



Nasjonalt Senter for Gastroenterologisk Ultrasonografi

National Centre for Ultrasound in Gastroenterology
Haukeland University Hospital, Bergen, Norway

Liver cirrhosis and portal hypertension assessed by ultrasound and elastography

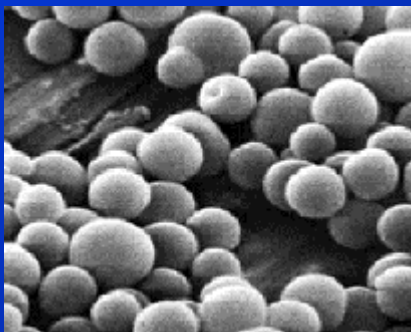
Odd Helge Gilja, MD, PhD

Professor

Department of Medicine

Haukeland University Hospital

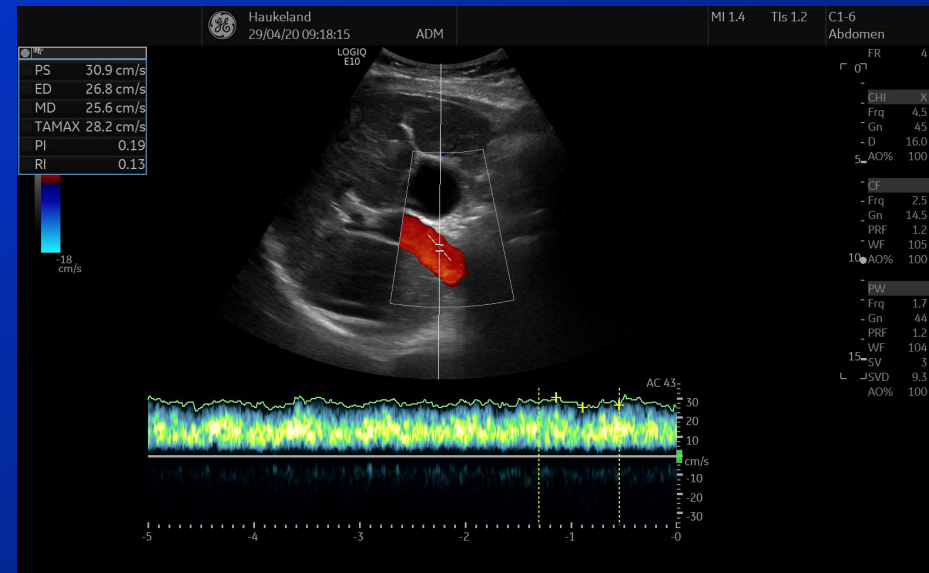
Bergen, Norway





Agenda

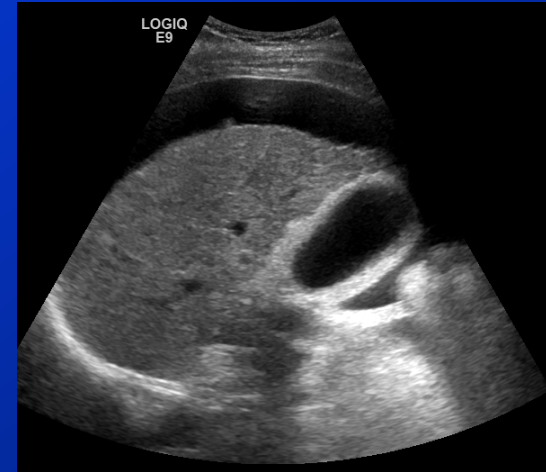
- Ultrasound of patients with liver fibrosis / cirrhosis
 - Bmode
 - Doppler
 - Elastography
 - CEUS
- Complications of cirrhosis
 - **Portal hypertension**
 - Mechanisms
 - Ultrasound findings
 - Elastography





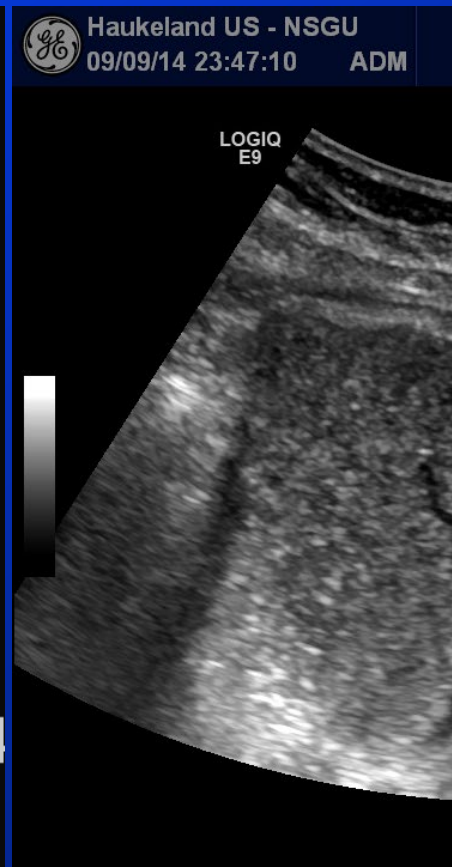
Ultrasound in the evaluation of cirrhotic livers

- Size of liver
- Size of left lobe and caudate lobe
- Capsule smoothness
- Ascites
- Echogenicity, homogeneity, nodularity, focal lesions
- Bile ducts and gallbladder
- Diameter of portal vein (+ splenic vein and spleen)
- Doppler measurements:
 - Color and pulsed Doppler of portal and hepatic veins
 - Doppler of hepatic artery (TX)
- Elastography, mainly right lobe
- CEUS
- US-guided biopsy and ablation procedures





The Liver capsule



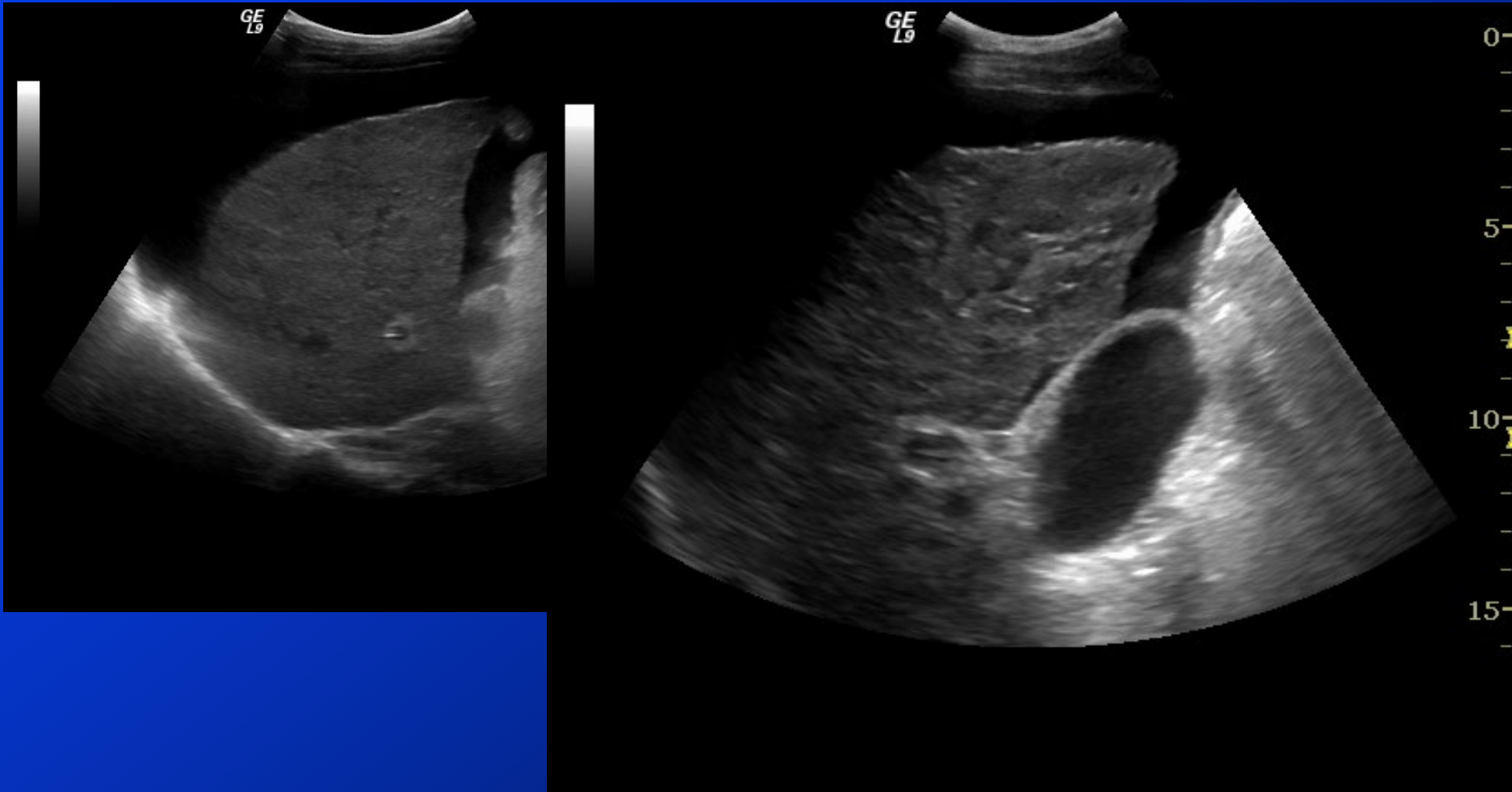
Normal

Cirrhosis

Use high frequency (9-12 MHz)

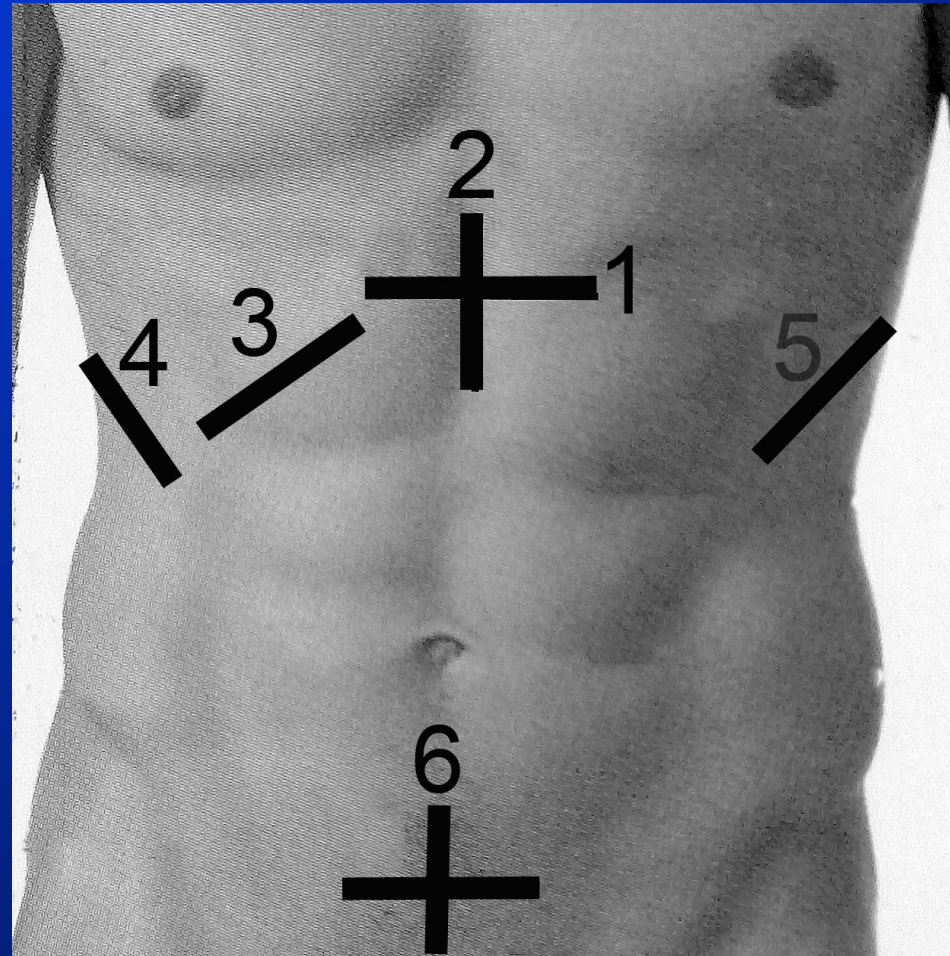
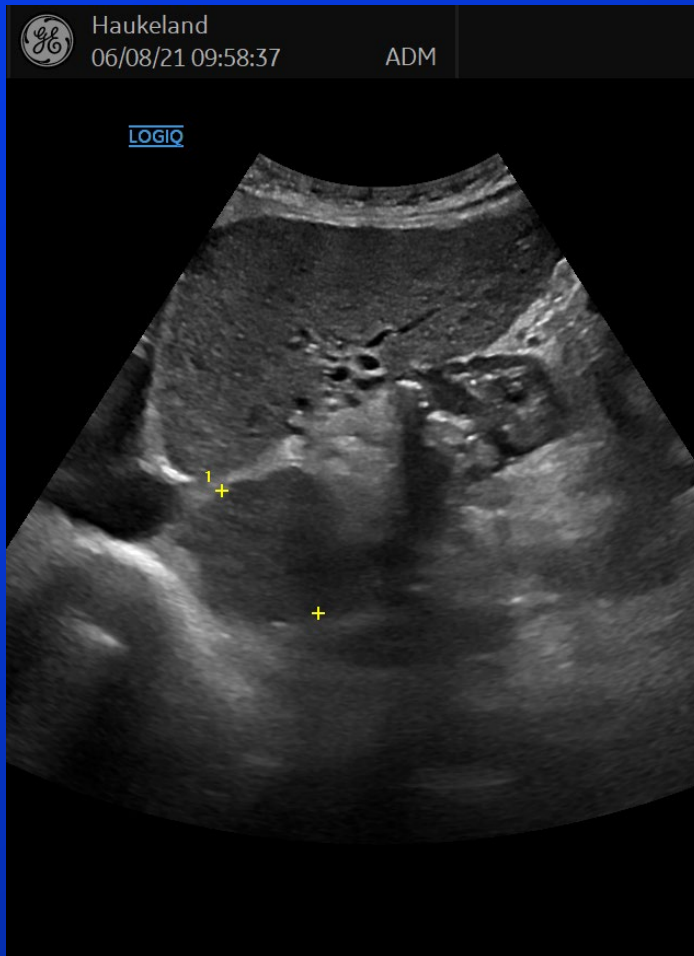


