Ultrasound – Liver Transplant Protocol

PURPOSE:
To evaluate the liver following liver transplantation; to interrogate the bile ducts; to screen for hepatocellular carcinoma; to evaluate for findings of portal hypertension; and to assess the hepatic vasculature.

SCOPE:
Applies to all ultrasound abdominal studies performed in Imaging Services / Radiology

ORDERABLE:
- US Liver Transplant with Doppler

CHARGEABLES:
- US Abdomen Limited (CPT 76705)
- US Abdominal Doppler Complete (CPT 93975)

INDICATIONS:
- History of liver transplant; allograft dysfunction;
- Immediate post-operative evaluation to establish baseline;
- Suspicion for portal or hepatic vein thrombosis; Budd-Chiari Syndrome;
- Known or suspected hepatic artery stenosis; follow up to angioplasty and/or stent;
- Signs or symptoms of liver dysfunction including elevated liver function tests (LTFs);
- Jaundice, elevated bilirubin, or other signs of biliary obstruction;
- Suspicion for recurrent liver disease such as viral hepatitis (HBC; HCV; HIV), alcohol abuse, or fatty liver disease;
- Findings of portal hypertension such as ascites, splenomegaly, varices;
- Provided history of or screening for cirrhosis or hepatocellular carcinoma (HCC);
- Evaluation for possible fluid collection; pain, fever, sepsis or other clinical issue in a liver transplant patient;
- Abnormal findings on other imaging studies suggesting recurrent chronic liver disease/cirrhosis;

CONTRAINDICATIONS:
- No absolute contraindications

EQUIPMENT:
- Curvilinear transducer, frequency range of approximately 1-9 MHz that allows for appropriate penetration and resolution depending on patient's body habitus.
- Linear array transducer, frequency range of 7-18 MHz, to evaluate the hepatic capsule.

PATIENT PREPARATION:
- Patient should be NPO for 4-6 hours prior to study.

EXAMINATION:

GENERAL GUIDELINES:

A successful examination includes the evaluation of:
- Liver, including parenchymal architecture and capsular contour; screening for focal lesions;

- Bile ducts;
- Abdominal cavity for ascites; fluid collections around liver transplant and in abdominal wall;
- Spleen size;
- Evaluation of the upper abdominal vasculature including hepatic arteries, portal veins, splenic vein, superior mesenteric vein, hepatic veins, inferior vena cava (IVC), and abdominal aorta.

EXAM INITIATION:

- Introduce yourself to the patient
- Verify patient identity using patient name and DOB
- Explain test
- Obtain patient history including symptoms. Enter and store data page
- Place patient in supine or left lateral decubitus (LLD) position with arm above head.

TECHNICAL CONSIDERATIONS:

- Review any prior imaging, making note of associated abnormalities requiring evaluation.
- Review surgical history and note surgical anatomy and reconstruction technique.
- Deep inspiration facilitates imaging of the liver dome and right hepatic lobe in the supine position via subcostal approach.
- In LLD position, the liver shift towards the midline, improving accessibility for scanning and facilitating intercostal scanning for the posterior liver.
- Liberal use of cine sweeps allows for better evaluation of focal or indeterminate findings.
- Assess the perihepatic area for fluid collections; if a fluid collection is visualized document and measure; evaluate with and without color
- Doppler:
    - Optimize color Doppler setting to show optimal flow
        - Adjust scale and gain to maximally fill the vessel of interest without artifact
            - Light color in the middle of the vessel lumen
        - Use Power Doppler if suspect absent flow with color Doppler
    - Optimize spectral Doppler
        - Place time-gate centrally within the vessel of interest
        - Adjust scale to extend spectral waveform (amplitude adequate for interpretation)
        - Reduce aliasing for high flow evaluation
        - Decrease scale and wall filter for low-flow vessels
        - Increase or decrease spectral Doppler gain as needed for optimal viewing of the waveform
    - As much as possible, utilize angle correction of $\leq 60^{o}$ to measure velocities
        - Angle correction should always be parallel to the vessel wall
        - For certain anatomy, may need to try from different approaches to optimize angle
    - Evaluate proper, right and left hepatic arteries using angle correction. If anastomosis is seen (by focal turbulence; focal narrowing), measure velocities proximal to (within common hepatic artery), at, and distal to (PHA) the anastomosis.
    - Evaluate hepatic vein phasicity during suspended respiration or shallow breathing
        - Deep inspiration may dampen hepatic venous flow
    - If a TIPS is present, survey the entire TIPS – see *US Liver TIPS* protocol

