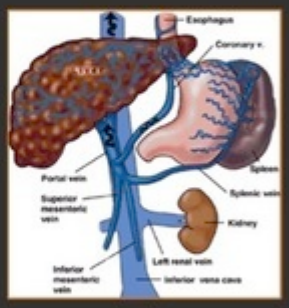
slide22.jpg

Doppler Ultrasound – Cirrhosis and Portal Hypertension

8. **Porto-systemic venous collaterals** – shunting of blood from the portal to the systemic circulation.

- **Short gastric varices:** courses between the spleen and the greater curvature of the stomach.
- **Left gastric varices (coronary varices):** curses from the splenic or portal veins to the lesser curvature of the stomach. Dilatation of the coronary vein (>7mm) is associated with severe PH (HVPG > 10mmHg).

These veins communicate with systemic esophageal veins and are known as gastroesophageal varices.



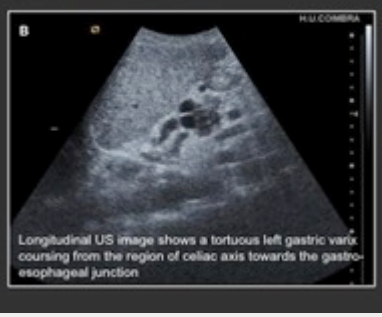
- **Paraumbilical veins:** originates from the left portal vein and runs inferiorly through the falciform ligament towards the anterior abdominal wall where it connects with the systemic epigastric veins or with the subcutaneous veins originating the *caput medusae*.
- **Splenorenal-mesenteric collaterals:** courses between the splenic hilum and the left renal vein.

slide23.jpg

Doppler Ultrasound – Cirrhosis and Portal Hypertension

US scan of the spleen. Tangle of vessels are seen at the upper pole of the spleen, corresponding to short gastric varices.

Color Doppler image shows a recanalized paraumbilical vein that carries blood towards the umbilicus.



Longitudinal US image shows a tortuous left gastric varix coursing from the region of celiac axis towards the gastro-esophageal junction

(D) US scan of the spleen revealed anechoic tubular structures adjacent to the lower pole of the spleen, communicating to the left renal vein (not shown).

(E) A large varix occupies the space between the splenic hilum (s) and the left kidney (k)

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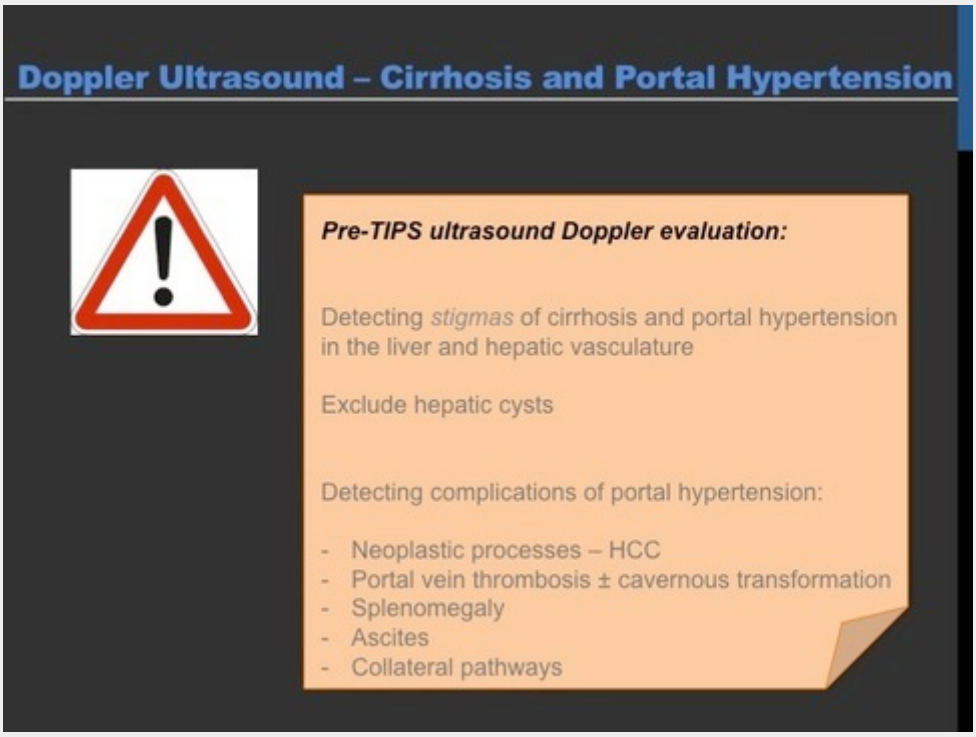