Liver cirrhosis



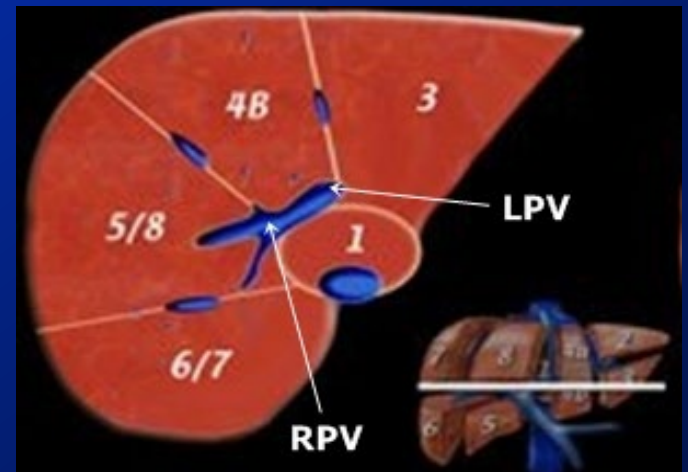


Lobus caudatus (S1) in a sagittal section from Station 2



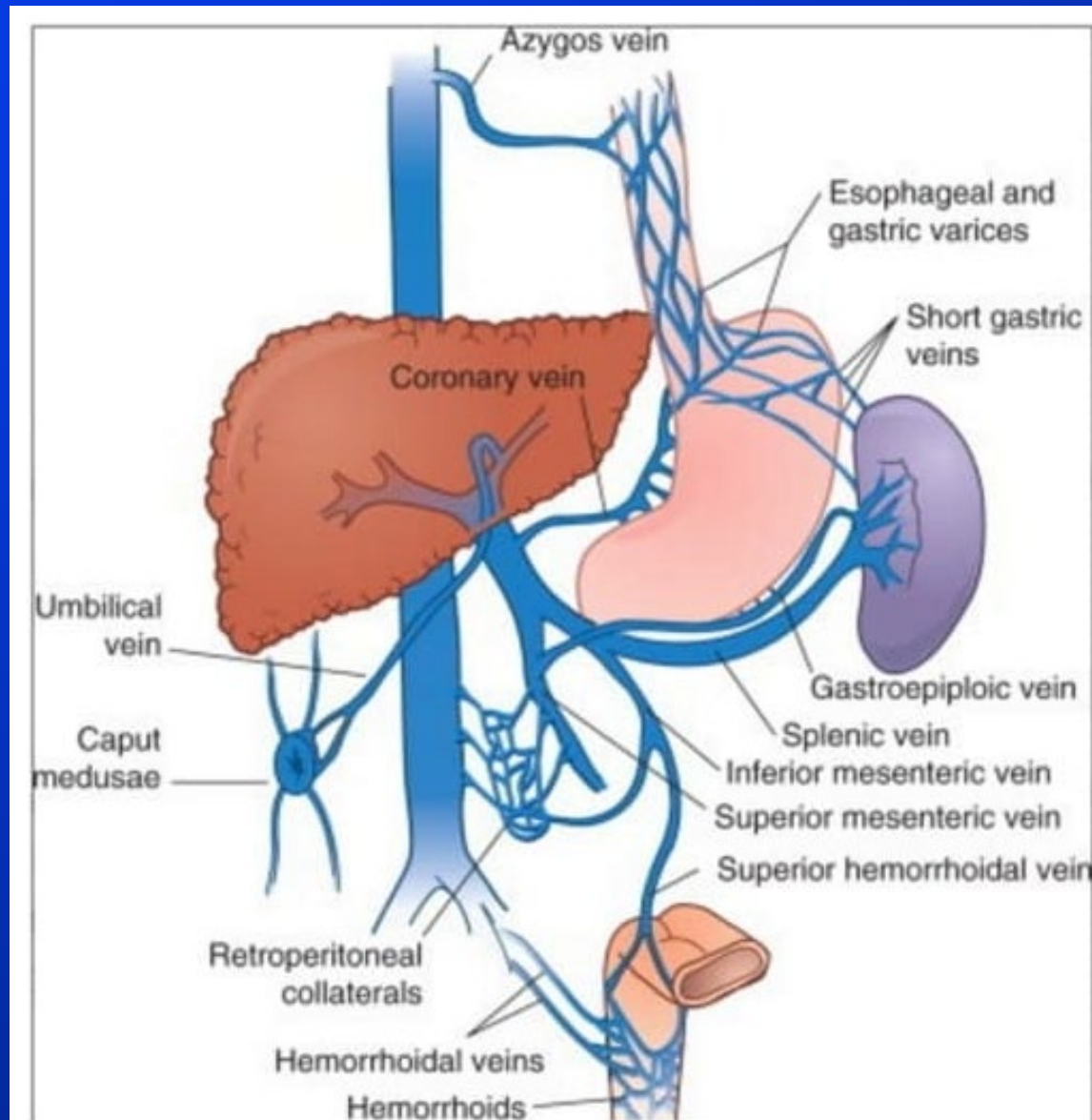


Enlarged caudate lobe





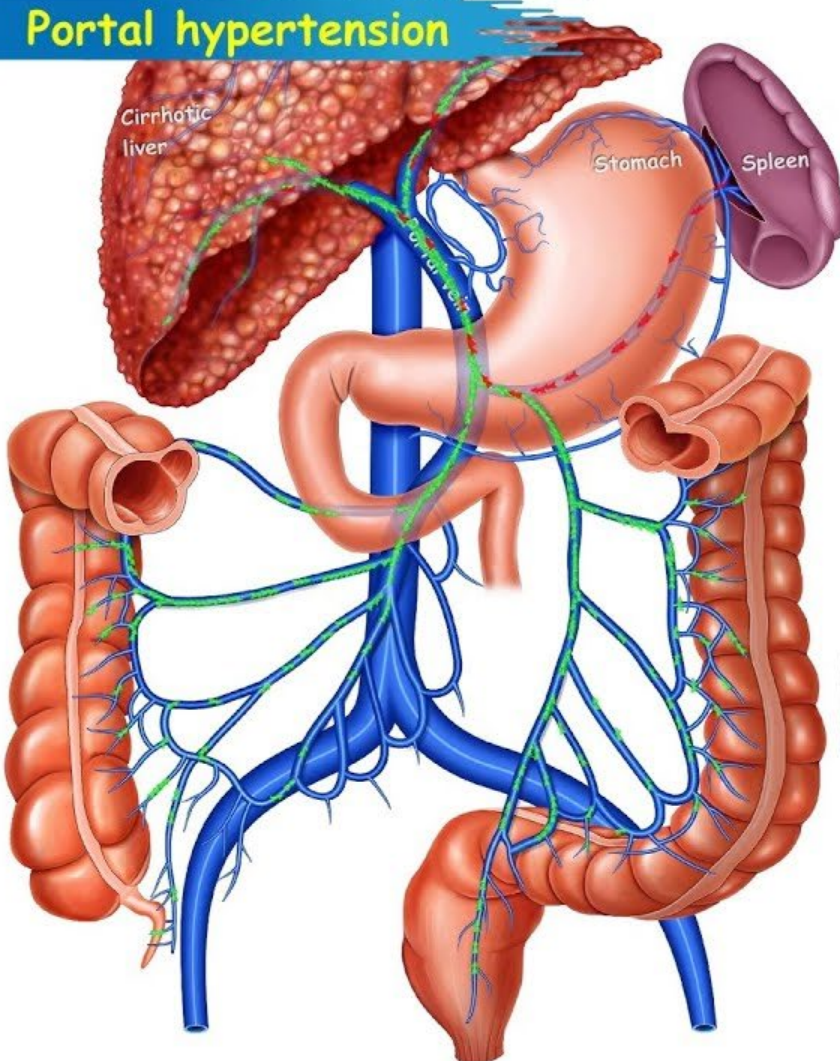
Portal hypertension





Definitions of portal HT

Portal hypertension



Portal Hypertension



Portal venous pressure

≥ 6 mm Hg

➤ Portal hypertension

> 10 mm Hg

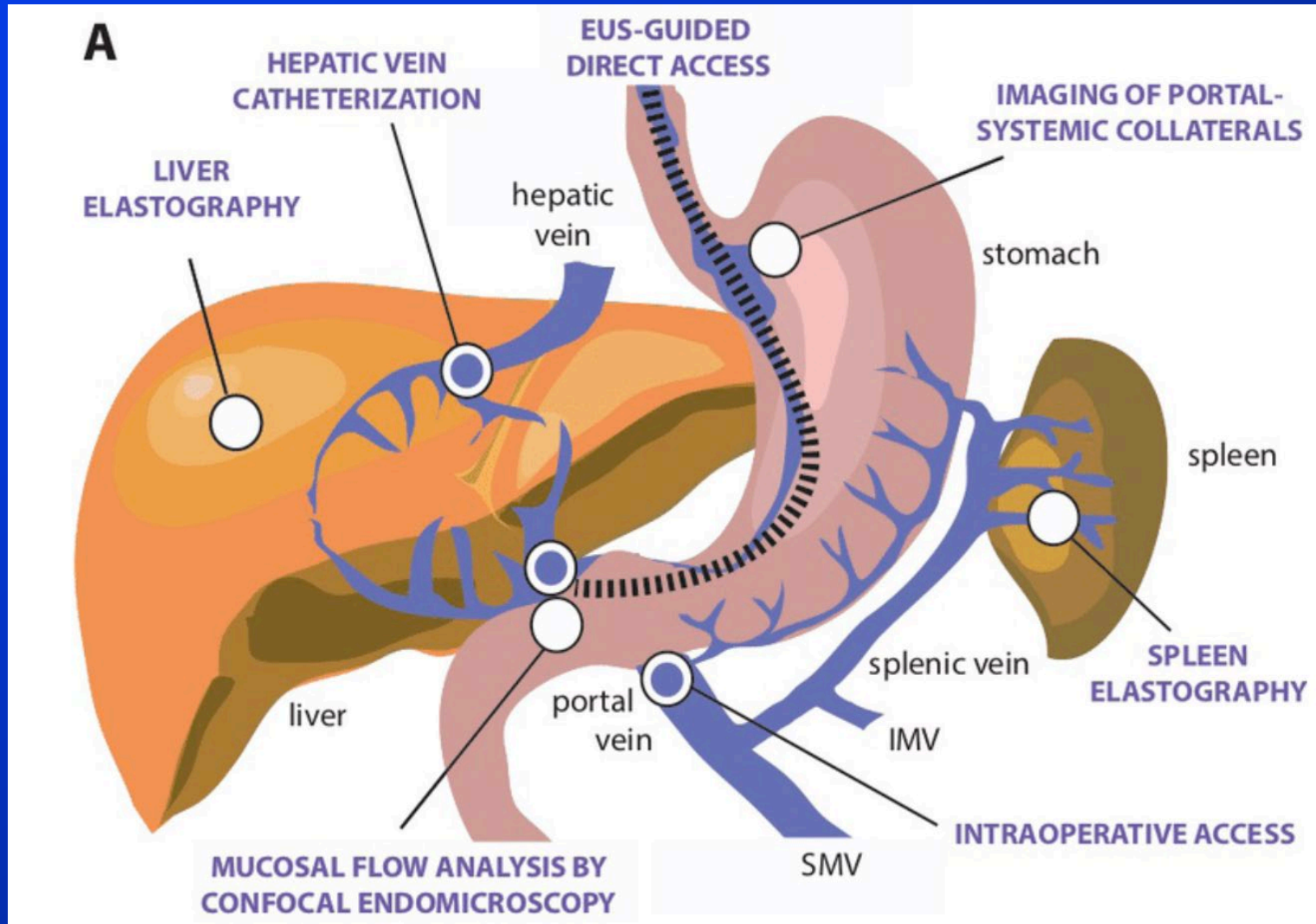
➤ Clinically significant portal hypertension

> 12 mm Hg

➤ Portal hypertension associated with complications

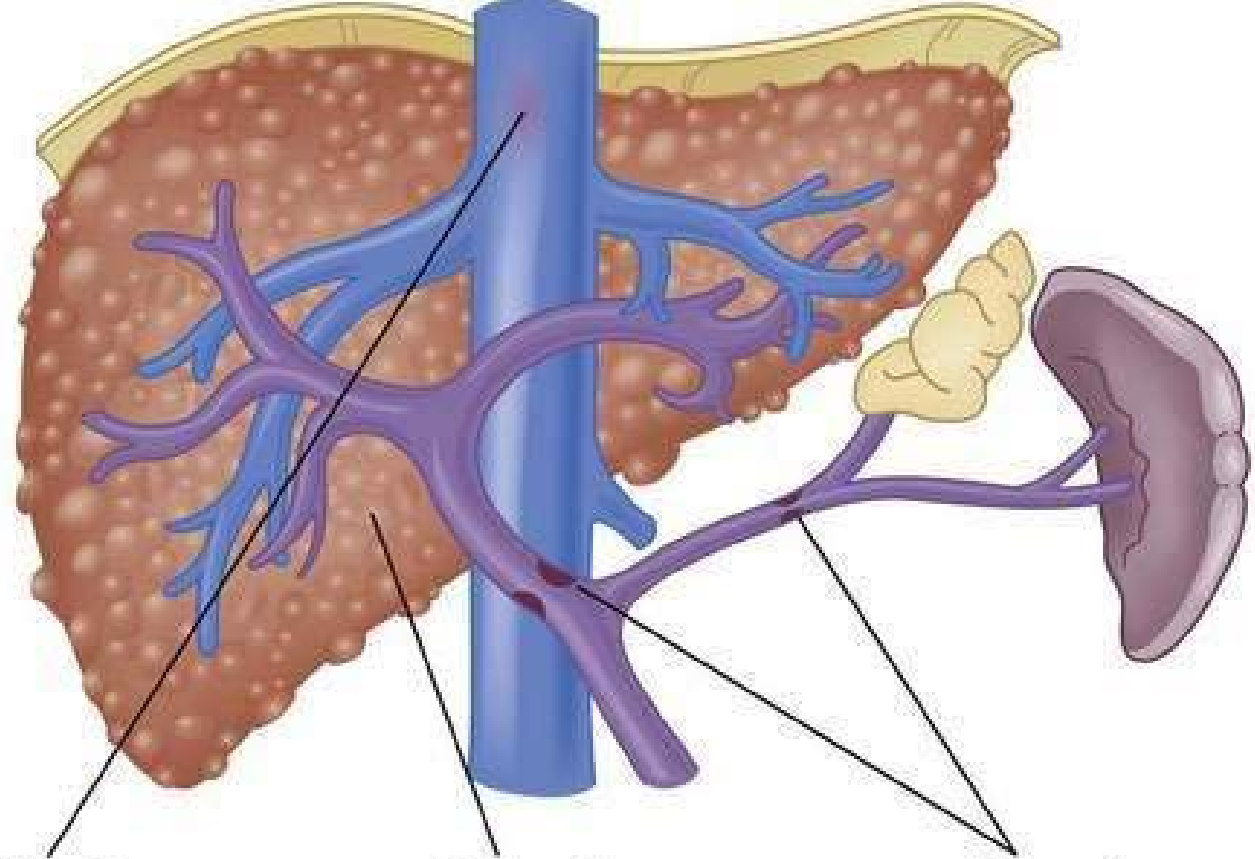


How to measure portal pressure?





Causes of portal HT



Posthepatic

Budd-Chiari syndrome
Constrictive pericarditis
Inferior vena caval obstruction
Right-sided heart failure
Severe tricuspid regurgitation

Intrahepatic

Presinusoidal

Idiopathic portal hypertension
Primary biliary cirrhosis
Sarcoidosis
Schistosomiasis

Sinusoidal

Alcoholic cirrhosis
Alcoholic hepatitis
Cryptogenic cirrhosis
Postnecrotic cirrhosis