- **Liver**
  - Liver should be evaluated for focal and/or diffuse abnormalities. Liver echogenicity should be compared with that of the right kidney and pancreas.
  - Cine sweeps, including as much hepatic parenchyma as possible, should be acquired in the transverse orientation for both lobes from dome to inferior most margin. Longitudinal sweeps of the left lobe (from lateral tip to midline/IVC) and right lobe (from the IVC to the lateral border) should be obtained in both the supine and LLD positions.
  - In the absence of ascites, nodular liver surface contour is best seen with a linear array transducer.
  - Evaluate the parenchyma adjacent to the gallbladder fossa, fissure for the falciform ligament, and portal bifurcation for areas of focal fatty sparing.
  - Evaluate subphrenic, subhepatic, and peri-caval regions for post-operative fluid collections. Abdominal wall along the surgical incision can also be included if infection is clinically suspected.
- **Bile Ducts**
  - Intra/extrahepatic bile ducts should be evaluated for dilatation, wall thickening, and intraluminal findings.
    - Color Doppler may be used to differentiate hepatic arteries and portal veins from dilated intrahepatic bile ducts
  - Two types of biliary anastomoses are possible: duct-to-duct (choledochocholedochostomy), and duct-to-bowel (choledochojejunostomy). For duct-to-bowel anastomosis, the extra-hepatic bile duct may be difficult to visualize. If seen, common duct should be imaged longitudinally, adjacent to the main portal vein, distinguished from the hepatic artery by color Doppler.
  - The duct should be measured from inner wall to inner wall at the porta hepatis near the crossing of the right hepatic artery. Remainder of the common duct should be evaluated as far distally as possible.
- **Spleen Size**
  - Deep inspiration facilitates imaging of the spleen.
  - Longitudinal spleen measurement: taken from inferior most tip to highest point along diaphragm, *crossing through the splenic hilum.*
  - Transverse measurements: *oriented 90 degrees* relative to longitudinal measurement, calipers placed at greatest thickness and width at the same level.
  - Evaluate for splenic vein varices with color Doppler evaluation of splenic hilum.
- **Collections and Ascites**
  - Assess the perihepatic area for fluid collections; if a fluid collection is visualized document and measure; evaluate with and without color
  - Evaluate RUQ with attention to fluid peripheral to the liver and in the subhepatic space
  - Evaluate LUQ with attention to fluid peripheral to the spleen
  - Evaluate RLQ and LLQ for fluid in the paracolic gutters
  - Evaluate midline pelvis for pelvic free fluid
  - Document the extent and location of any fluid identified
  - Provide stationary cine images to show mobility of debris, if present

DOCUMENTATION:

- **Liver**

- Liver Capsule *not needed for post-op transplant
  - With a linear 9, 12, or 18MHz transducer, include high-resolution images of hepatic capsule and underlying parenchyma for nodularity.
  - Obtain both representative images from both left lobe and right lobe (if visualized well), still images (TRV and LONG)
  - CINE CLIP in LONG during breathing cycle (inhalation and exhalation), with probe stationary, from both left lobe and right lobe (if visualized well).
- Longitudinal images (minimum):
  - LEFT LOBE
    - Left lobe left of midline
    - Left lobe at midline. Include proximal abdominal aorta, celiac artery, and SMA.
    - Left lobe with IVC. Include caudate lobe, MPV, and pancreatic head.
    - Left lobe with left portal vein
    - CINE LOOP: from lateral tip to IVC/right of midline
  - RIGHT LOBE
    - Right lobe near midline
    - Right lobe with right kidney Right lobe including right hemi-diaphragm and pleural space
    - Right lobe far lateral
    - CINE LOOP: from midline to lateral most margin, using multiple acoustic windows if necessary.
- Transverse images (minimum):
  - Dome with hepatic veins. Include entire right and left lobe (on separate images as needed)
  - LEFT LOBE
    - Left lobe dome
    - Left lobe with left portal vein
    - Left lobe inferior tip
    - CINE CLIP: from dome to inferior most margin
  - RIGHT LOBE
    - Right lobe dome
    - Right lobe with right portal vein
    - Right lobe with main portal vein
    - Right lobe mid lobe
    - Right lobe with right kidney
    - Right lobe near liver tip
    - CINE CLIP: from dome to inferior most margin, using multiple acoustic windows if necessary
- REPEAT IMAGES IN LLD
  - Repeat TRV images of hepatic dome
  - Repeat Long images of right lateral margin of right lobe
  - Repeat any images of areas not seen well supine
  - Repeat Long and Trans Rt Liver cines in LLD

- **Bile Ducts**
  - Common duct with largest diameter measurement at porta hepatis.
- **Spleen**