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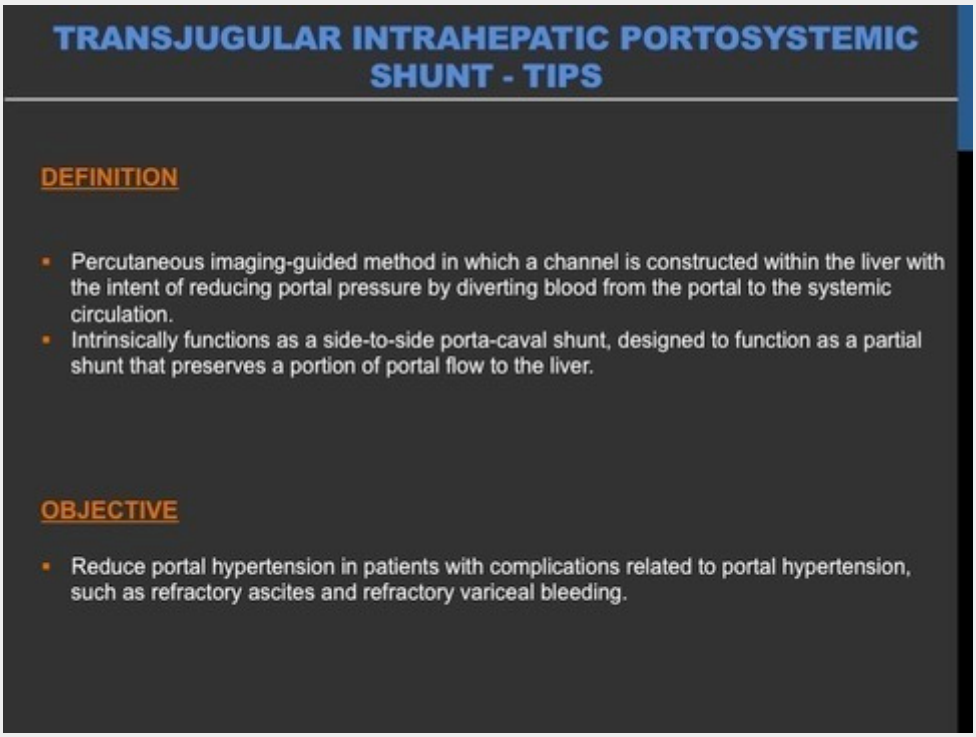