Postsinusoidal

Sinusoidal obstruction syndrome

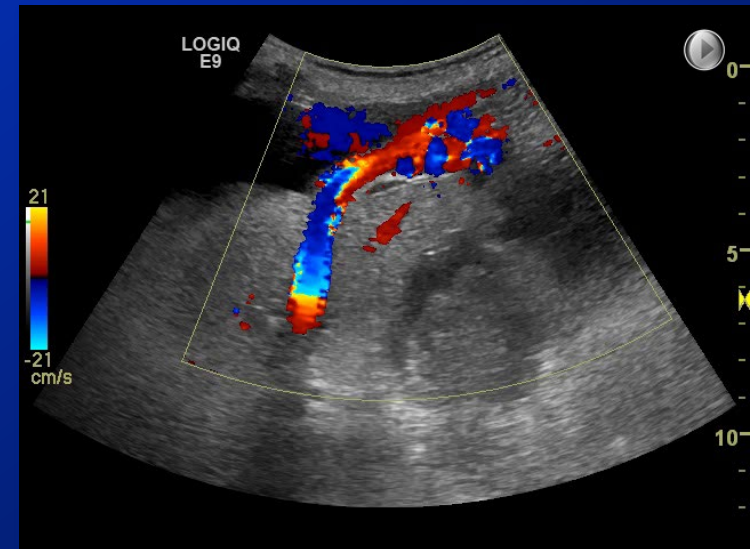
Prehepatic

Portal vein thrombosis
Splenic vein thrombosis



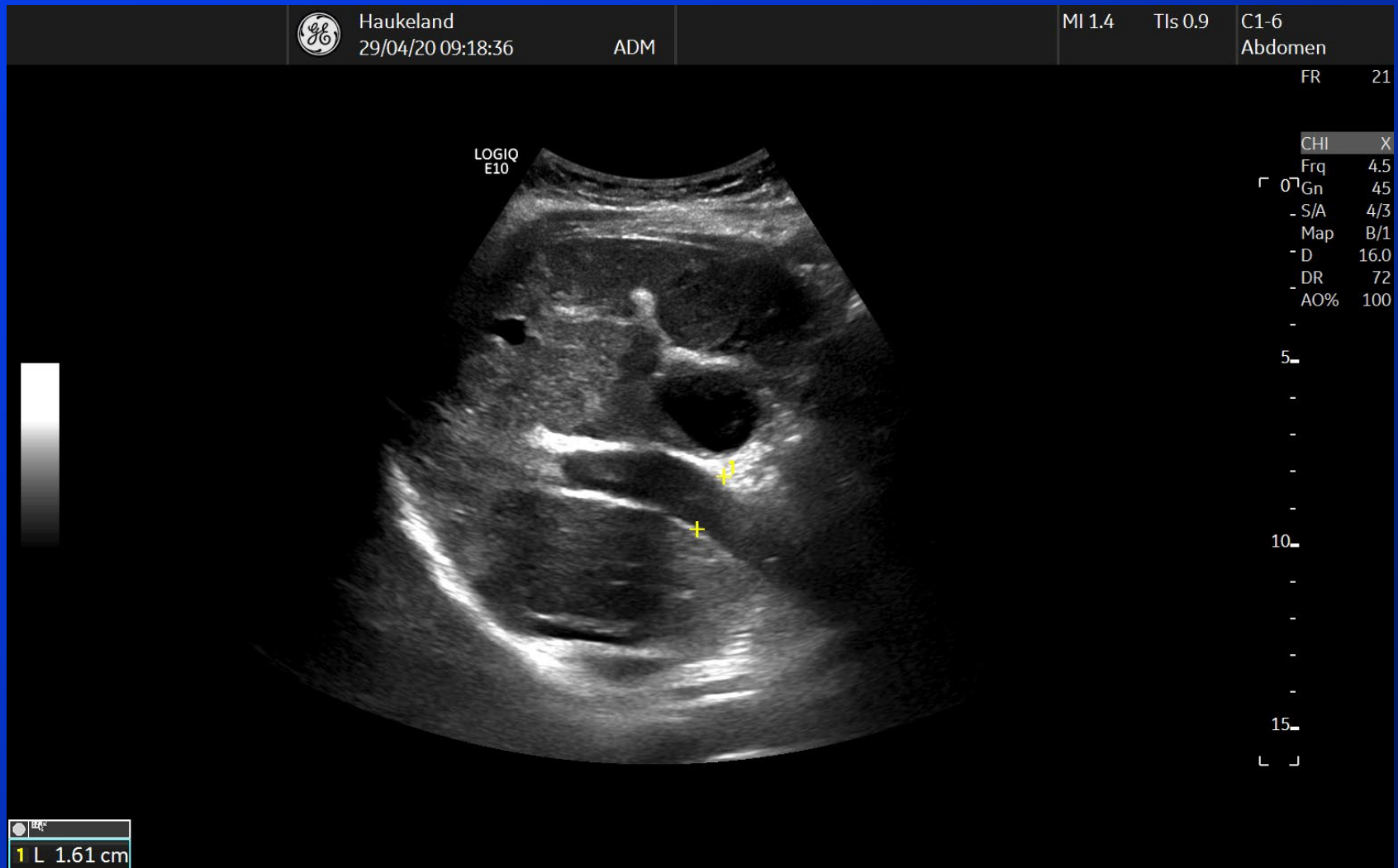
Signs (indirect) of portal hypertension seen by US

- Dilated portal vein (>13 mm)
- Decreased velocity in portal vein (<13 cm/sec)
- Reversed flow in portal vein
- Dilated splenic vein (> 10 mm)
- Shunts in the splenic hilum
- Recanalization of umbilical vein
- Enlarged spleen
- Esophageal varices / gastropathy





Vein diameter measurement



Ideally to be measured where the hepatic artery crosses the portal vein



V. Porta – Diameter and velocity

GE Haukeland US 09/29/10 09:20:35 ADM MI 1.2 TIs 1.7 C1-5 GASTRO

FR 24

CHI

0-Frq 5.0

Gn 64

-S/A 1/1

Map F/1

-D 12.0

DR 66

-AO% 100

LOGIQ
E9

1 Vel 12.7 cm/s

18
-7
cm/s

LOGIQ
E9

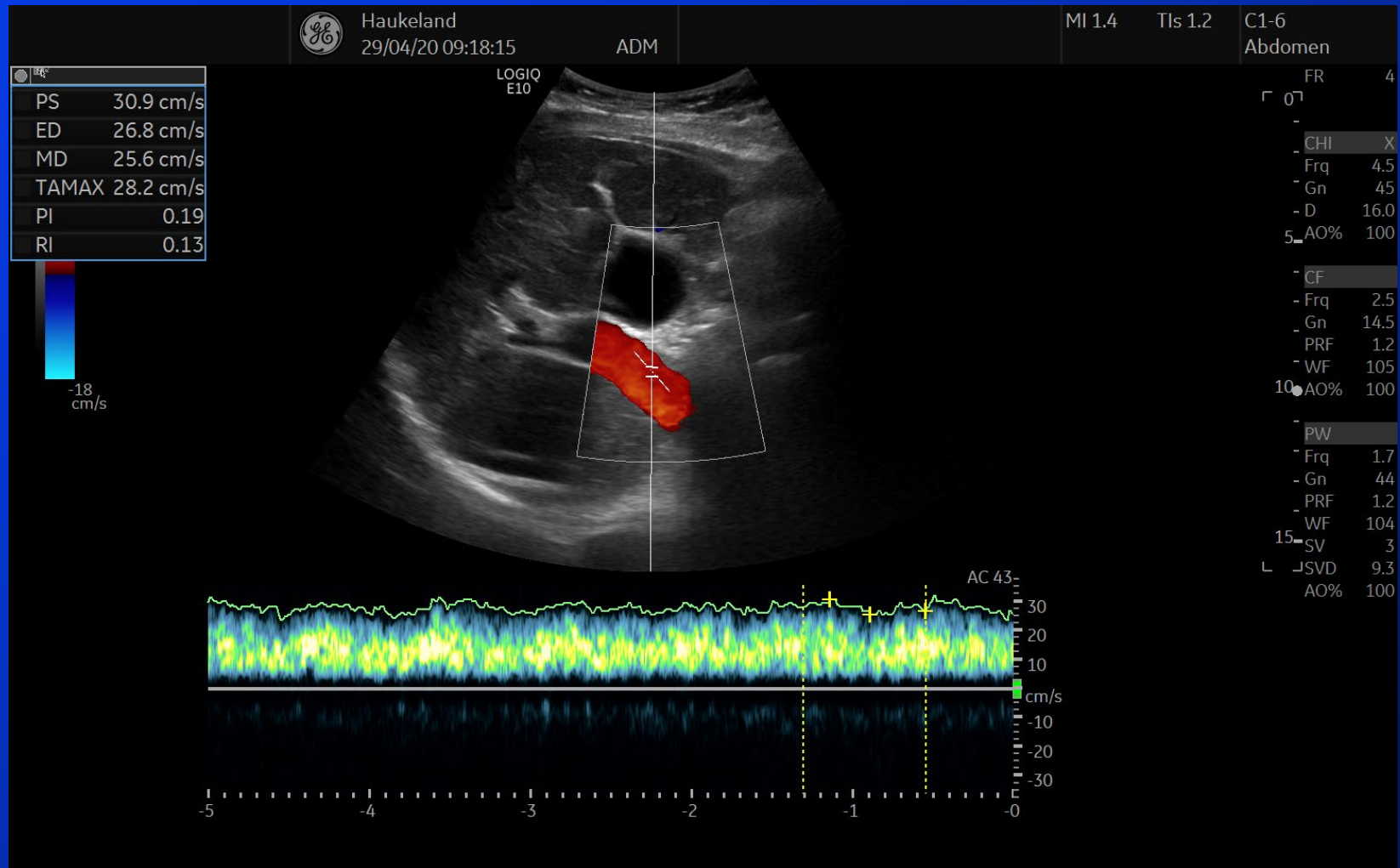
AC 46

cm/s

-5 -4 -3 -2 -1 -0

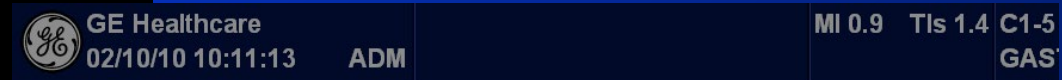
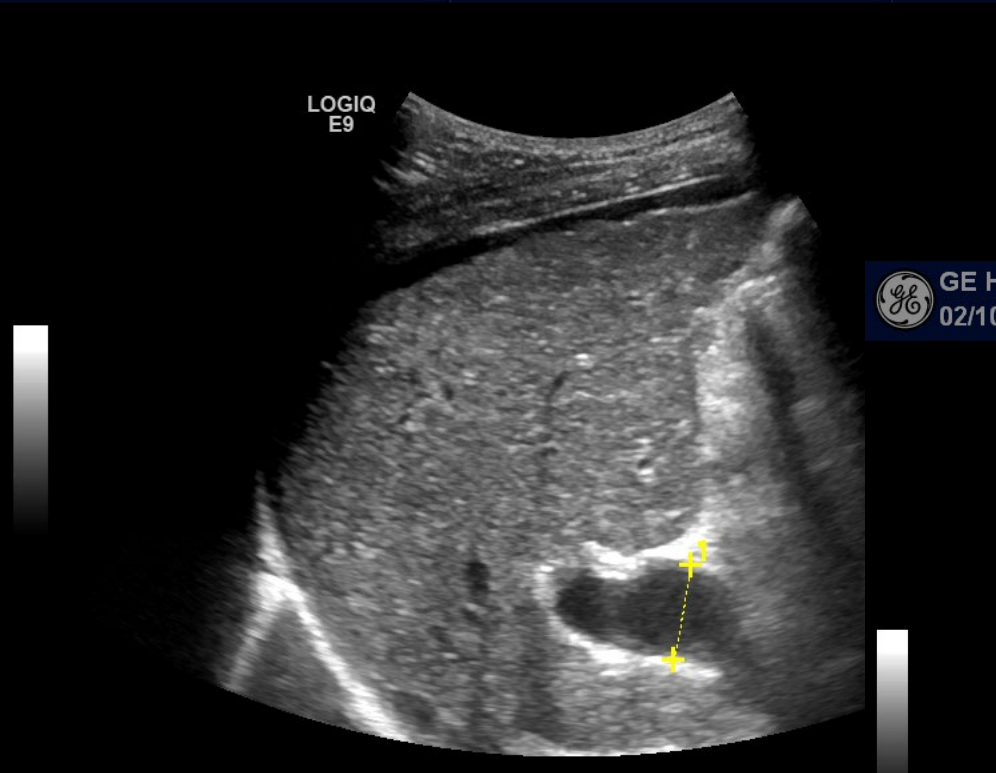


Velocity measurement (PW)





Portal vein measurement

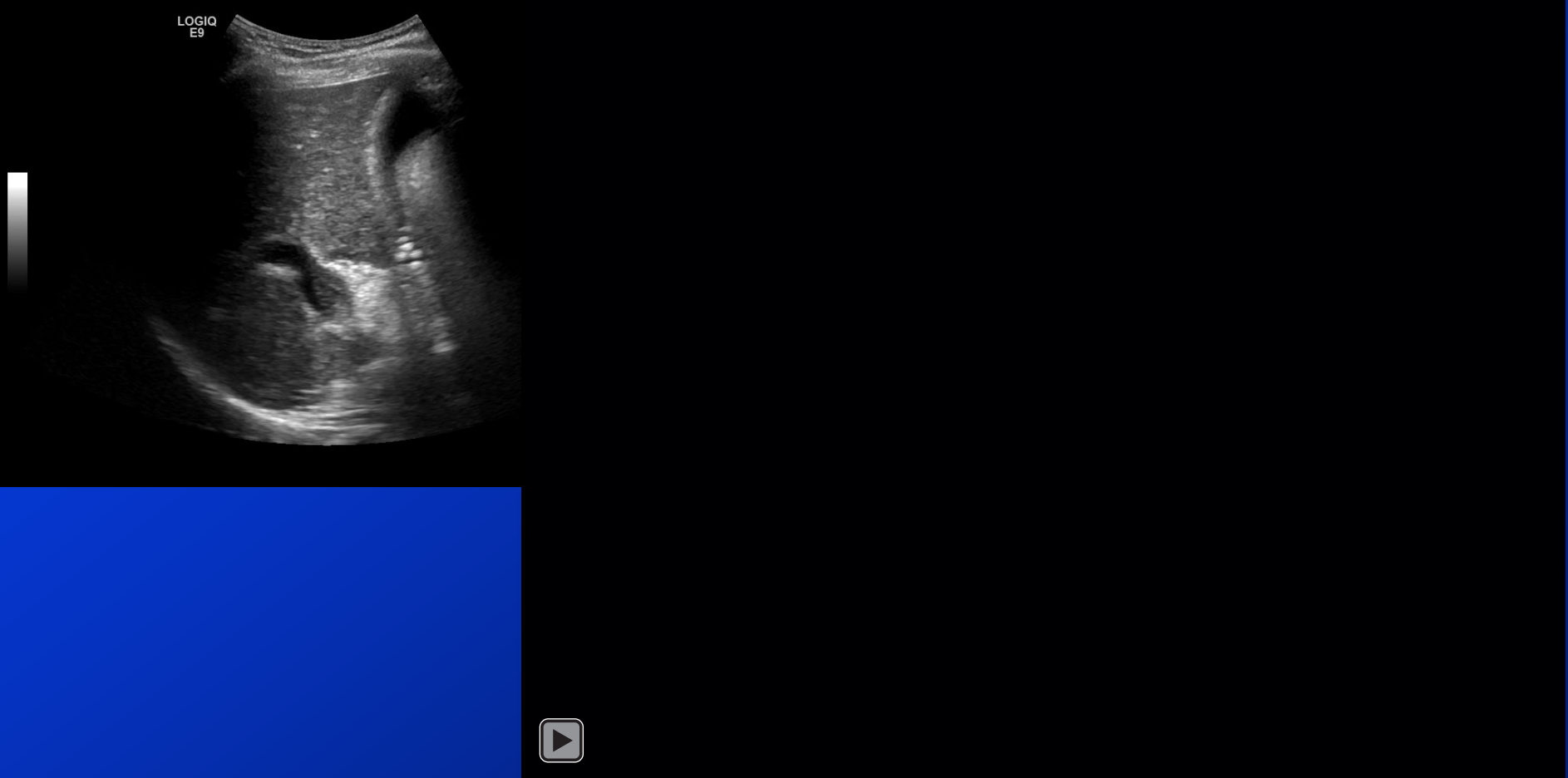




Color Doppler flow in real-time

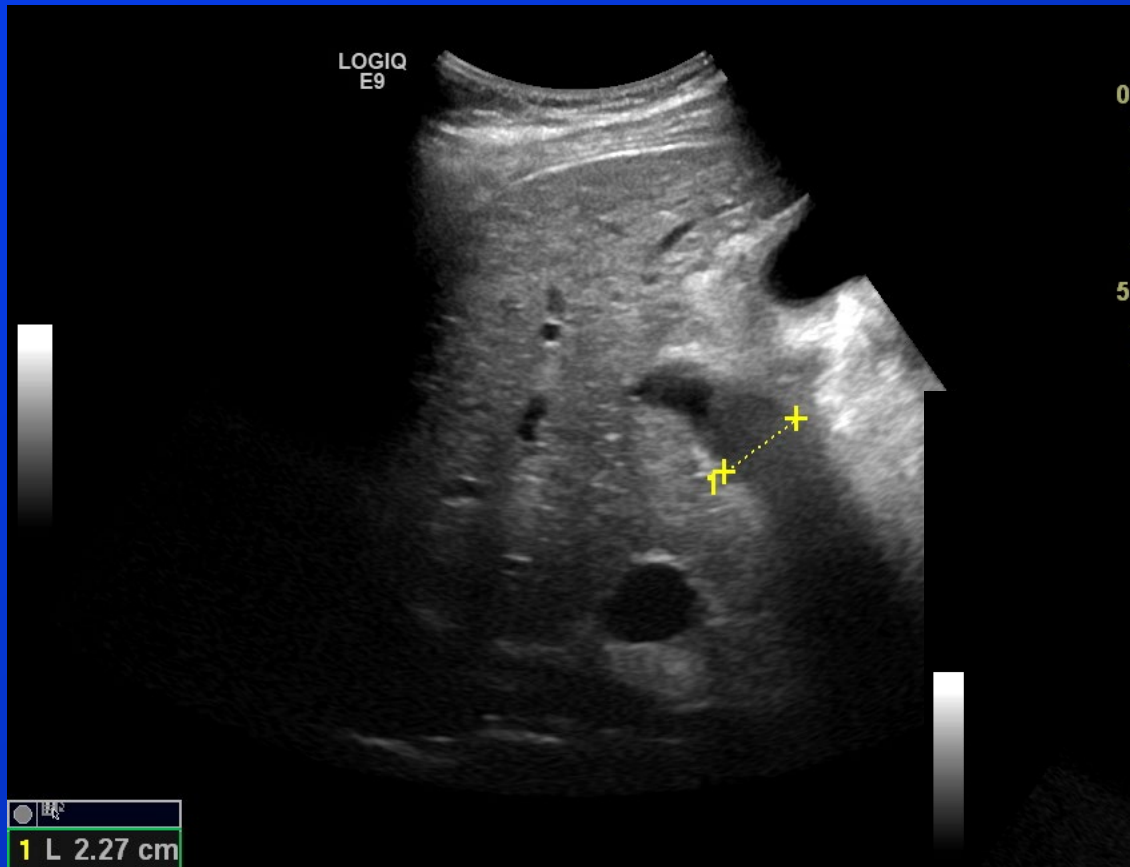
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GASTRO
EP 24