- Color Doppler evaluation at splenic hilum to document varices.
- Longitudinal spleen measurement, from inferior most tip to highest point along diaphragm (**+ calipers**), *crossing through the splenic hilum (arrow).*
- Transverse measurements: *oriented 90 degrees* relative to longitudinal measurement at the hilum/hilar vessels, calipers placed at greatest thickness (+[1] **calipers** ~~X~~). Width (+[2] **calipers** ~~+~~) measured transverse to longitudinal measurements at same position.
- ***See appendix for images on accurate spleen measurements***
  - Splenic Volume

- **Ascites:**
  - Transverse images:
    - RLQ; LLQ; Midline pelvis
  - Stationary cine images of mobile debris, if present
- **Other:**
  - In the post-operative period, make note of any subphrenic, subhepatic, or abdominal wall fluid collections. Obtain representative grayscale images, without and with color, in TRV and LONG, and obtain measurements in two planes.

- **Doppler**

Anatomy	Grey Scale	Color Doppler	Waveform	*PSV	RI	++SAT
Hepatic artery: proper	x	x	x	x	+x	+x
Hepatic artery: anastomosis%	x	x	x	x		
Hepatic artery: common%	x	x	x	x		
Hepatic artery: right	x	x	x		x	x
Hepatic artery: left	x	x	x		x	x
Splenic vein: hilum	x	x	x			
Splenic vein: pancreatic tail	x	x	x			
Splenic vein: confluence	x	x	x			
^^Superior mesenteric vein	x	x	x			
Portal vein: main	x	x	x	+x		
Portal vein: right	x	x	x	x		
Portal vein: left	x	x	x	x		
Hepatic vein: right	x	x	x			
Hepatic vein: middle	x	x	x			
Hepatic vein: left	x	x	x			
&IVC	x	x	x			
^TIPS: portal vein end	x	x	x	x		
^TIPS: middle	x	x	x	x		
^TIPS: hepatic vein/IVC end	x	x	x	x		
Data page with measurements						

* If there is no phasic waveform, then measure peak velocity

+ Relevant anastomosis for each vessel should be specifically interrogated, if evident sonographically. Obtain measurements prior to, at, and distal to each evident anastomosis.

++ Acceleration Time should be calculated from the last end-diastolic up to the first peak in the proceeding waveform/cycle.

% If arterial anastomosis is identified, then spectral evaluation prior/proximal to (common hepatic artery), at, and after/distal to (proper hepatic artery) the anastomosis are required. Otherwise, PHA only.

& In the case of a piggyback hepatic venous anastomosis, both the recipient IVC and the piggybacked hepatic vein confluence/donor IVC segment should be interrogated.

^ If present or if visible (review *US Liver TIPS* Protocol)

^^ If thrombus is seen or suspected, otherwise, not routinely required

- **Data Page(s)**

PROCESSING:

- Review examination images and data
- Export all images to PACS
- Confirm data transferred to Imorgon, and complete Imorgon worksheet (UTSW only) Document relevant history and any study limitation

REFERENCES:

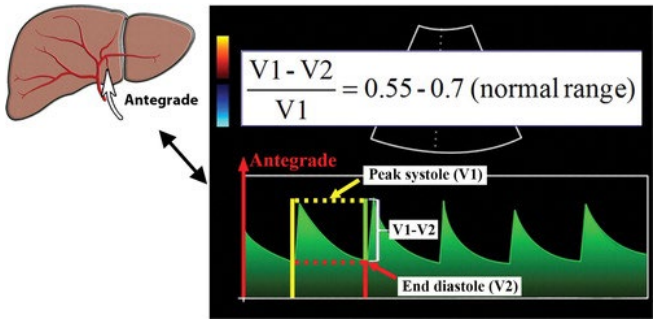
- ACR-AIUM-SRU Practice Guideline (Revised 2020)
- IAC Guidelines (Updated 2018)
- Radiology (2011) 260(3): 884-891
- Radiographics (2011) 31(1): 161-189

APPENDIX:

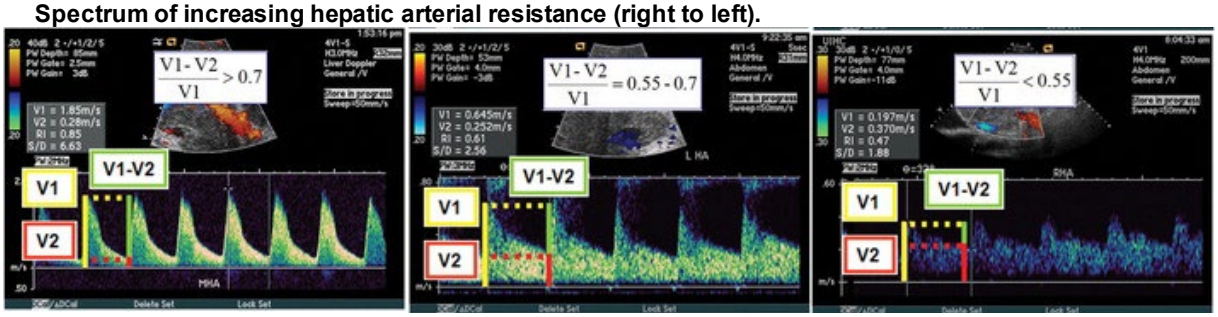
Transplant liver

- Relevant anastomosis for each vessel should be specifically interrogated, if evident sonographically
- Determine if the patient underwent a caval interposition technique, in which case both proximal and distal anastomoses should be interrogated, or a piggy back, in which case there will be a blind-ending oversewn end of the donor vena cava—thrombus may form in this structure. A velocity gradient $\geq$ 3 and turbulent flow may indicate a significant stenosis.
- The portal vein anastomosis can frequently be identified as an area of subtle narrowing. A velocity gradient $\geq$ 3 and turbulent flow may indicate a significant stenosis.
- Hepatic artery:
  - RI 0.55-0.70 normal range; abnormal elevation $\geq$ 0.80
  - In the immediate post-transplant period, transient elevation in RIs is not unexpected and should resolve over the subsequent 48-72 hours.
  - Tardus parvus waveform:
    - SAT >0.07 msec AND PSV >48 cm/sec (69% sensitive, 99.1% specific)
    - Absence of tardus parvus waveform has a high NPV for stricture, dissection, or thrombosis

Normal Arterial Waveforms:



Spectrum of increasing hepatic arterial resistance (right to left).



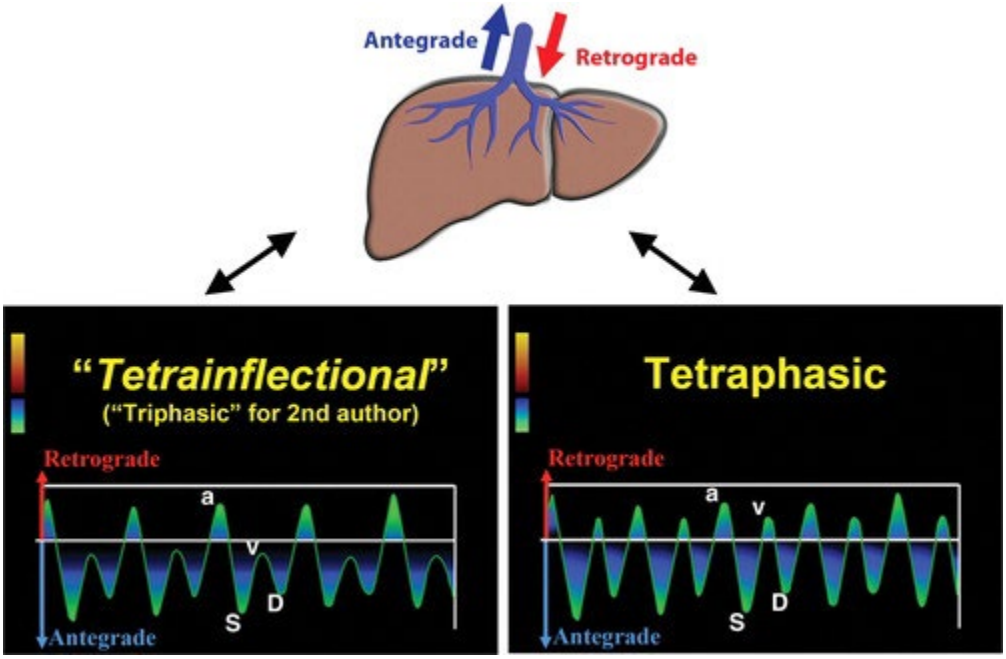
Causes of Elevated Hepatic Arterial Resistance (RI > 0.7)

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

Causes of Decreased Hepatic Arterial Resistance (RI < 0.55)

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

Normal Hepatic Waveforms:



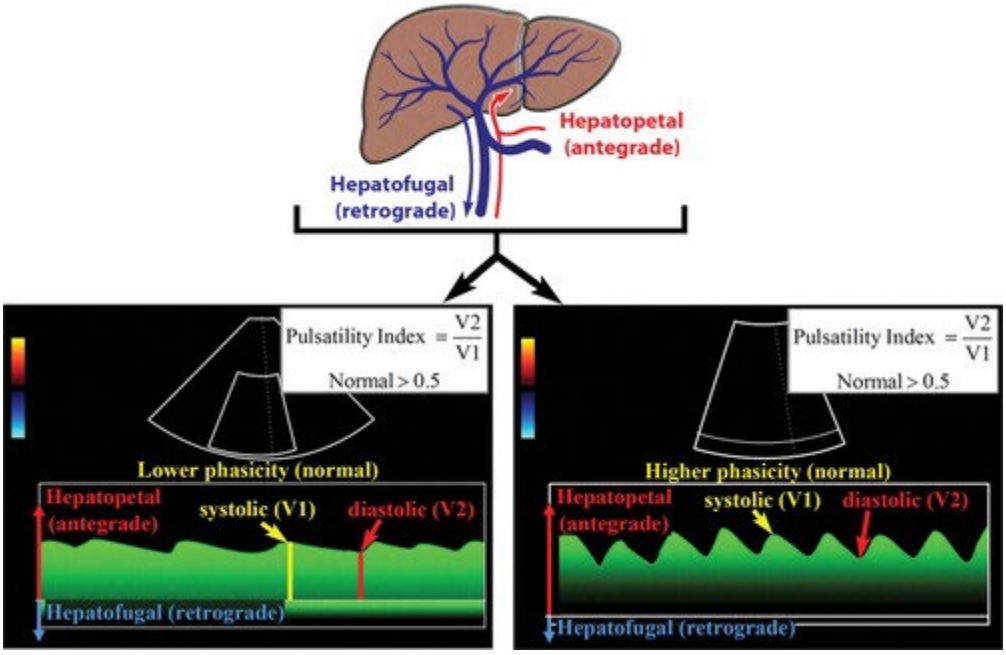
Causes of Pulsatile Hepatic Venous Waveform

Tricuspid regurgitation
Decreased or reversed *S* wave
Tall *a* and *v* waves
Right-sided CHF
Maintained *S* wave/*D* wave relationship
Tall *a* and *v* waves

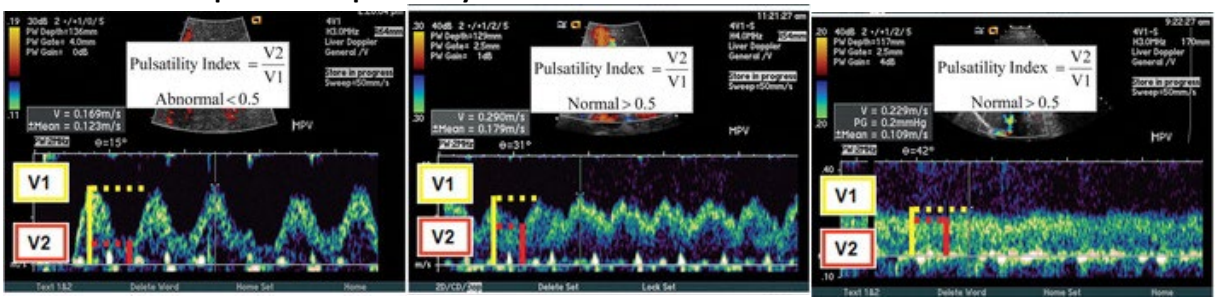
Causes of Decreased Hepatic Venous Phasicity

Cirrhosis
Hepatic vein thrombosis (Budd-Chiari syndrome)
Hepatic veno-occlusive disease
Hepatic venous outflow obstruction from any cause

Normal Portal Veins:



Assessment of portal vein pulsatility



Causes of Pulsatile Portal Waveform

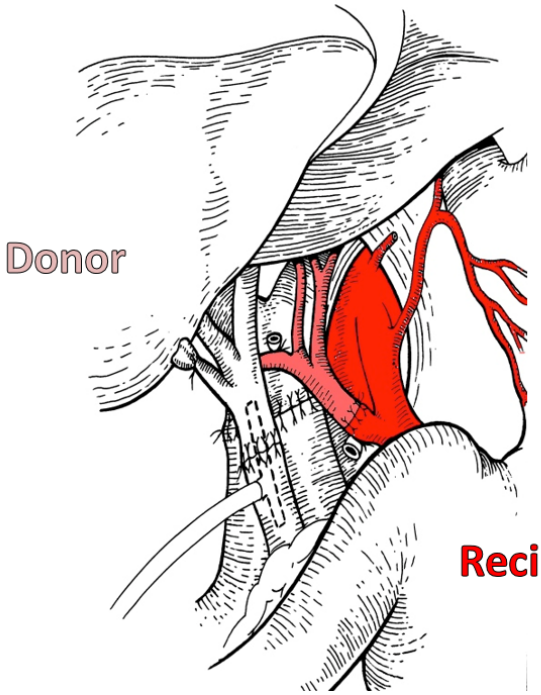
Tricuspid regurgitation
Right-sided CHF
Cirrhosis with vascular arterioportal shunting
Hereditary hemorrhagic telangiectasia–arteriovenous fistulas