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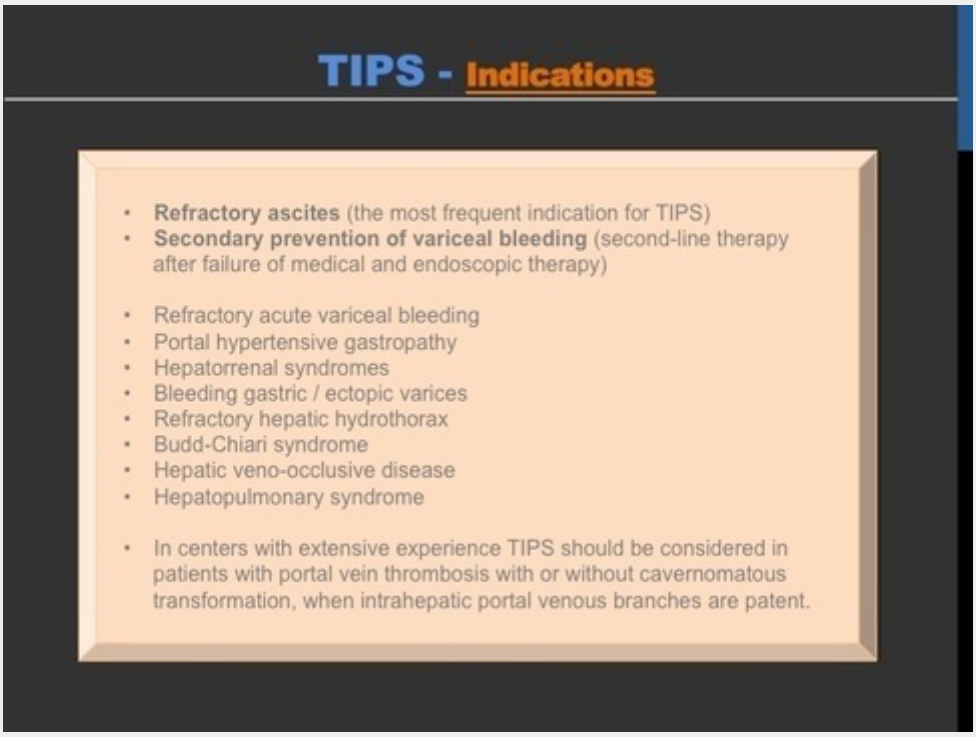

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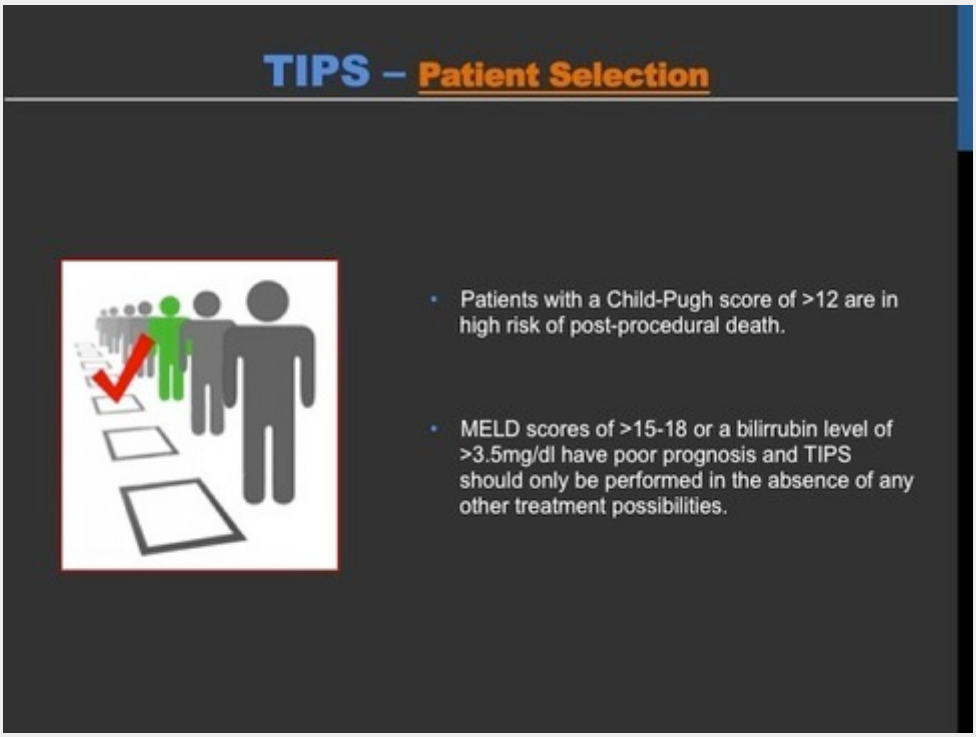