LOGIQ
E9





Portal Vein Thrombosis



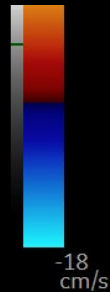
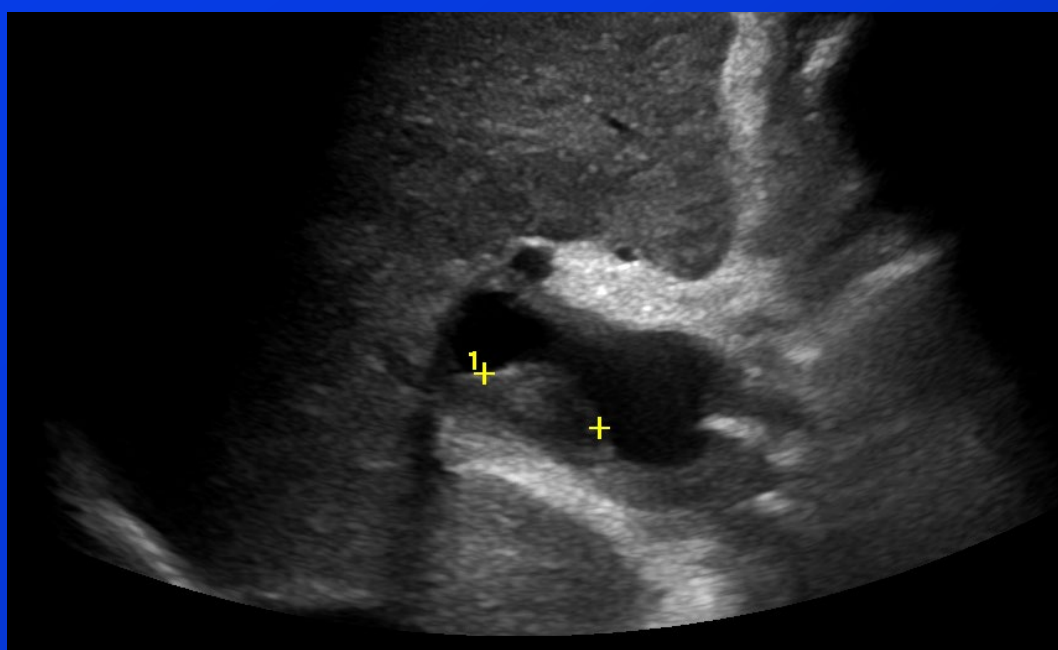


Portal Vein Thrombosis



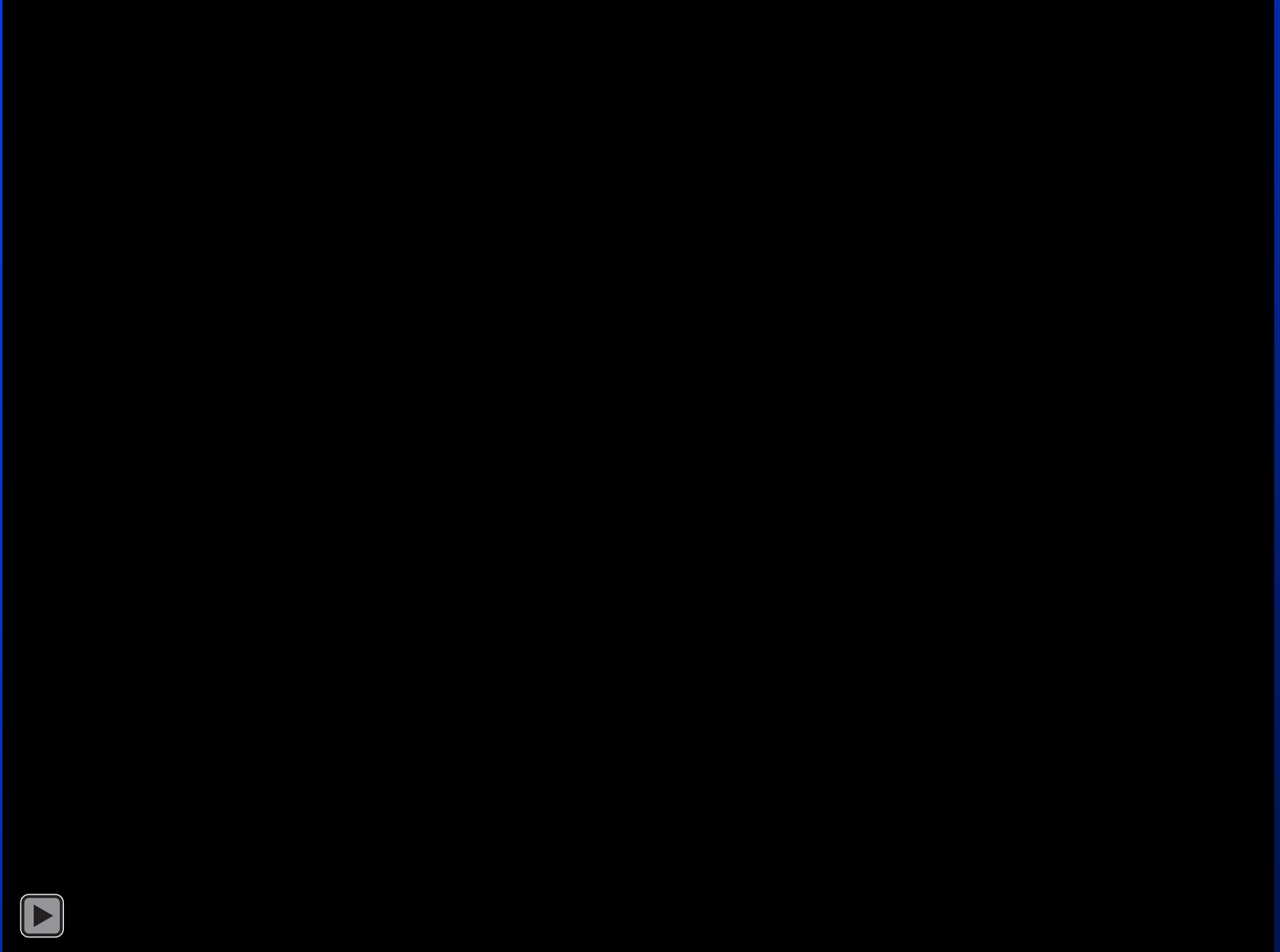


Portal Vein Thrombosis





Portal Vein Thrombosis – Benign?



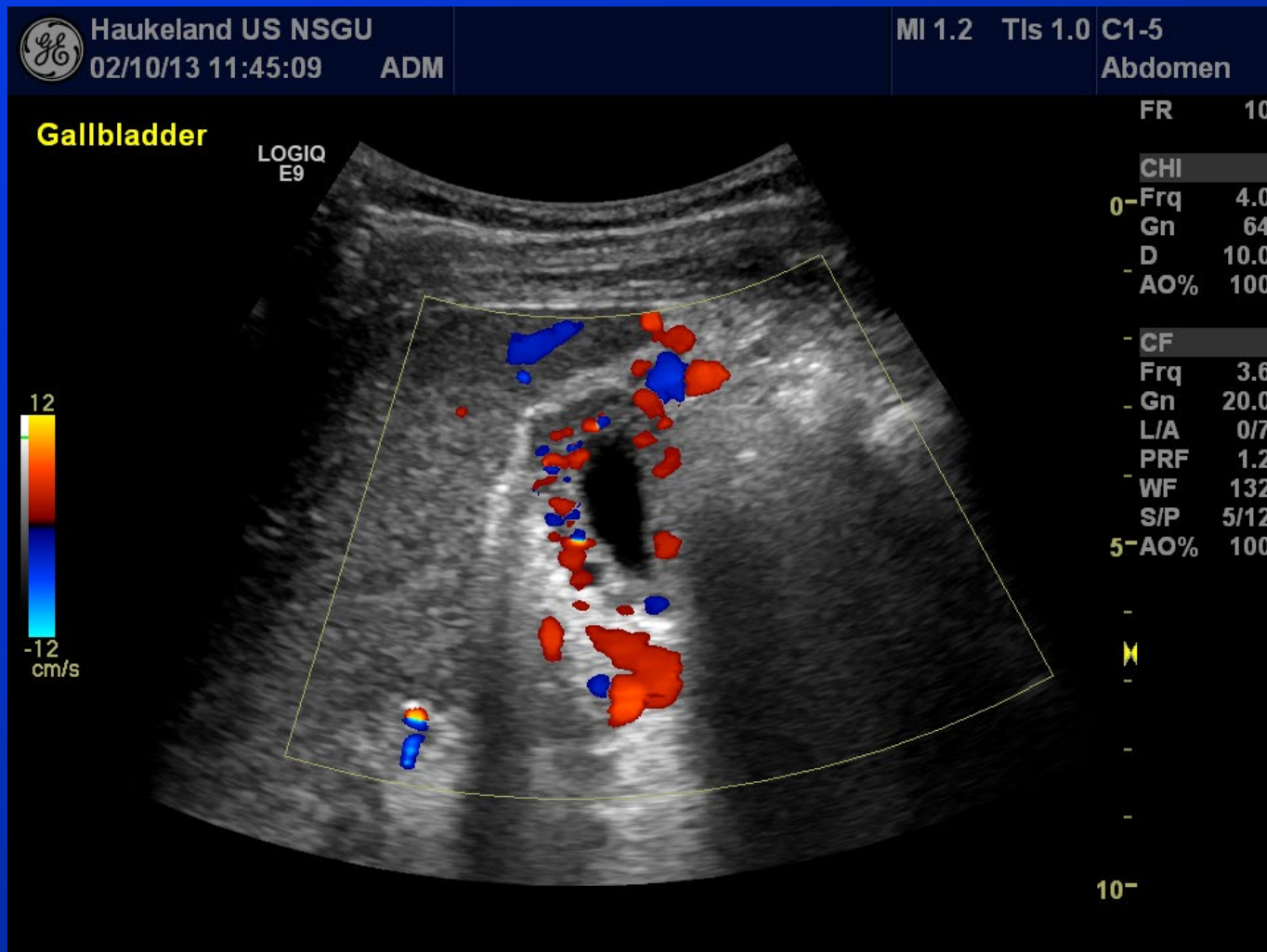


Portal Vein Thrombosis – Benign?



