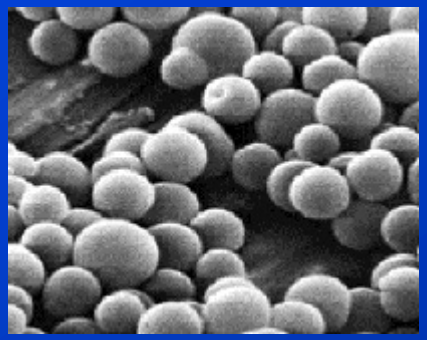
Nasjonalt Senter for
Gastroenterologisk Ultrasonografi

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

The use of ultrasound in liver diseases



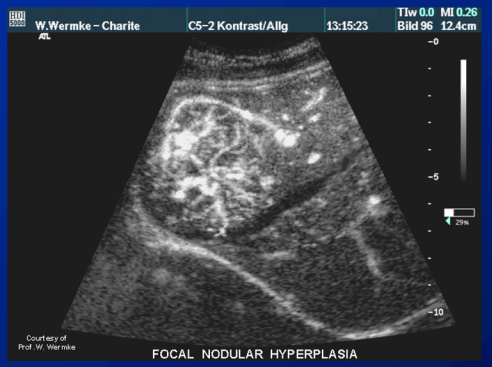
Odd Helge Gilja, MD, PhD

Professor

Department of Medicine

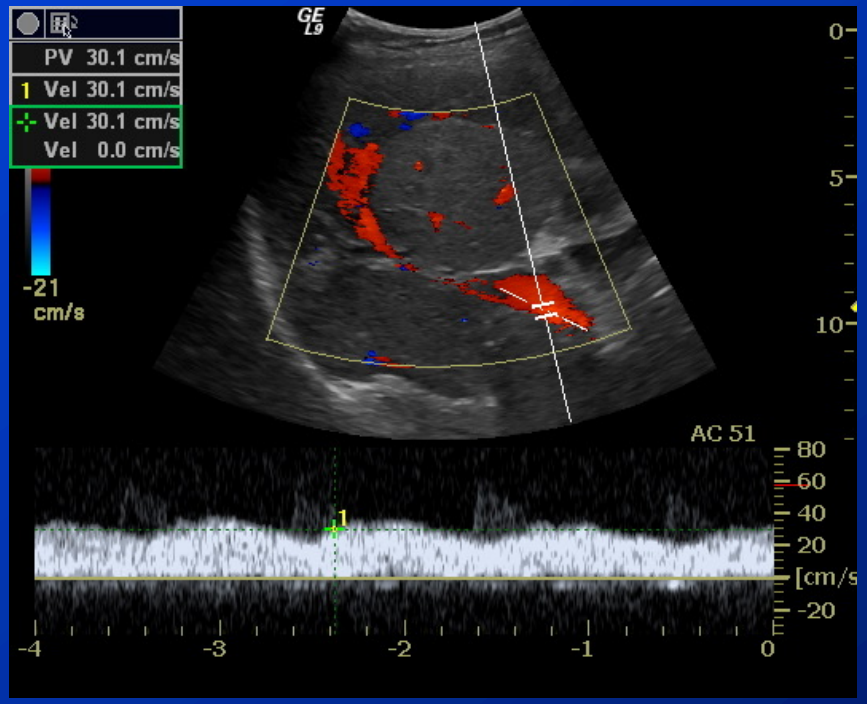
Haukeland University Hospital

Bergen, Norway



The Ultrasound Tool-box

- Ultrasound of liver
  - B mode
  - B-Flow
  - Doppler
    - Color Doppler
    - Pulsed Doppler
  - Elastography
    - Strain imaging
    - Shear wave
  - Contrast-US (CEUS)

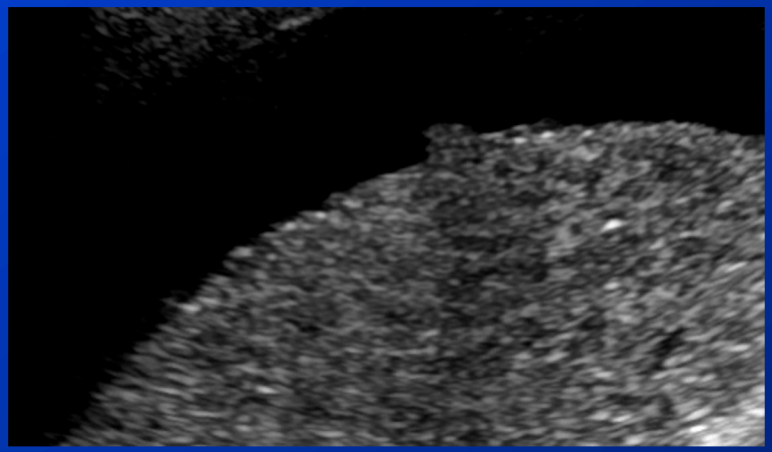


- US-guided liver biopsy (Menghini and Pistol)
- US-guided ablation techniques
- Sonoporation therapy