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TIPS – Contra-Indications

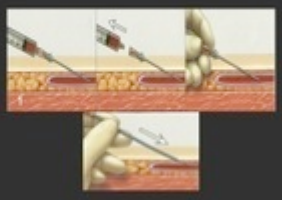
Absolute
- Unproved portal hypertension
- Primary prevention of variceal bleeding
- Congestive heart failure
- Polycystic liver disease
- Uncontrolled systemic infection or sepsis
- Unrelieved biliary obstruction
- Severe pulmonary hypertension
- Severe tricuspid regurgitation

Relative:
- Hepatocarcinoma large and central
- Hepatic venous obstruction
- Portal vein thrombosis
- Severe coagulopathy (INR>5)
- Thrombocytopenia (<20 000)
- Moderate pulmonary hypertension
- Hepatic encephalopathy poorly controled

slide29.jpg

TIPS – Technique

1. Jugular access (right internal jugular vein) – Seldinger technique



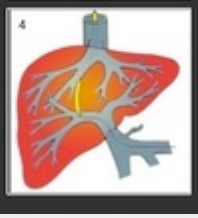
2. A catheter is placed and guided through the superior vena cava, right atrium and inferior vena cava into a hepatic vein. (Because of large size and consistent and predictable relation to the portal veins, the right hepatic vein is the preferred hepatic vein branch for the creation of a TIPS shunt).

3. Selective catheterization of a suitable branch of the RHV

(Pressure measurements are preformed at this point, including central venous pressures, at the level of right atrium and IVC and free and wedged hepatic venous pressures).

4. A needle inserted through the catheter is then used to puncture the liver from a central portion of the hepatic vein and enter the main portal branch (usually the right portal vein).

The puncture could be navigated with ultrasound.



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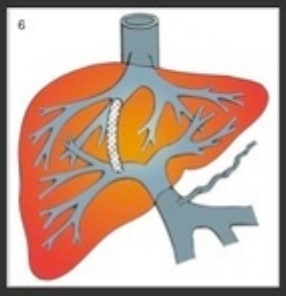
TIPS – Technique

5. Dilatation of the needle tract by a balloon catheter – establishing of a connection between the portal and systemic circulation directly inside the liver parenchyma.

6. Insertion of a TIPS stent graft



7. The final step of the TIPS procedure is placement of a pigtail catheter over the portal vein guide wire for follow up portography and pressure measurements.

slide31.jpg

TIPS – Technique

Suprahepatic flebography

Advance of needle into the portal vein

Transhepatic portogram shows colateral circulation – left gastric vein varices

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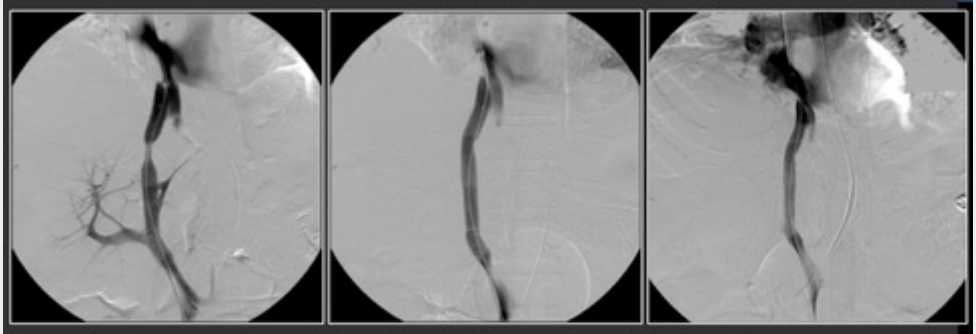
TIPS – Technique



Tract dilatation using a 10mm angioplasty balloon catheter. The narrowed part of the balloon is in the intraparenchymal part of the tract.