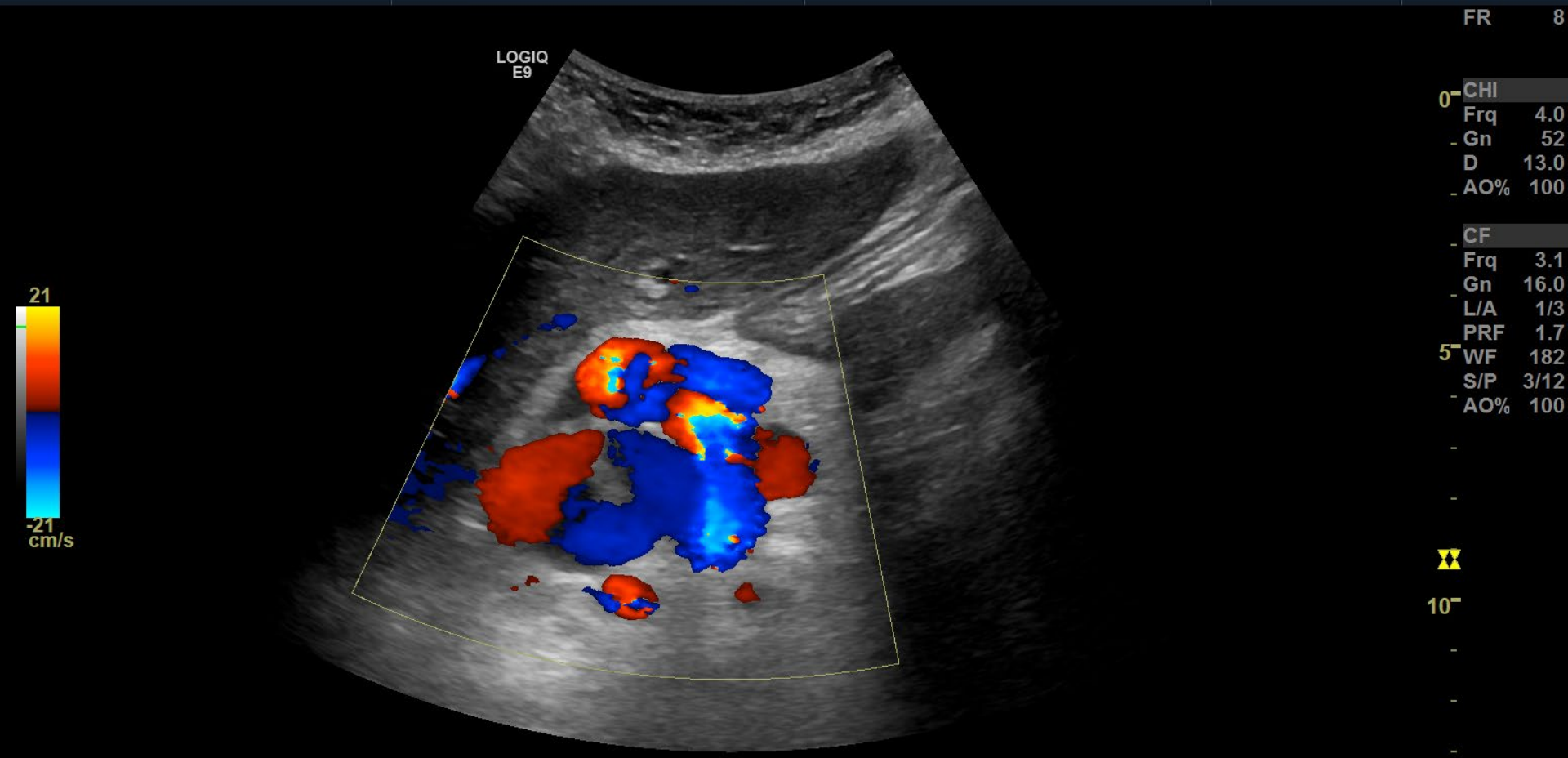


Venous stasis in the galbladder



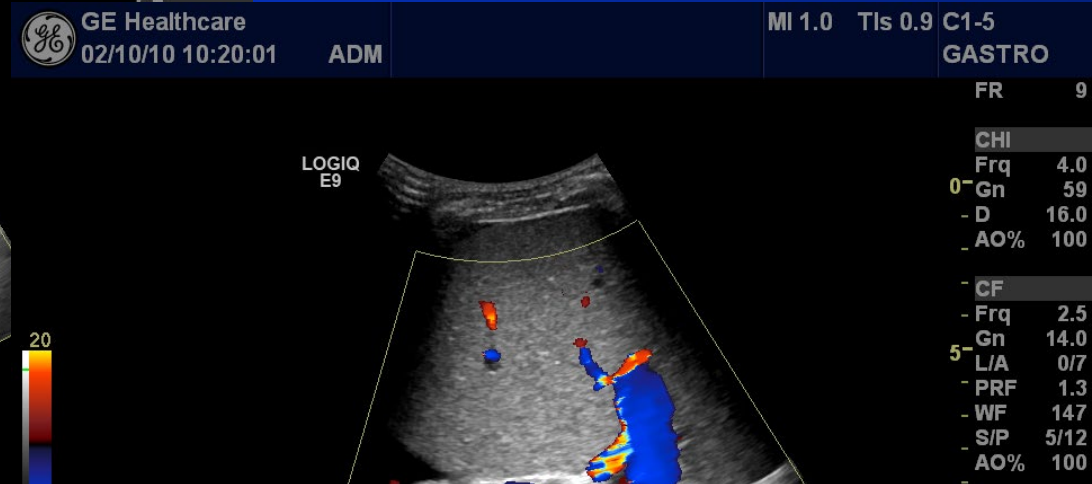


Shunting in the anterior abdomen





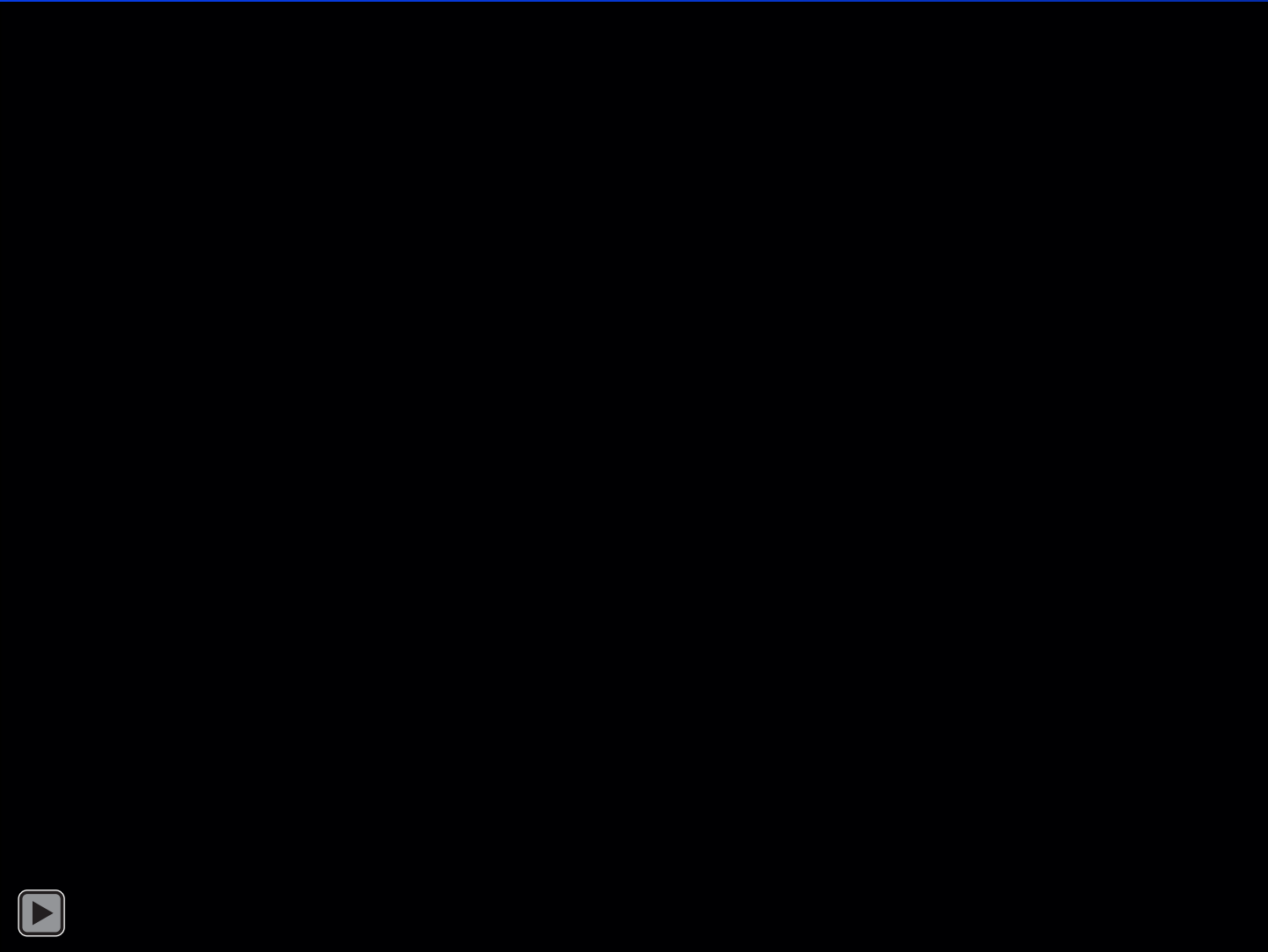
Dilated splenic vein in Portal HT



10-
15-
-

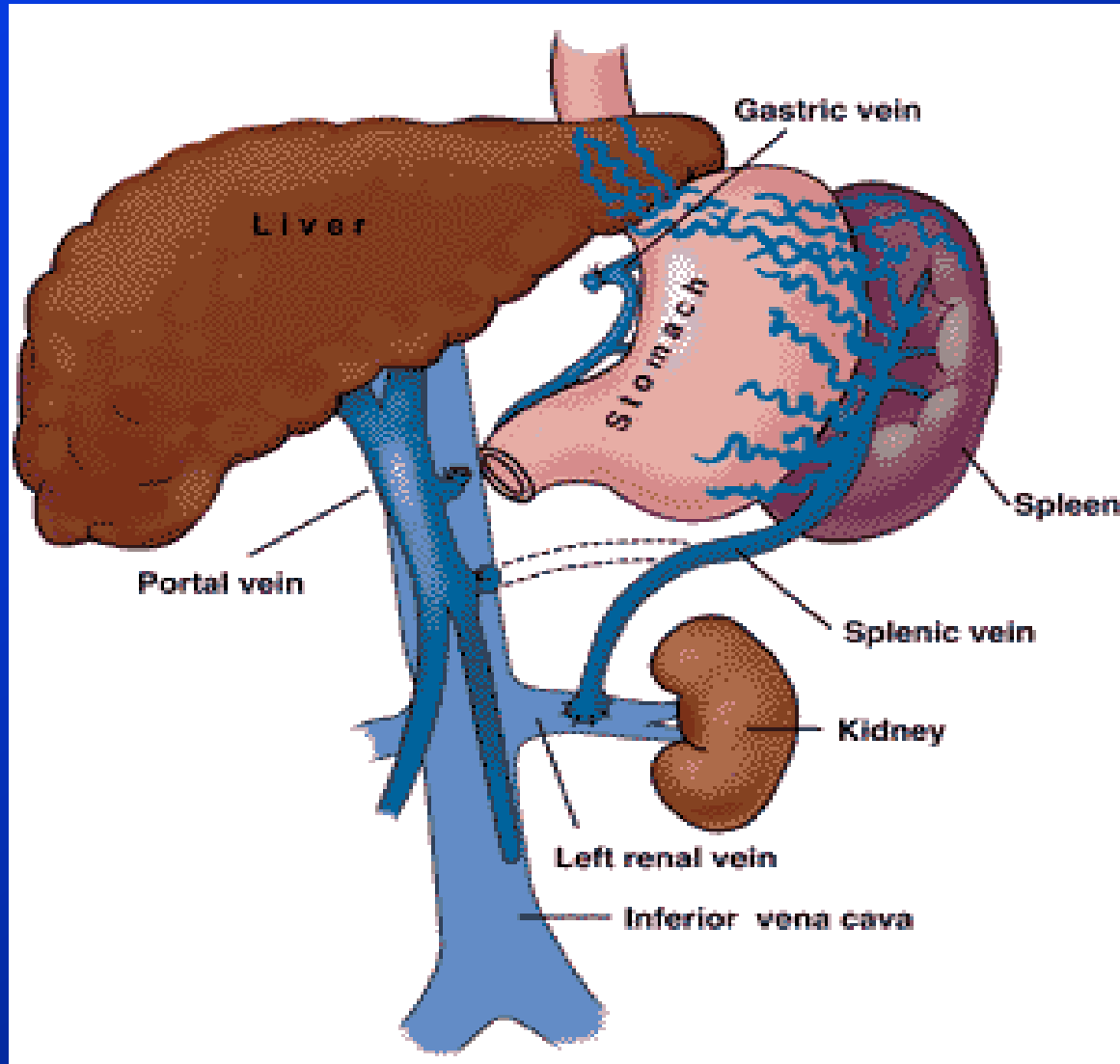


Splenic shunts



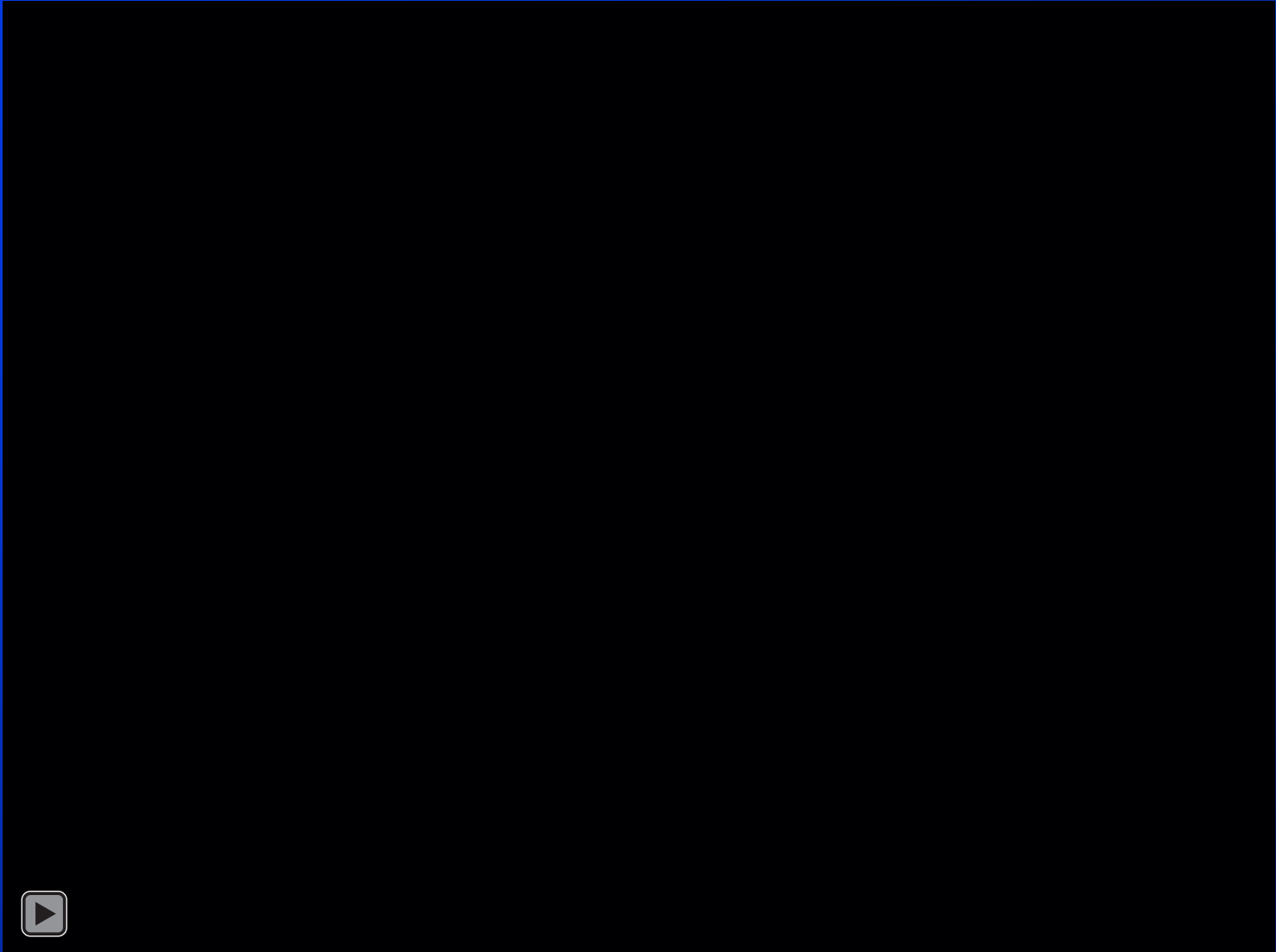


Splenorenal Shunt