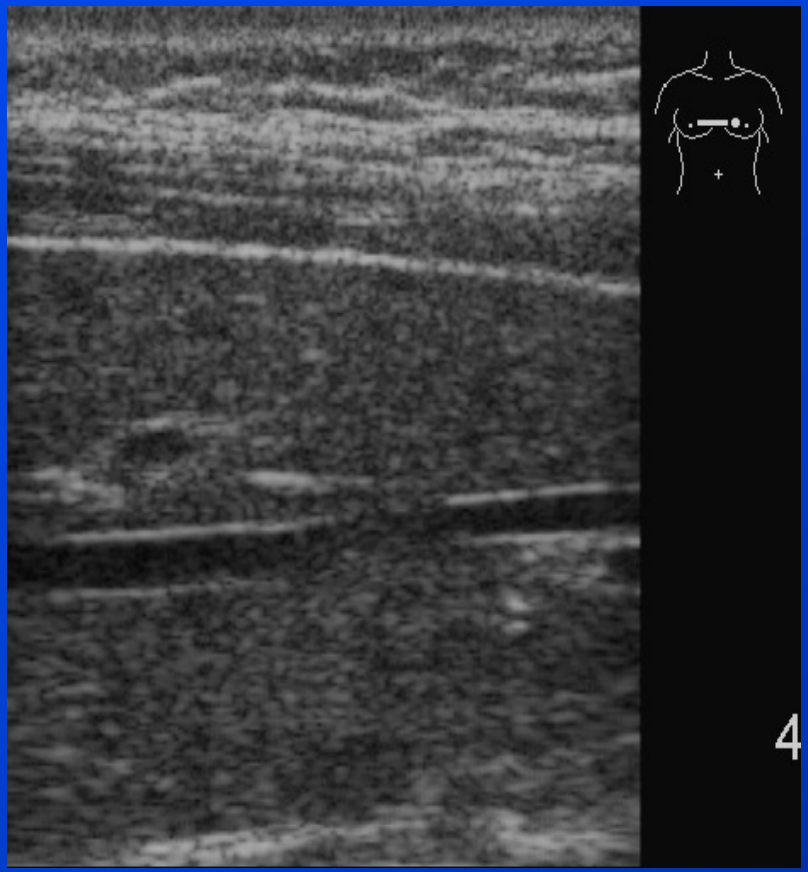
Ultrasound of the Liver

-What do we look for ?

- Echogenicity
- Size, capsule and form
- Any lesions?
- Liver veins
- Portal vein
- Arteria hepatica
- Intrahepatic bile ducts