TIPS made with covered stent between portal and middle hepatic veins

Portal venogram obtained after TIPS insertion shows flow through covered stent. Peripheral portal vein branches are no longer opacified because of reversal of flow

slide33.jpg

TIPS – Complications

Complications	Frequency (%)
TIPS Dysfunction *1 - Occlusion / Stenosis - Thrombosis	 18-78 10-15
Encephalopathy - New/worse - Chronic	 10-44 5-20
Transcapsular puncture	33
Stent migration or non-optimal placement	10-20
Hemolysis	10-15
Sepsis	2-10
Hemobilia	<5
Intraperitoneal bleeding	1-2
Hepatic infarction	1
Fistulae and endotipsitis	rare

*1 When TIPS were created with bare metal stents, the loss of primary patency was around 50% at one year follow-up. In this era, with use of expanded polytetrafluoro-ethylene (ePTFE)– covered stent-graft, the patency has vastly improved and stenosis occurs in just 8-20% of TIPS.

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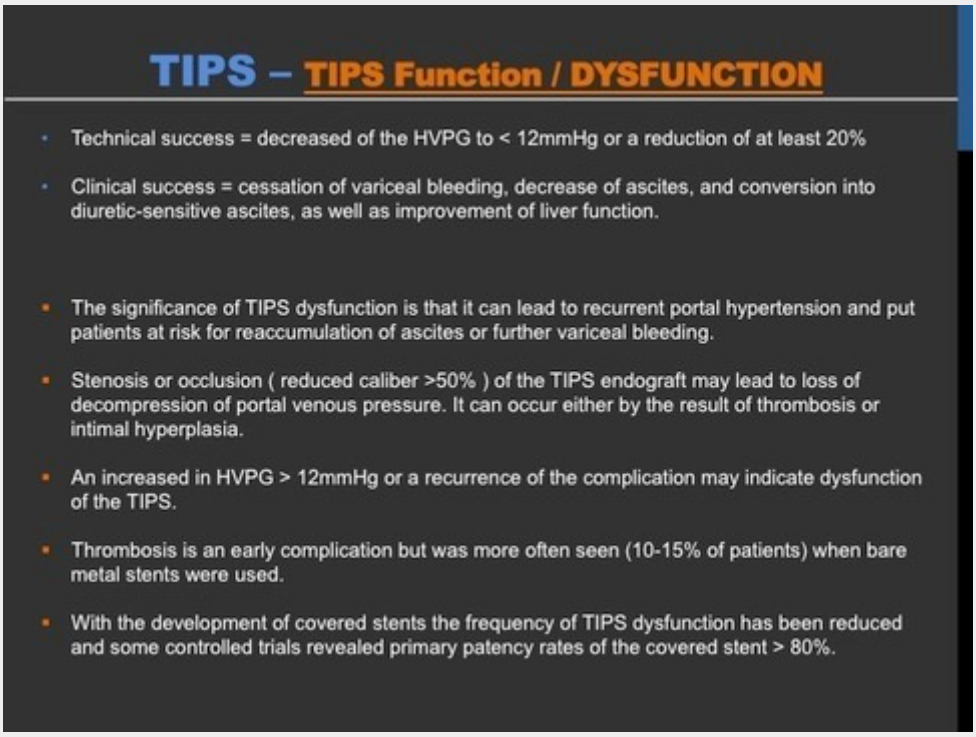