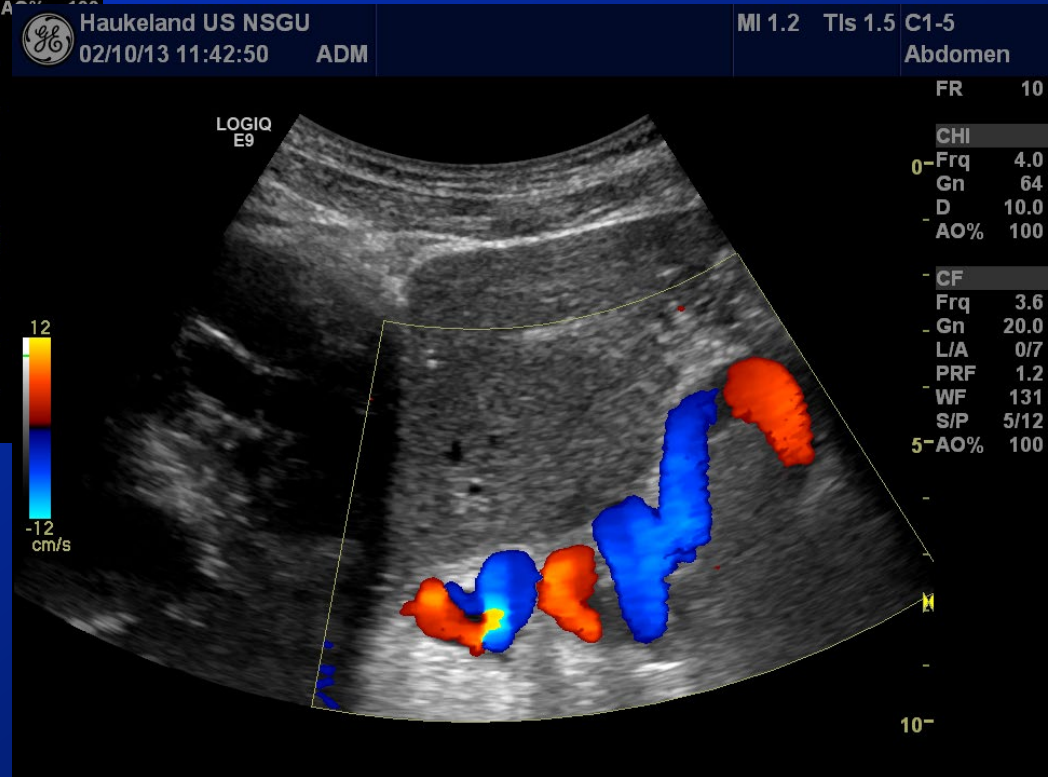


Spleno-renal shunt



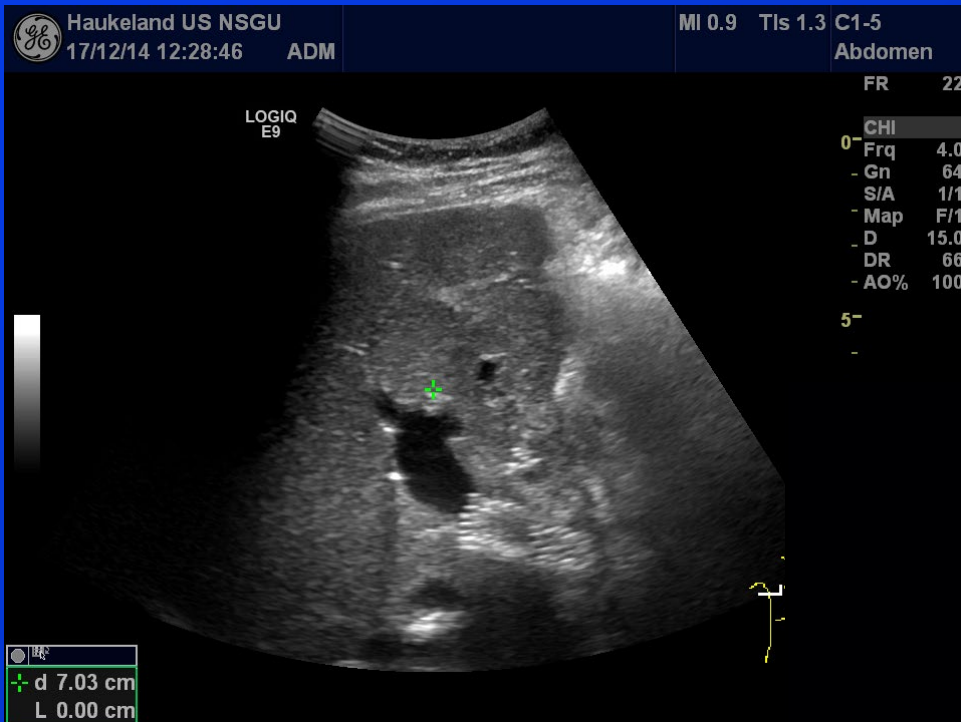


Esophageal Varices detected with transabdominal ultrasound





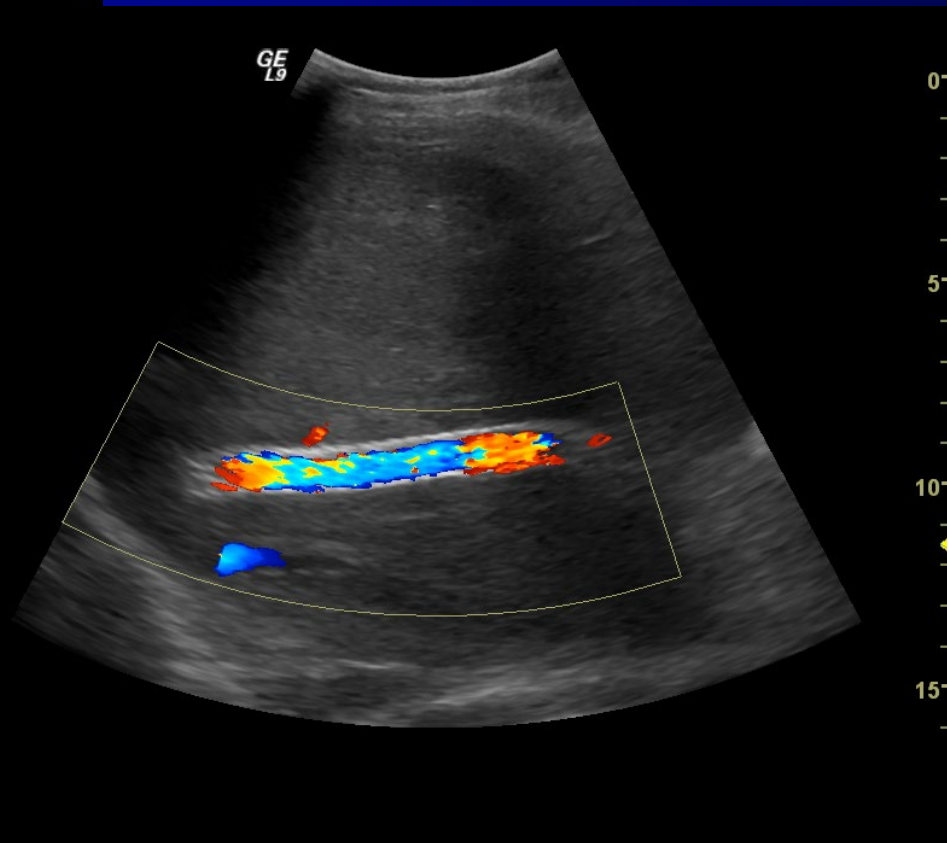
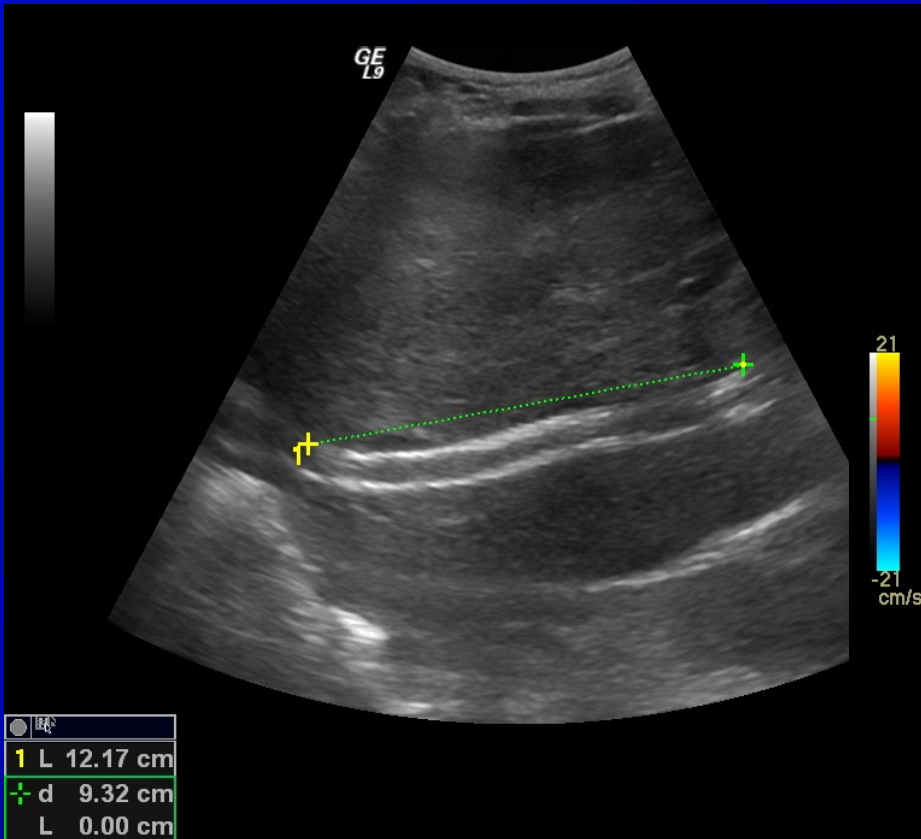
A short stent in the portal vein





Ultrasound for TIPS evaluation

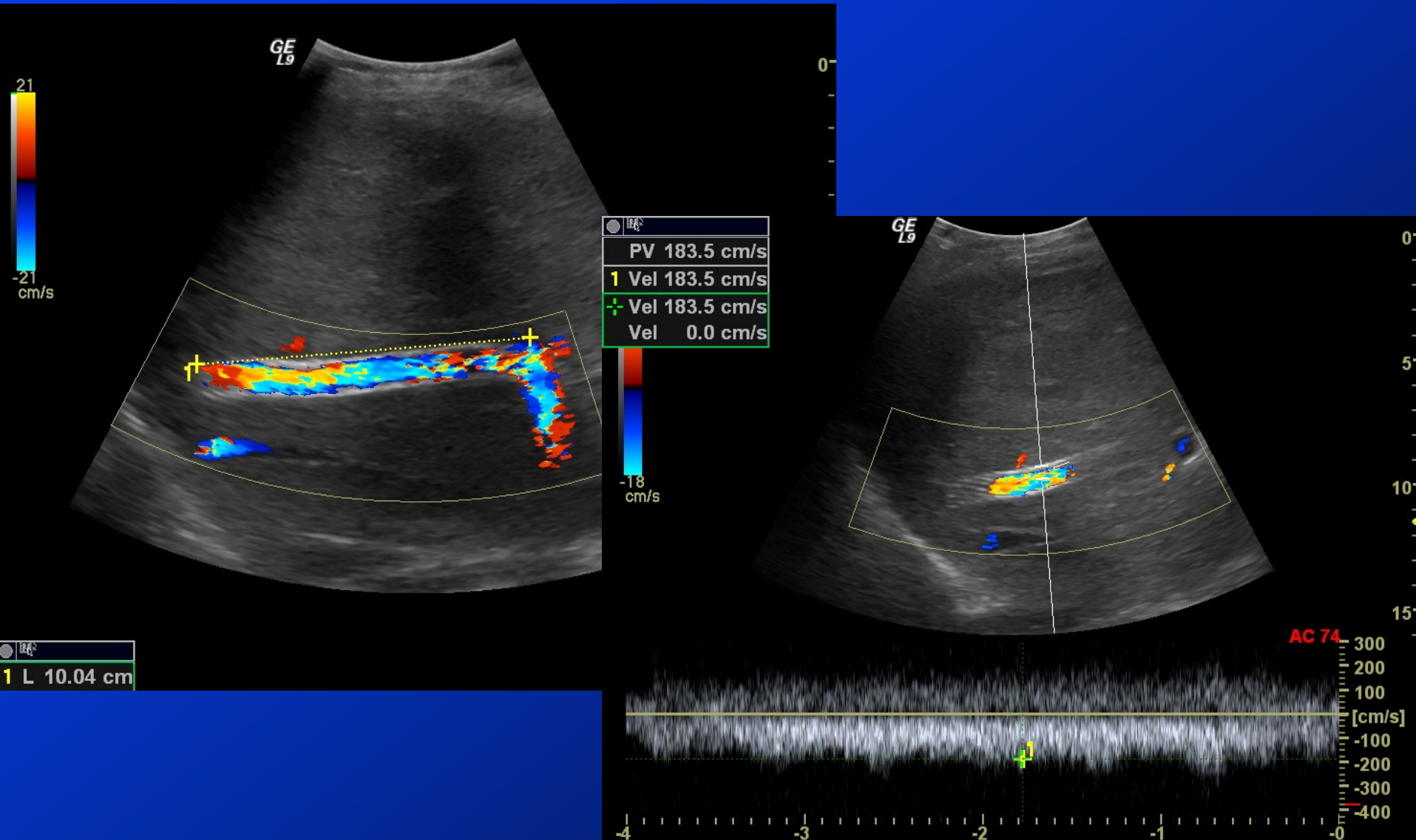
Transjugular Intrahepatic
Porto-systemic Shunt