Findings of Portal Hypertension

Low portal venous velocity (<16 cm/sec)
Hepatofugal portal venous flow
Portosystemic shunts (including a recanalized umbilical vein)
Dilated portal vein

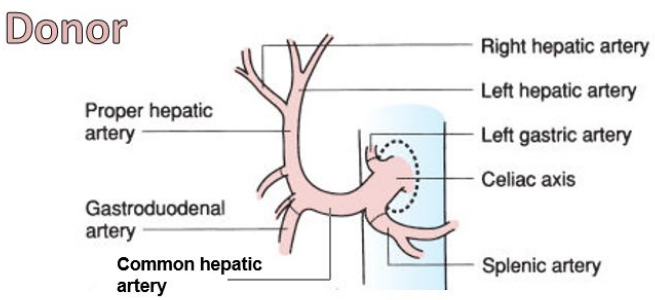
Typical Liver Transplant Anastomoses:

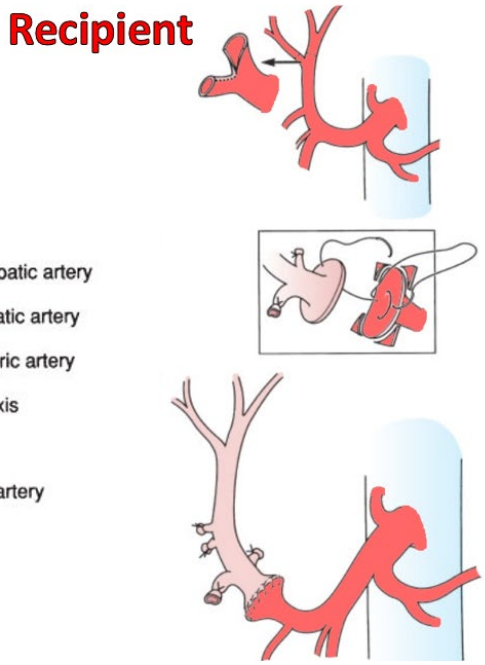
Normal Arterial Anatomy



- Arterial Anastomoses
  - Usually **end-to-end**
  - Several variants possible, depending on number of donor vessels
    - Replaced right
    - Replaced left
    - etc