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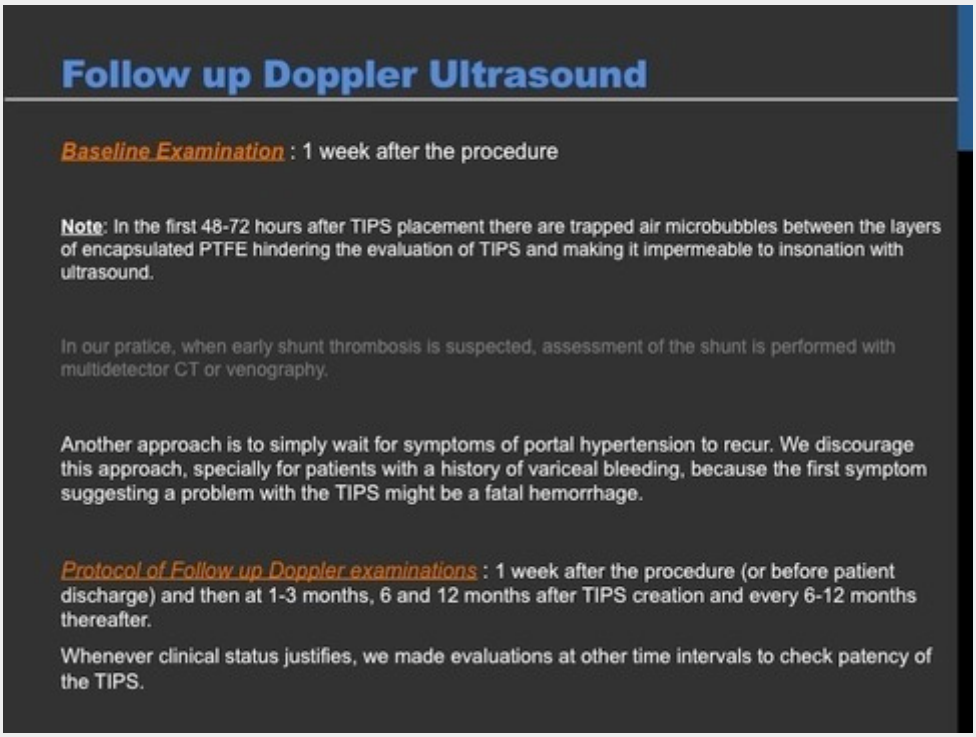


slide36.jpg

Follow up Doppler Ultrasound – What evaluate ?

- Despite reports of variable success rates, ultrasound has remained an integral part of TIPS surveillance because it is non-invasive, inexpensive, and widely available.

1. **Liver morphology and focal liver lesions**

2. **Vascular evaluation:**

- Assessment and study of the permeability and flow direction in:

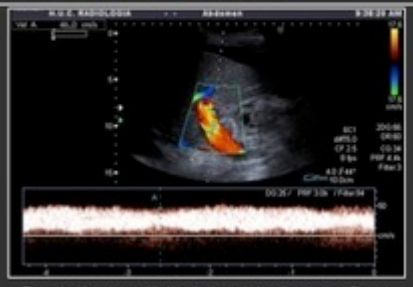
- *Portal vein and its branches*
- *Hepatic veins and* any hepatic vein segment between the cephalic portion of the TIPS and the IVC _The hepatic vein with the shunt, usually the right, is checked in both proximal to and just beyond its junction with the stent.
- Inferior vena cava
- Splenic vein

slide37.jpg

Follow up Doppler Ultrasound

Portal Vein

- Main portal vein velocity after TIPS is typically higher than its pre-TIPS value
- MPV velocity: > 30cm/s
- With shunt dysfunction, the flow in the portal vein leading up to the TIPS is diminished and the MPV velocity drops often below 30cm/s.



Doppler tracing obtained at portal vein shows flow direction towards the portal vein end of the TIPS (hepatopetal) and velocity of 46cm/s.

- Flow direction in the portal system is towards the portal vein end of the stent:
- MPV and splenic vein = hepatopetal flow
- Right and left portal veins = hepatofugal flow (towards the inflow of the shunt). If the patient has patent paraumbilical vein collaterals, the flow within the left portal vein will continued to be hepatopetal.

Left portal vein with hepatofugal flow - flowing out of the diseased liver and towards the inflow of the shunt

slide38.jpg

Follow up Doppler Ultrasound

3. **Evaluation of TIPS**

- Position of the stent: the cephalic end of the shunt is most commonly located immediate to the connection of the right hepatic vein with the IVC, and the caudal end is located in the right portal vein.
- Lumen of TIPS : anechoic lumen without wall thickening

Two cases of baseline examination following TIPS placement. Grey-scale image of the right lobe of the liver. The TIPS is seen coursing from the porta hepatis region to the junction of the right hepatic vein with inferior vena cava. The mesh like appearance of the shunt is due to the echo reflection of the individual wire elements of the stent

slide39.jpg

Follow up Doppler Ultrasound

- Check permeability and flow direction : the lumen should be completely filled by the turbulent, periodic flow and the direction of flow should be from the portal vein to the hepatic vein.