Most important indications:
Intractable variceal bleeding
Non-responding ascites

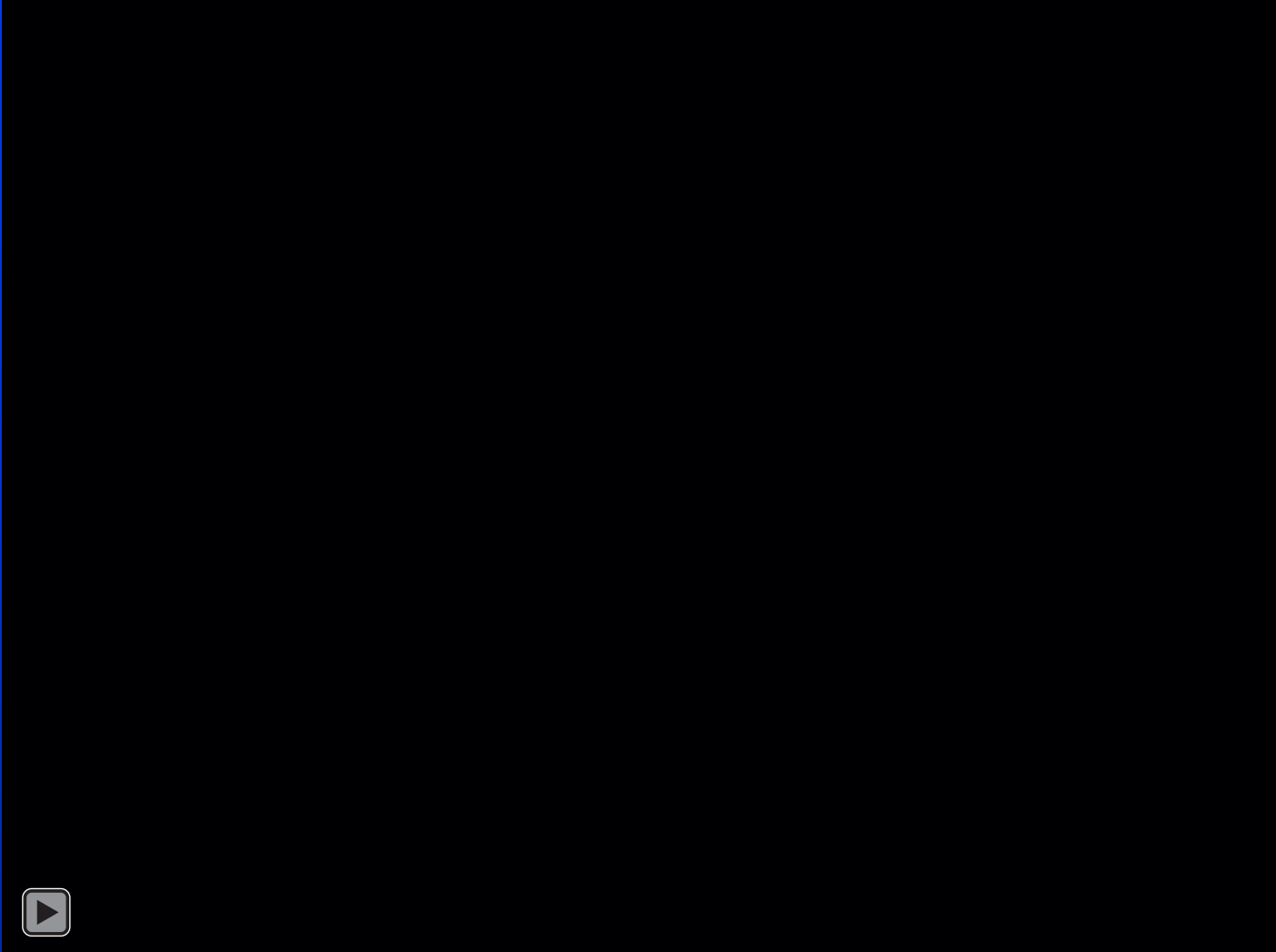


Ultrasound for TIPS evaluation



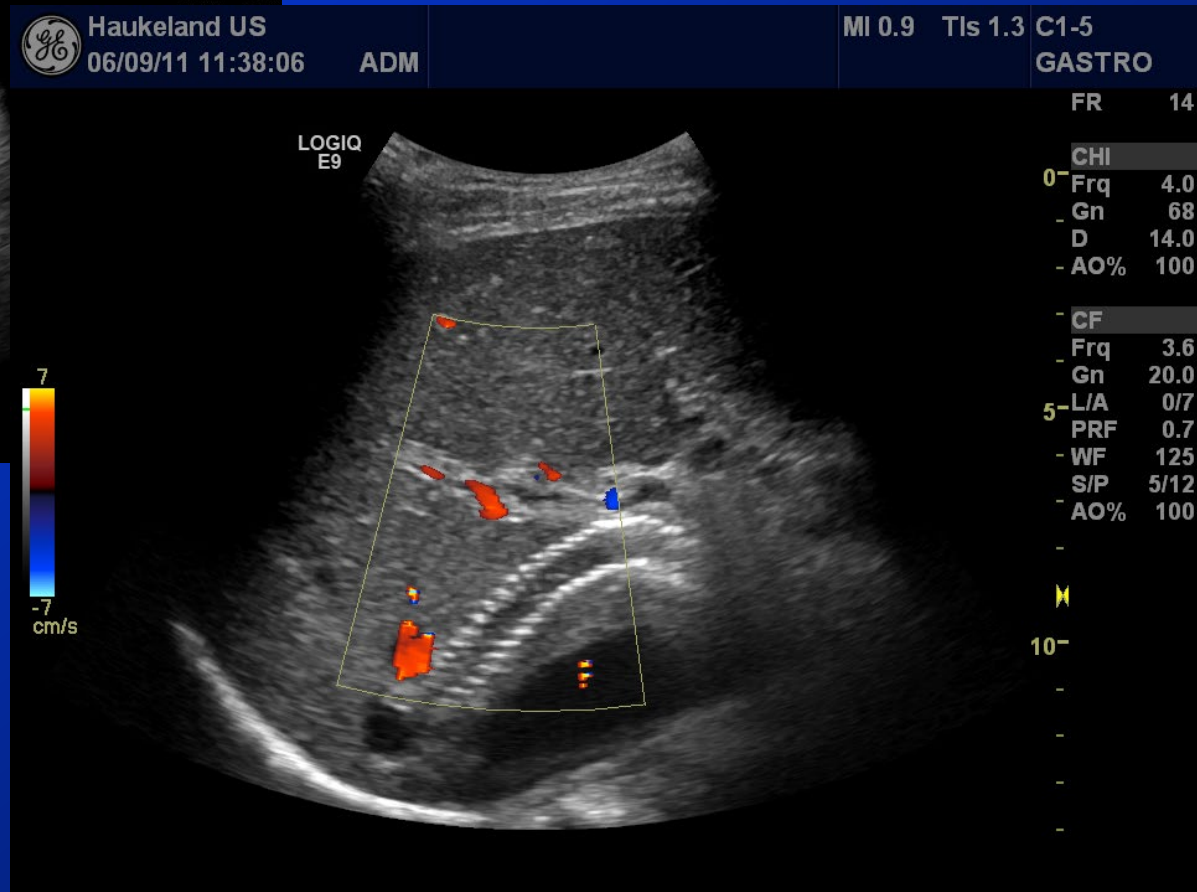


Real-time US Doppler evaluation





US for TIPS evaluation - Failure

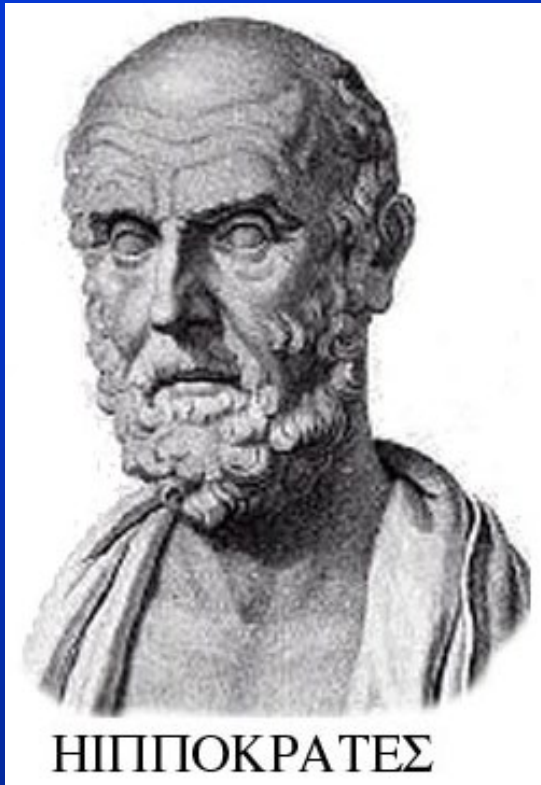




About liver elasticity

- *“When the liver is stiff, the prognosis is bad”*

Hippocrates 460-377 BC



ΗΙΠΠΟΚΡΑΤΕΣ



Elastography Methods

Eur J Ultrasound, 2017

	method	type of force	applied force	property displayed/measured	qualitative or quantitative	imaging or measurement	commercial implementation	illustration
displacement or strain imaging	strain elastography (SE) and strain rate imaging (SRI)	quasi static	mechanically induced – either active external displacement of tissue surface ¹ or passive internal physiologically induced ²	strain or strain rate	qualitative, although tools often provided to analyse image characteristics	full area image, refreshed at up to the ultrasound frame rate ³	Esaote GE Hitachi Aloka Philips Samsung Medison Siemens Toshiba Ultrasonix Mindray Zonare	Active quasi-static, surface displacement – e.g. press with imaging transducer Passive, internal, physiological motion
	acoustic radiation force impulse (ARFI) imaging		ultrasound induced – focused radiation force impulse at depth	displacement	qualitative	single image within a box	Siemens	Localized displacement at depth from a focused ultrasound radiation force impulse Dynamic displacement
shear wave speed MEASUREMENT	transient elastography (TE) ⁴	dynamic	mechanically induced – impulse ("thump") at tissue surface	shear wave speed ²	quantitative	single measurement, beam-line average	Echosens	Surface impulse – thump with a probe transducer Axial shear wave pulse
	point shear wave elastography (pSWE), also known as ARFI quantification ⁴		ultrasound induced – focused radiation force impulse at depth	shear wave speed ²	quantitative	single measurement, ROI average	Siemens Philips Hitachi-Aloka	Deep shear waves from focused ultrasound radiation force impulse Lateral shear wave pulse
shear wave speed IMAGING	shear wave elastography (SWE)		ultrasound induced – radiation force impulses focused at various depths	shear wave speed ²	quantitative	single image within a colour box image within a colour box, running refresh	Siemens Toshiba Philips Mindray Zonare	Deep shear waves from focused ultrasound radiation force impulse Lateral shear wave pulse
	two dimensional and three dimensional shear wave elastography (2D-SWE and 3D-SWE) ⁴		ultrasound induced – radiation force down multiple simultaneous lines in a "comb push" combined with directional filtering	shear wave speed ²	quantitative	single image within a colour box	GE	Deep shear waves from comb of ultrasound radiation force impulse Lateral (vertical) shear wave pulse comb
			ultrasound induced – radiation force focus swept over depth faster than shear wave speed to create a Mach cone	shear wave speed ²	quantitative	image within a colour box, refreshed at up to several per second ³	SuperSonic Imagine	Deep shear waves from swept-focus ultrasound radiation force impulse Lateral (vertical) shear wave pulse

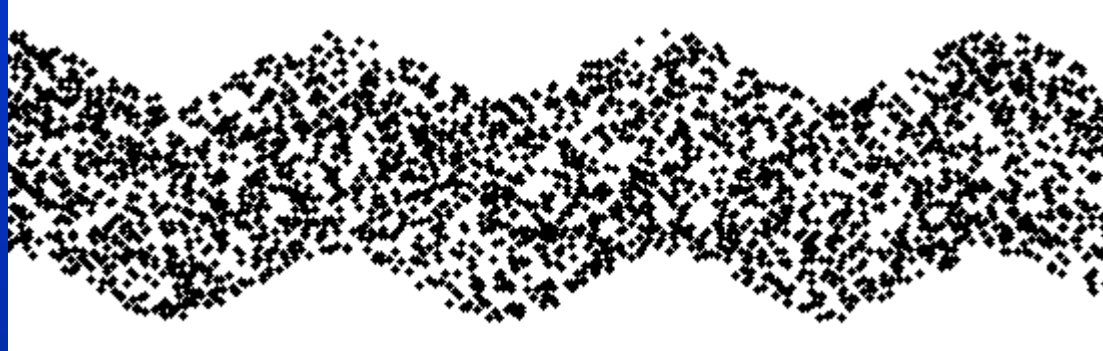
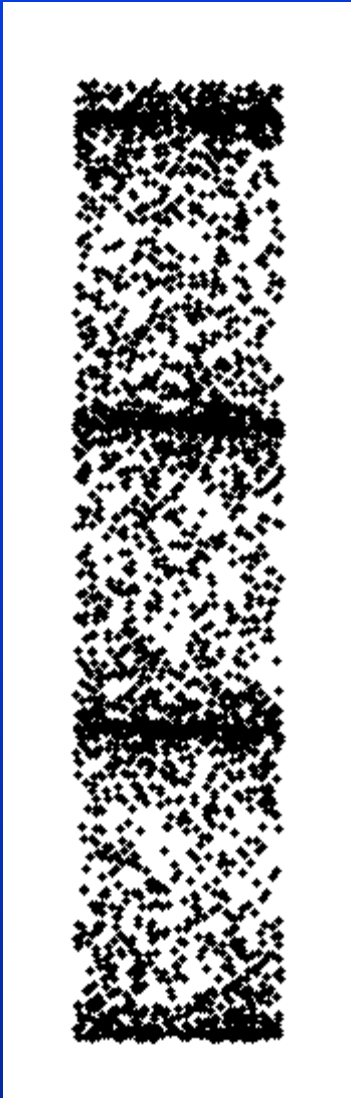


Longitudinal and Shear Waves

Ultrasound
Wave

$$c_l = \sqrt{\frac{K}{\rho}}$$

$c_l \sim 1540$ m/s
in tissue



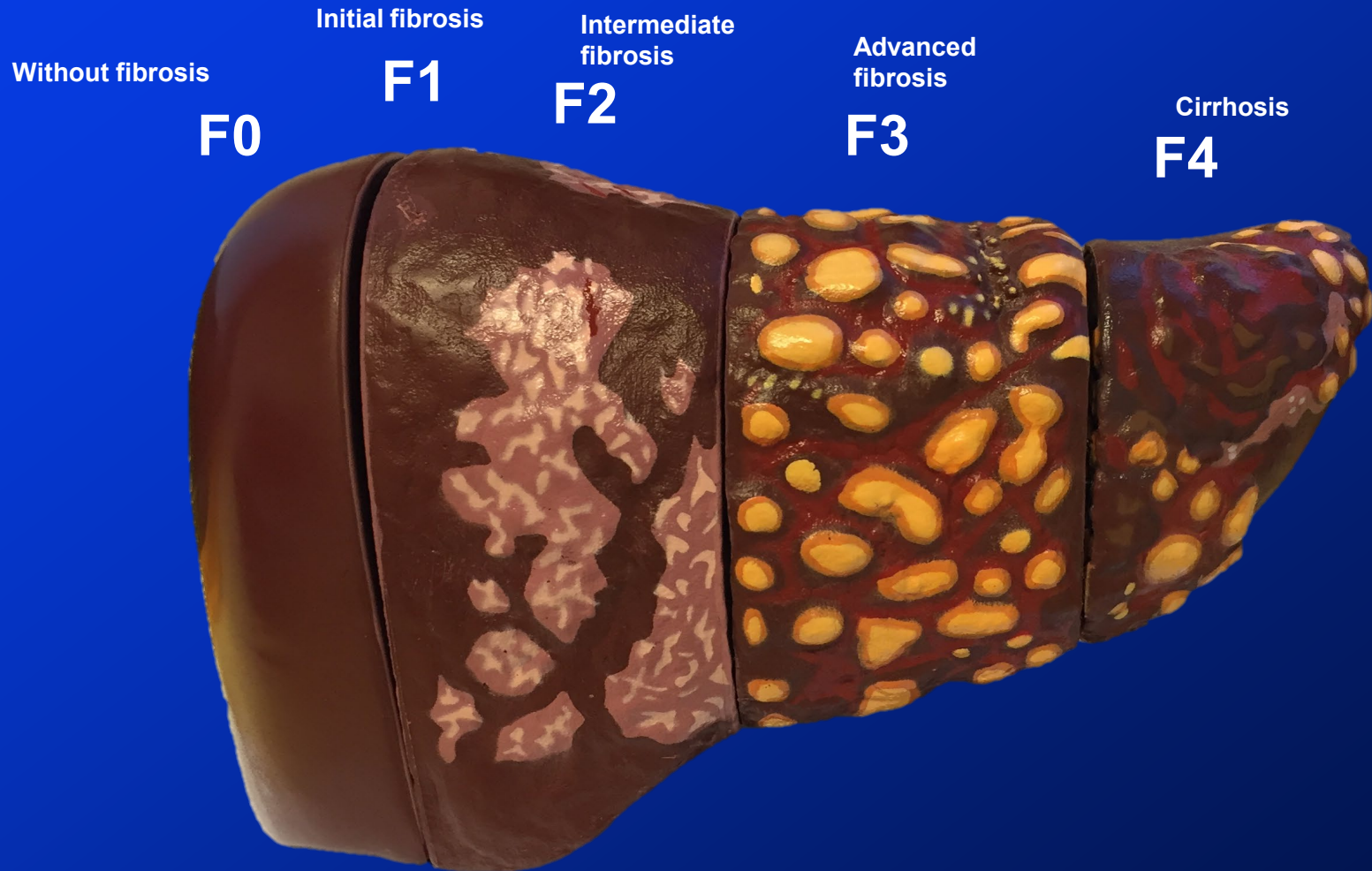
Shear Wave

$$c_t = \sqrt{\frac{E}{3\rho}}$$

$c_t = 1-10$ m/s in tissue

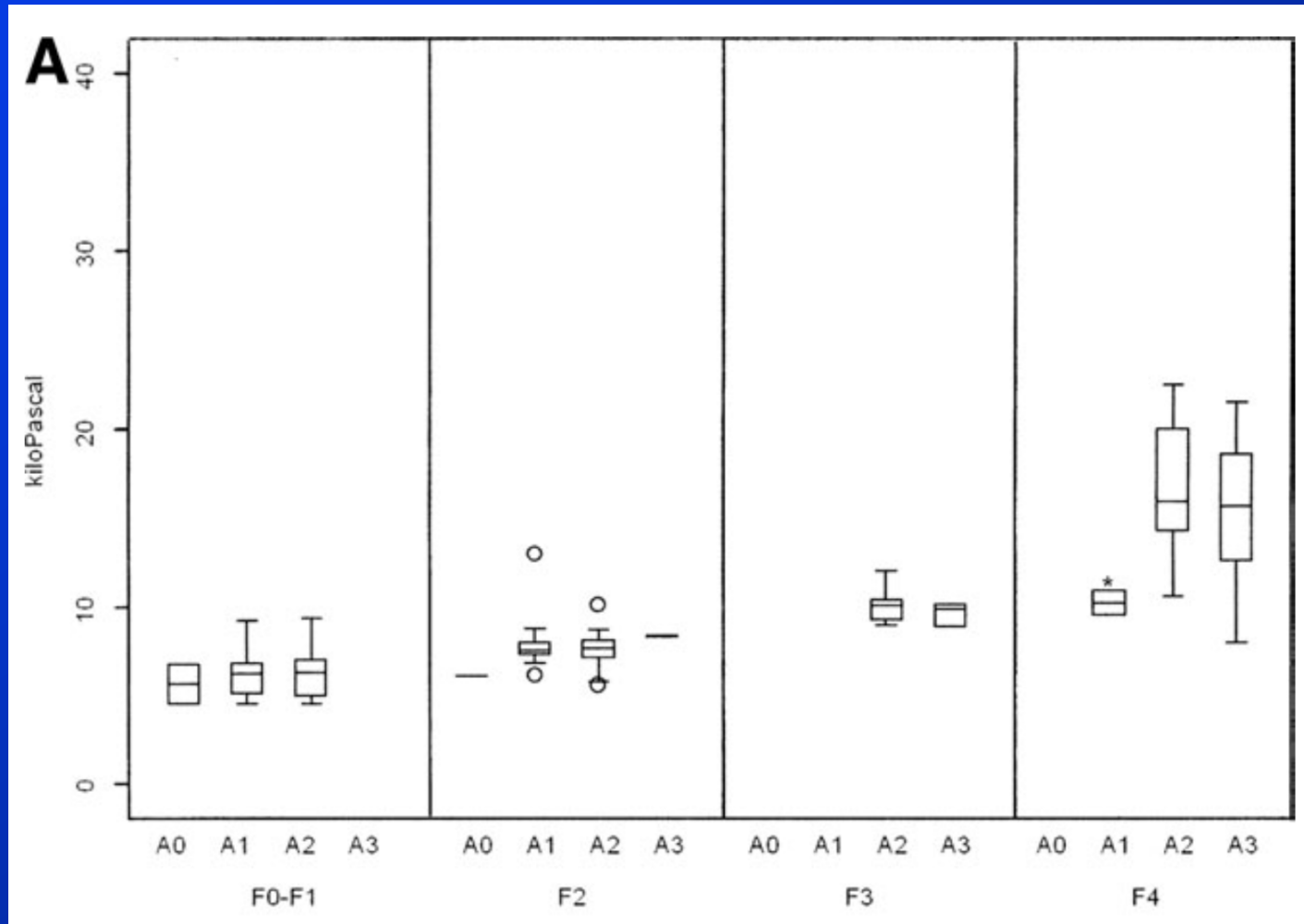


The Metavir Score





SWE correlation with F0-4 score





GL on Liver elastography - 2017

Guidelines & Recommendations

Thieme

EFSUMB Guidelines and Recommendations on the Clinical Use of Liver Ultrasound Elastography, Update 2017 (Long Version)

EFSUMB-Leitlinien und Empfehlungen zur klinischen Anwendung der Leberelastographie, Update 2017 (Langversion)