- Arterial Anastomoses
  - **Carrel Patch**

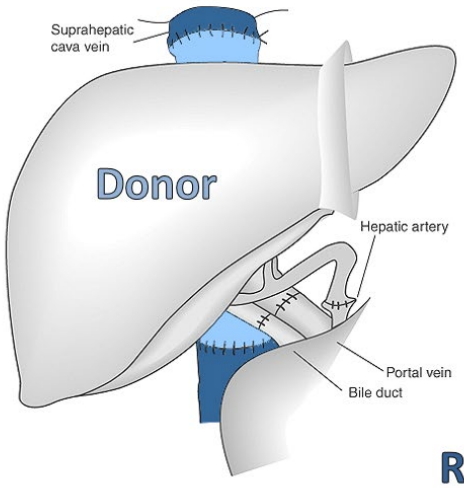




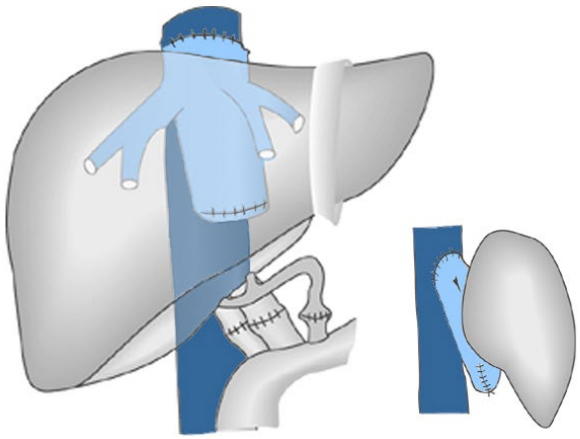
Normal Venous Anatomy

- Venous/Caval Anastomosis

End-to-end Interposition

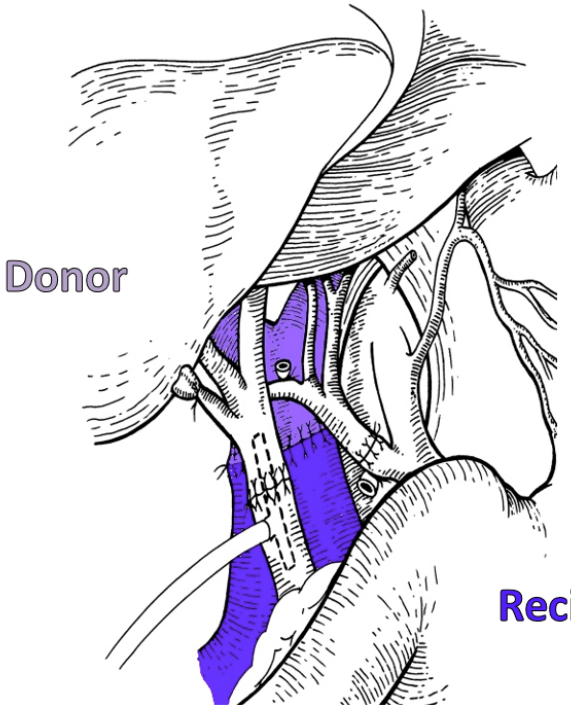


End-to-side Piggyback



Recipient

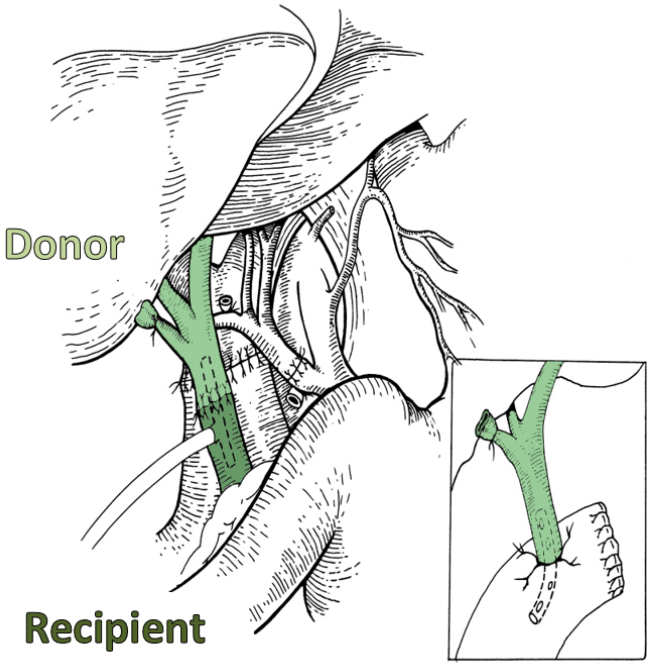
Normal Portal Anatomy



- Portal venous anastomosis
  - **End-to-end**
  - **Jump graft in setting of chronic PV thrombosis/occlusion**