Color Doppler image of the TIPS. The entire lumen is saturated with color indicating patency. Note the non-uniforming of color encoding.

slide40.jpg

Follow up Doppler Ultrasound

- Measure the flow velocity, with angle correction, in proximal, middle and distal portion of the TIPS.
- Thresholds velocities that are too high (> 200-250 cm/s – jet-effect zone beyond the stenosis) or too low (< 50 cm/s) are associated with high specificity and sensitivity for shunt dysfunction.
- **Normal flow velocity**: 90-190 cm/s
- Changes in the peak flow velocity ± 50cm/s within TIPS, in relation with the baseline examination also suggests TIPS dysfunction and should also prompt shunt venography and portosystemic pressure measurements.
- Velocities can also be variable through the shunt itself in a normal situation – usually velocities increased from the portal venous end to the hepatic venous end of the shunt.
- The flow is also more turbulent when multiple stents components are used and when overrinding stents cause a relative narrowing of the shunt lumen.

Spectral Doppler of the TIPS show an appropriately functioning TIPS.

slide41.jpg

Follow up Doppler Ultrasound – *Signs of TIPS Dysfunction*

- Shunt malfunction is the result of narrowing or occlusion caused by intimal hyperplasia or in situ thrombosis.
- Can occur anywhere within the stent but is most commonly in the cephalic portion of the TIPS or in the hepatic vein between the stent and the IVC.

Occlusion

- Absent flow at color Doppler US (you can use *Power Doppler* and low filters to identify low flow conditions and differentiate them from true occlusion).
- Aphasic spectral waveform.
- When flow velocity and direction in the portal veins is the same as it was prior to TIPS placement.

slide42.jpg

Follow up Doppler Ultrasound – *Signs of TIPS Dysfunction*

Stenosis

- Continuous waveform of the flow within the stent
- Abnormally high (>190 cm/sec) or abnormally low (<90 cm/sec) velocity within the shunt.
- Abnormal change in velocity (increase or decrease >50 cm/sec) compared with the prior examination.