29 recommendations

Authors

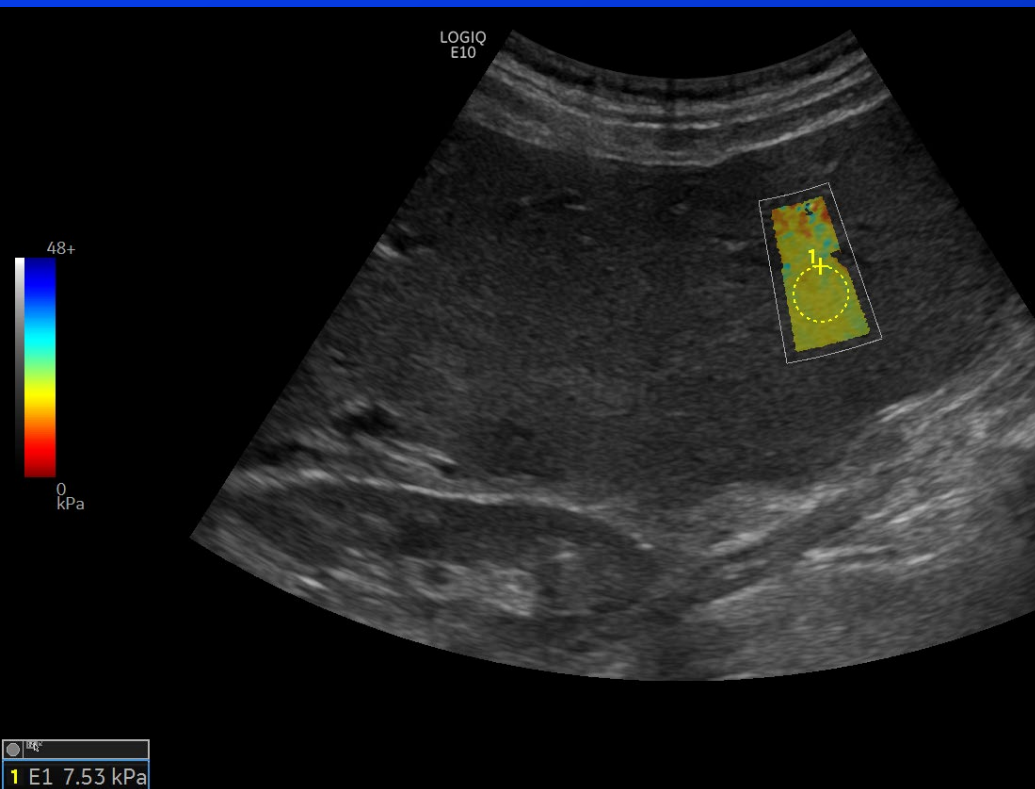
Christoph F. Dietrich^{1,2}, Jeffrey Bamber³,
Annalisa Berzigotti⁴, Simona Bota⁵, Vito Cantisani⁶,
Laurent Castera⁷, David Cosgrove⁸, Giovanna Ferraioli⁹,
Mireen Friedrich-Rust¹⁰, Odd Helge Gilja¹¹,
Ruediger Stephan Goertz¹², Thomas Karlas¹³, Robert de
Knegt¹⁴, Victor de Ledinghen¹⁵, Fabio Piscaglia¹⁶,
Bogdan Procopet¹⁷, Adrian Saftoiu¹⁸, Paul S. Sidhu¹⁹,
Ioan Sporea²⁰, Maja Thiele²¹

Affiliations

- 13 Department for Internal Medicine, Division of Gastroenterology and Rheumatology, University Hospital Leipzig, Leipzig, Germany
- 14 Department of Gastroenterology and Hepatology, Erasmus MC University Medical Center, Rotterdam, the Netherlands
- 15 Non-invasive diagnosis of liver fibrosis centre, Haut-Leveque hospital, Bordeaux University Hospital, Pessac, France
- 16 Unit of Internal Medicine, Dpt of Medical and Surgical Sciences, University of Bologna, S. Orsola, Bologna, Italy



Elastography – F1



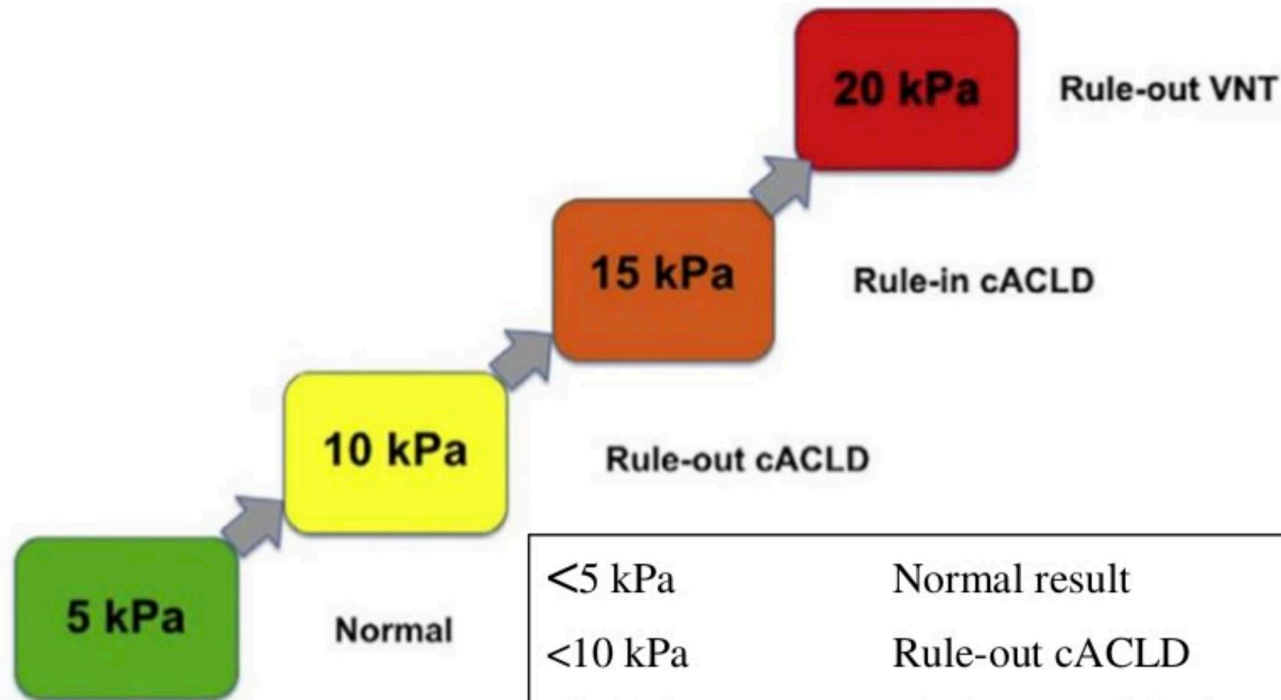
Haukeland
03/03/21 09:50:20

ADM

Parameter	Value	m1	m2	m3
B Mode Measurements				
Stiffness, kPa				
E1	7.30 kPa	7.53	7.30	
E2	7.49 kPa	7.49		
E3	7.73 kPa	7.73		
E4	7.18 kPa	7.18		
E5	7.54 kPa	7.54		
E6	7.88 kPa	7.88		
E7	7.81 kPa	7.81		
E8	7.83 kPa	7.83		
E9	7.93 kPa	7.93		
E10	7.86 kPa	7.86		
E Median	7.77 kPa			
E IQR	0.35 kPa			
E IQR/Median	4.5 %			



Rule of 5 in Elastography



<5 kPa	Normal result
<10 kPa	Rule-out cACLD
10-15 kPa	cACLD (need further confirmation)
15-20 kPa	Rule-in cACLD
> 20 kPa	Rule-in clinically significant PHT

cACLD: compensated advanced chronic liver disease – kPa: kilopascal

VNT: varices needing treatment

de Franchis R, Baveno VIF. J Hepatol 2015;63:743–752.



GE cut-offs of elasto measurements

LOGIQ E9 Shear Wave Elastography



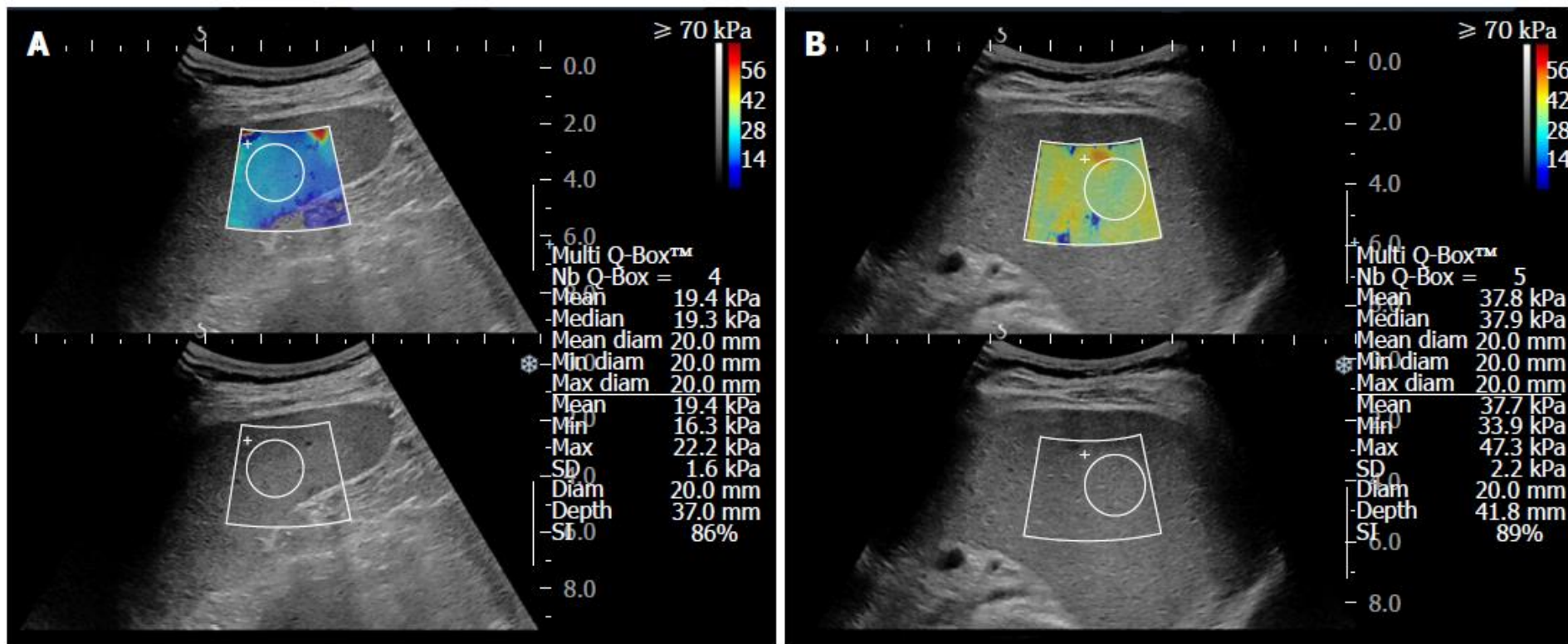
Liver Fibrosis Staging

Liver Fibrosis Staging	Metavir Score	kPa	m/s
Normal – Mild	F1	5.48 kPa – 8.29 kPa	1.35 m/s – 1.66 m/s
Mild – Moderate	F2	8.29 kPa – 9.40 kPa	1.66 m/s – 1.77 m/s
Moderate – Severe	F3	9.40 kPa – 11.9 kPa	1.77 m/s – 1.99 m/s
Cirrhosis	F4	> 11.9 kPa	> 1.99 m/s

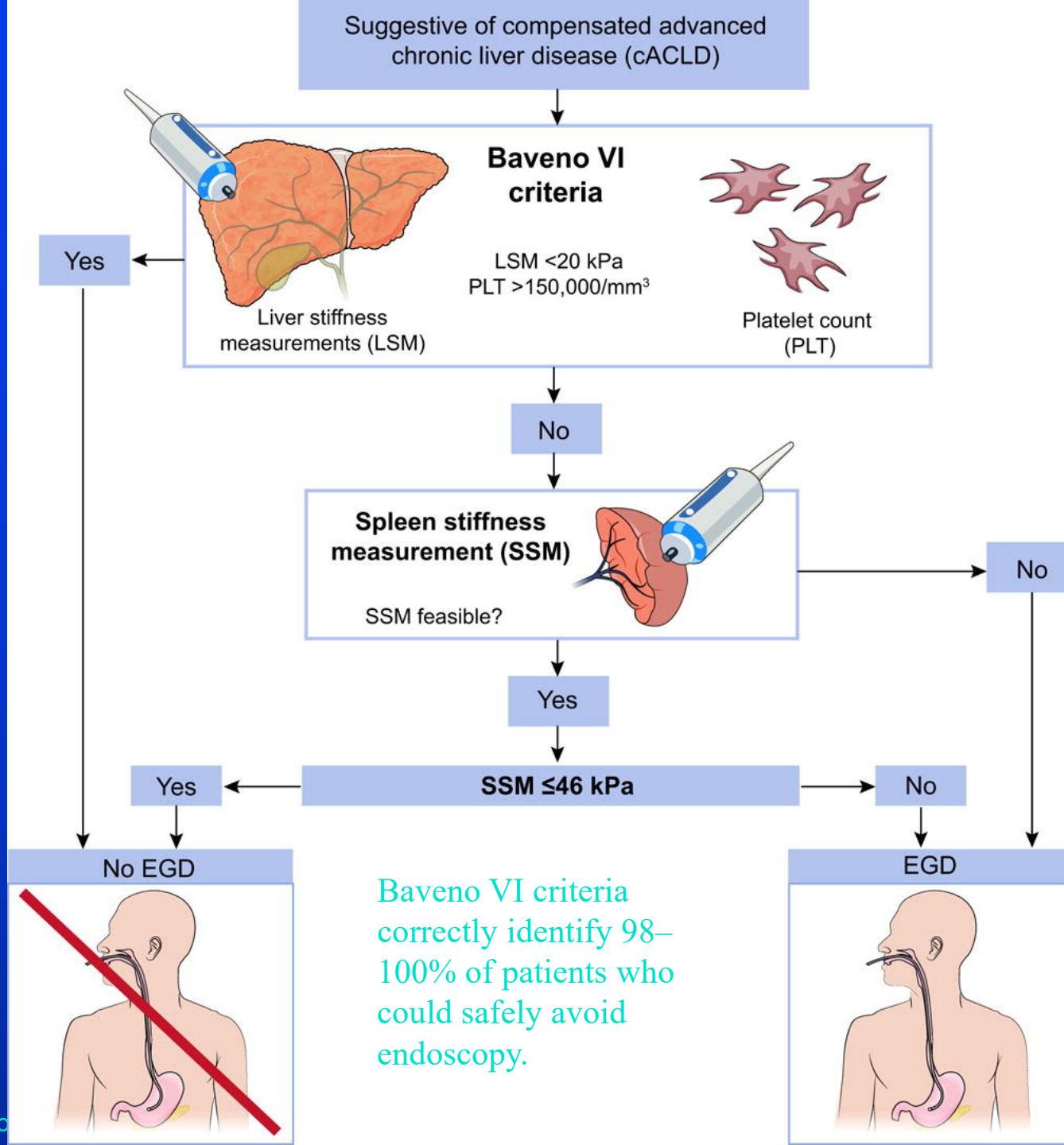
A GE study has demonstrated that LOGIQ™ E9 Shear Wave Elastography is a robust technique and capable of evaluating stiffness changes in the liver associated with fibrosis. Although a limited number of subjects were evaluated at the hospital in this study, liver stiffness measurements were shown to be useful for discriminating different stages of fibrosis. It is important to note that a small number of subjects with intermediate stages of fibrosis were evaluated in this study, and that a mix of disease etiologies were present. Therefore, the values shown may not be directly applicable to other patient populations. Data was acquired using LOGIQ E9 R5.1.0 equivalent software and the C1-6-D probe. For detailed information, please see the LOGIQ E9 Shear Wave Elastography white paper.



SWE of spleen



Spleen two-dimensional shear wave elastography images. Spleen 2D-SWE images of a 50-year-old male patient with normal SS (A) and 57-year-old female patient with liver cirrhosis who underwent endoscopic variceal ligation (B). A. The normal patient had a small size and measurable area of spleen. And the SS was measured to 19.4 kPa. B. Patient with liver cirrhosis had relatively large size and measurable area of spleen with good sonographic window. Increased spleen stiffness compared with that of normal patients was identified (37.7 kPa). 2D-SWE: Two-dimensional shear wave elastography; SS: Spleen stiffness. Jeong JY, Cho YS, Sohn JH. Role of two-dimensional shear wave elastography in chronic liver diseases: A narrative review. *World J Gastroenterol* 2018; 24(34): 3849-3860





Spleen SWE

Tab. 1

METAVIR score of liver fibrosis based on spleen elastography

Author	Spleen stiffness in kPa				
	F0	F1	F2	F3	F4
Leung et al.	17.3 ± 2.6	19.4	19.8	20.6	22
Rewisha et al.	19.41 ± 3.63		25.56 ± 5.36		46.19 ± 16.29
Giunta et al.	-	-	36	-	46
Grgurevic et al.	-	23	24		35



Ultrasound elastography

- Correlates well with histology regarding fibrosis
- Easy to perform
- Prolongs the US exam only with 2 min
- Provides valuable information to the clinician
- CT does not give data on liver stiffness
- MR elastography has low availability, is expensive and time consuming



Conclusion

- Ultrasound is very useful in the evaluation of liver fibrosis and cirrhosis
- Elastography is non-invasive and useful
 - saves some liver biopsies
- Many indirect US criteria for portal HT
- Ultrasound Doppler enables estimation of portal HT indirectly
 - Portal vein velocity: <13 cm/sec
 - Portal vein diameter: >13 mm



One stop shopping

- US B-mode
- Doppler
 - Color flow
 - Pulsed Doppler
- Elastography
 - Shear wave
 - Strain imaging
- CEUS
- US-guided biopsy