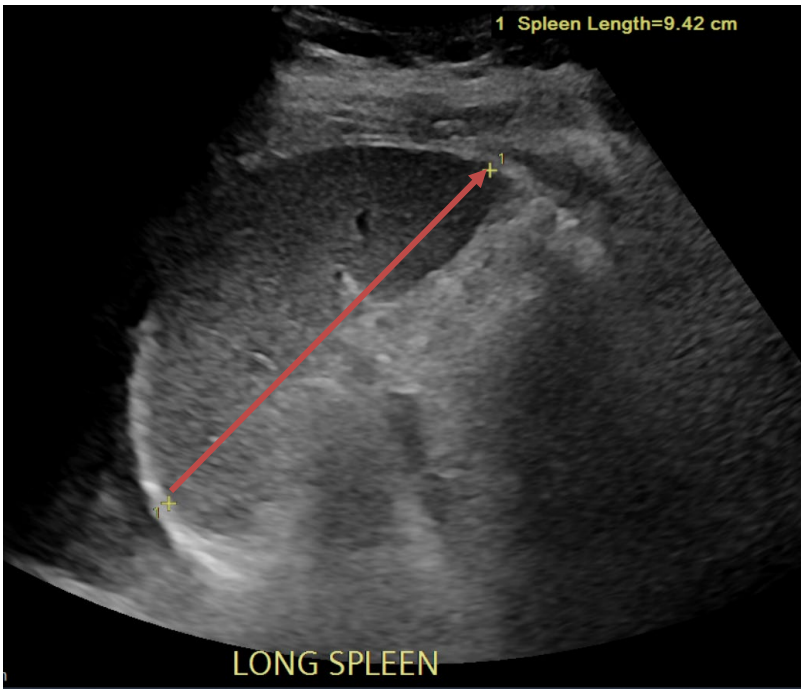
Recipient

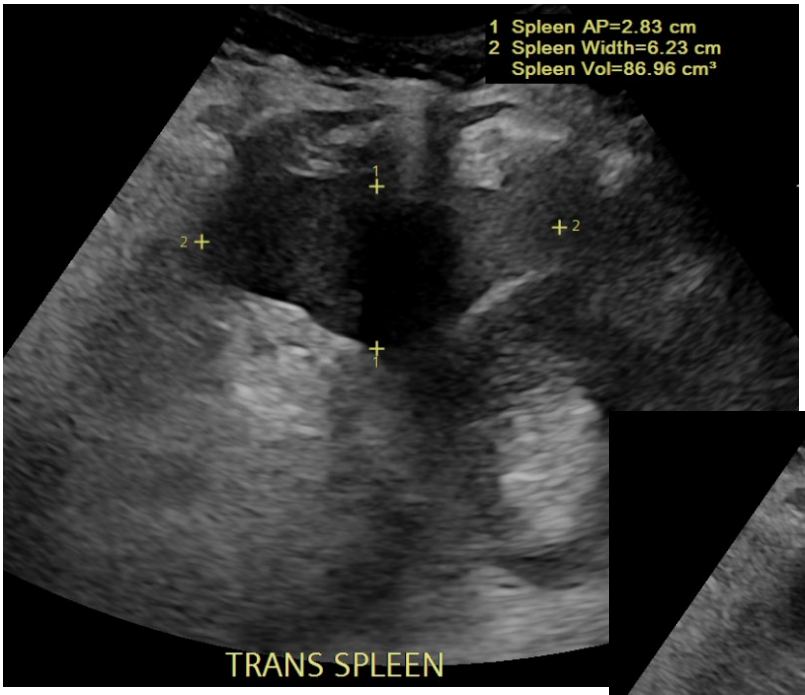
Normal Biliary Anatomy

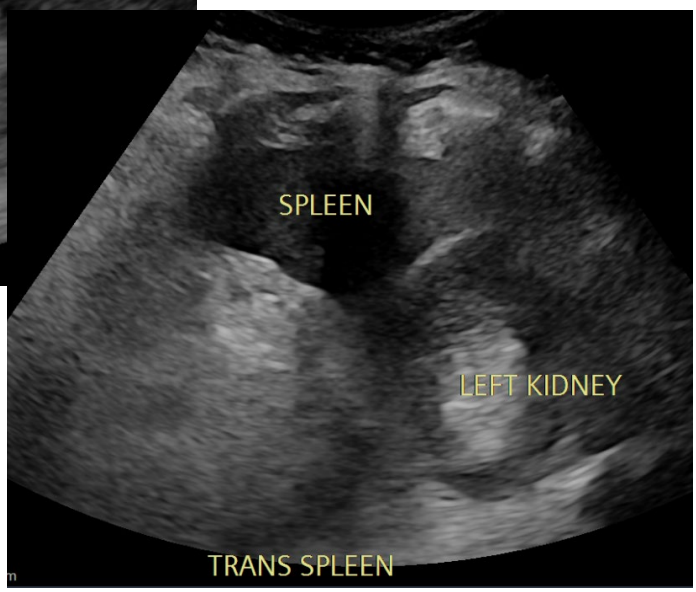


Biliary Anastomosis

- **Duct-to-Duct** (70%)
  - End-to-end choledochocholedochostomy
- **End-to-Bowel** (30%)
  - End-to-side choledochojejunostomy
    - Size discrepancy
    - Repeat transplants
    - Diseased native ducts
    - PSC


1 Spleen Length=9.42 cm
LONG SPLEEN


1 Spleen AP=2.83 cm
2 Spleen Width=6.23 cm
Spleen Vol=86.96 cm³
TRANS SPLEEN


SPLEEN
LEFT KIDNEY
TRANS SPLEEN

REVISION HISTORY:

SUBMITTED BY:	David T. Fetzer, MD	**Title**	Medical Director
APPROVED BY:	David T. Fetzer, MD	**Title**	Medical Director
APPROVAL DATE:	04-10-2018		
REVIEW DATE(S):	10-03-2018		Julie Champine, MD
REVISION DATE(S):	12-11-2019	**Brief Summary**	Routine formatting updates
REVISION DATE(S):	02-23-2020	**Brief Summary**	Clarifications regarding cine sweeps needed through liver. Removed liver length measurement
	05-31-2020		Updates based on AIUM Practice Parameter
	11-25-2024	**Jana Smith, RDMS, RVT**	Added to technical considerations and rearranged documentation requirements. Removed RI and SAT requirements for right and left hepatic arteries.
Reviewed	2-27-2025	**Sanjeeva Kalva**	reviewed
Revised	05-06-2025	**Jana Smith, RDMS, RVT; Sanjeeva Kalva, MD**	Added images and verbiage for spleen measurement clarification. Added Parkland logo. Re-added RHA and LHA RI and SAT requirements