Abnormally low velocity within distal end of the TIPS

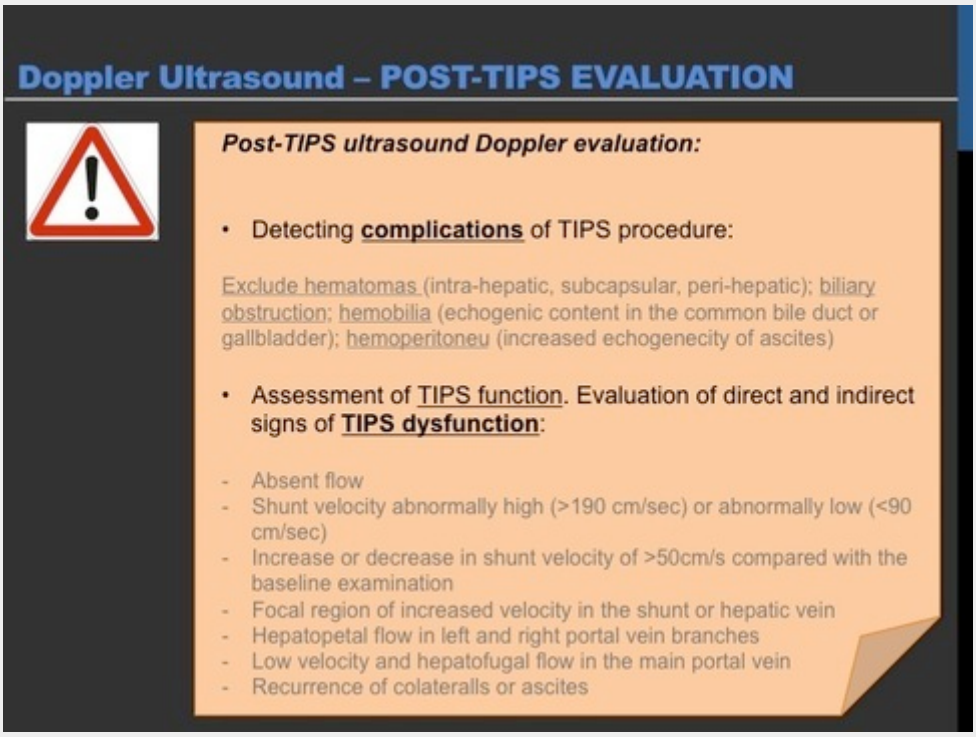
slide43.jpg

Follow up Doppler Ultrasound – *Signs of TIPS Dysfunction*

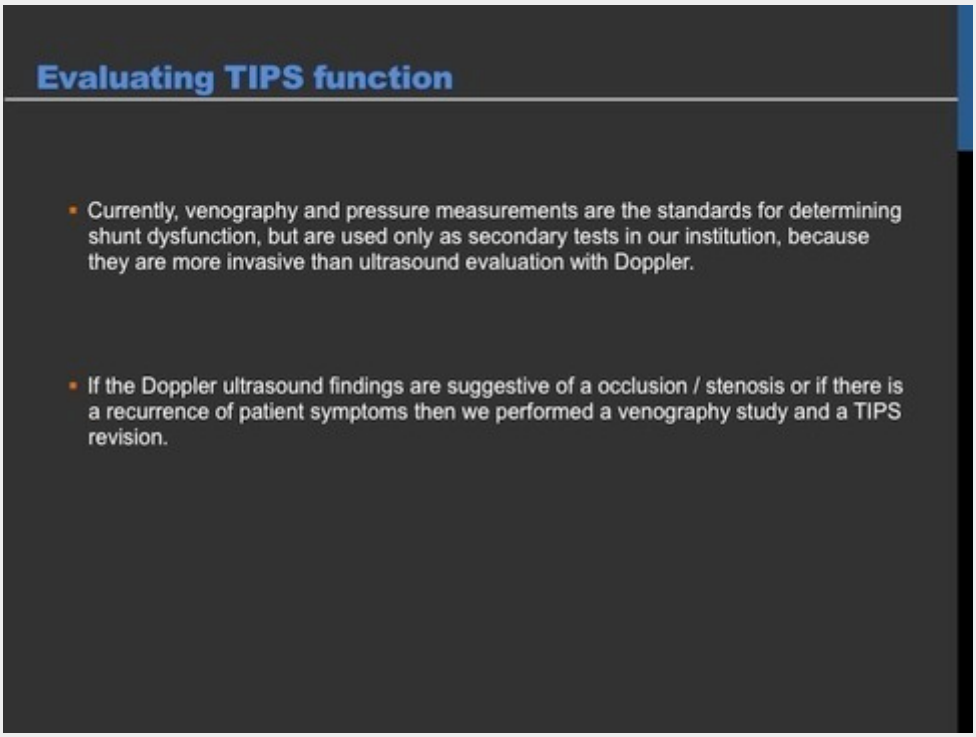
- Intrahepatic portal venous flow (right and left portal veins) that was hepatofugal on the prior examination and has changed to hepatopetal flow (in the absence of a recanalized paraumbilical vein).
- Hepatofugal or to-and-fro flow in the main portal vein and/or splenic vein.
- Low velocity (<30 cm/sec) in the main portal vein.
- Development or recurrence of collateral vessels such as a recanalized umbilical vein.
- New, recurrent or worsening ascites.

Indirect signs of TIPS dysfunction – hepatofugal flow in the main portal vein and low velocity

slide44.jpg



slide45.jpg



slide46.jpg

CONCLUSION

- TIPS is a technique developed to treat complications of portal hypertension.
- Doppler ultrasound evaluation is an invaluable non-invasive technique that permits an early diagnosis of shunt dysfunction.

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slide48.jpg


This work comes from:
Corresponding author: Luísa Andrade (lsa.c.andrade@hotmail.com)
HUC
Clínica Universitária de Radiologia
Centro Hospitalar e Universitário de Coimbra
Portugal
FACULDADE DE MEDICINA
UNIVERSIDADE DE COIMBRA
U
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