The Liver capsule



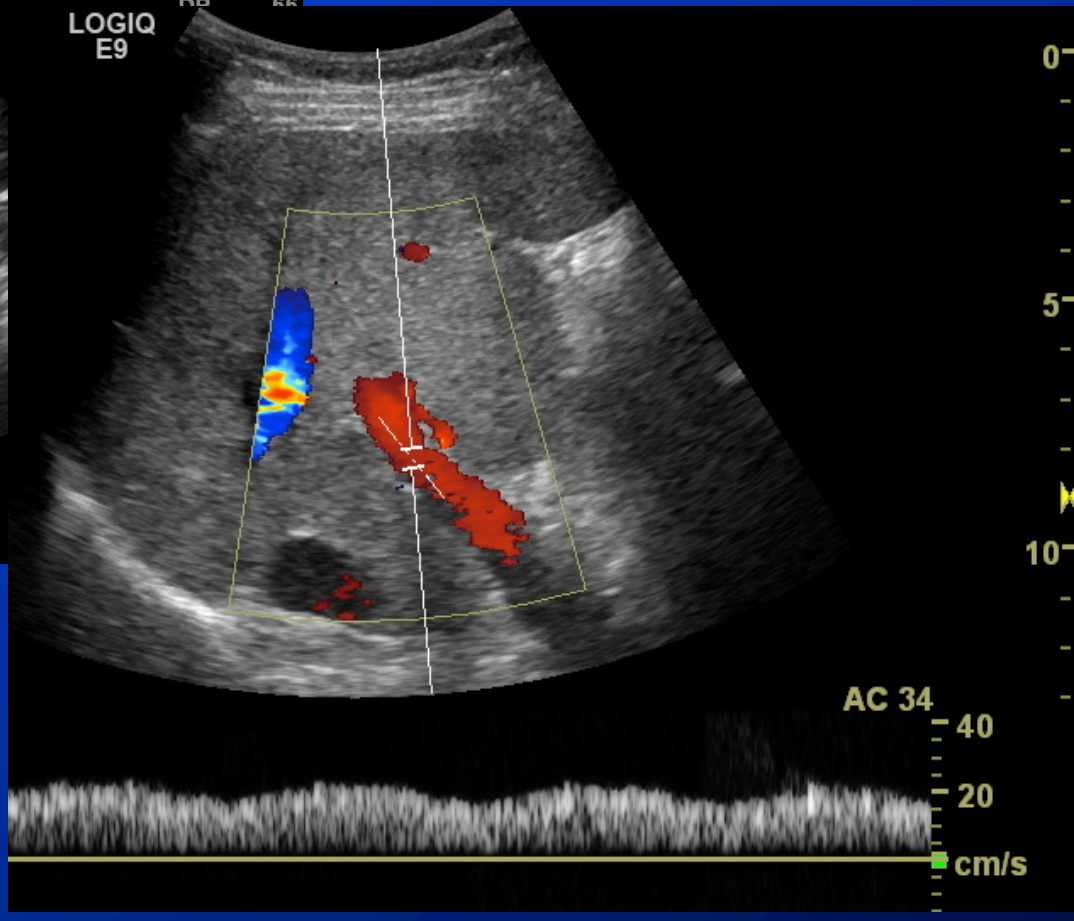
Normal

Cirrhosis

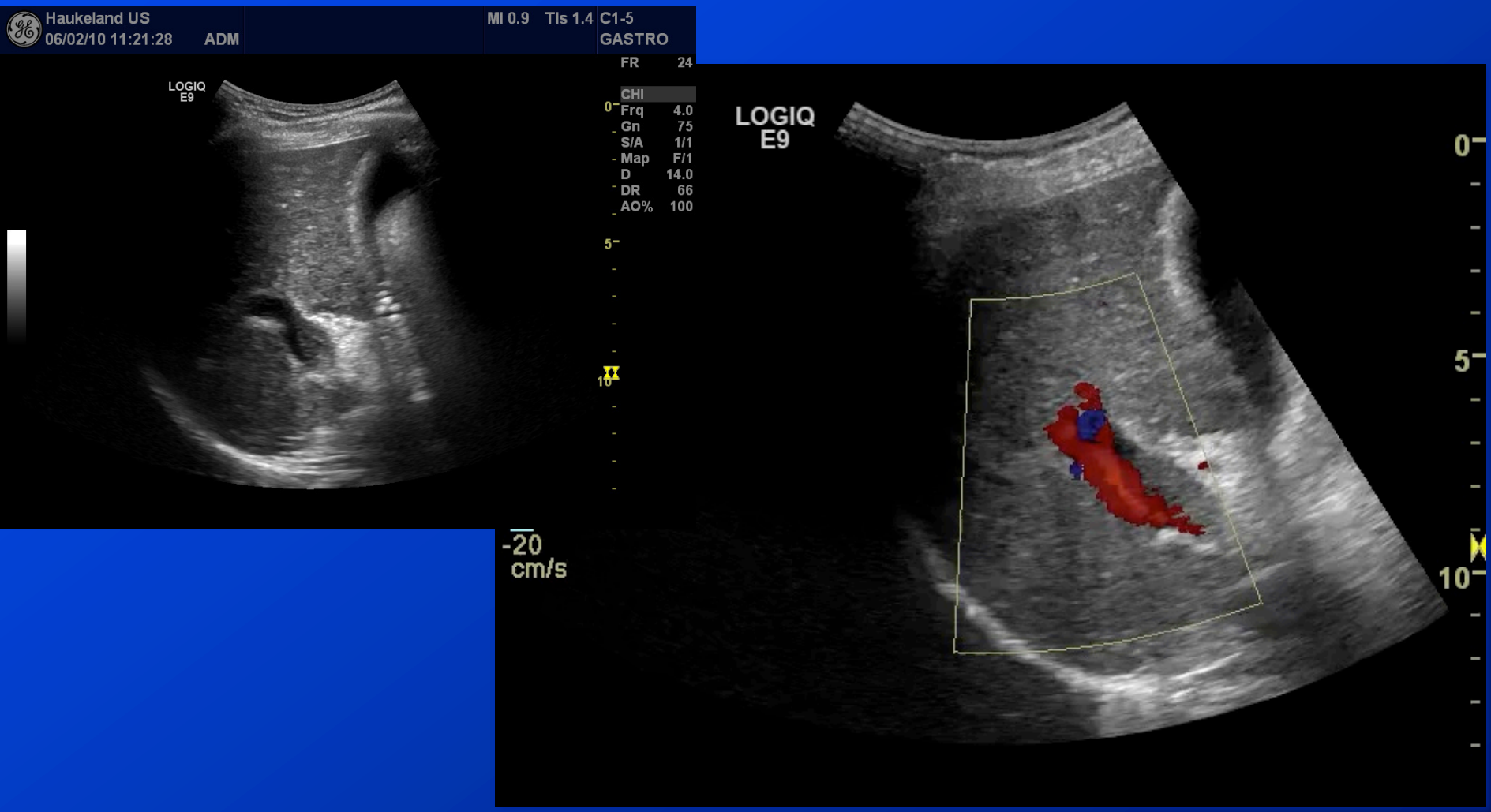
Use high frequency (9-12 MHz)

Vena Porta

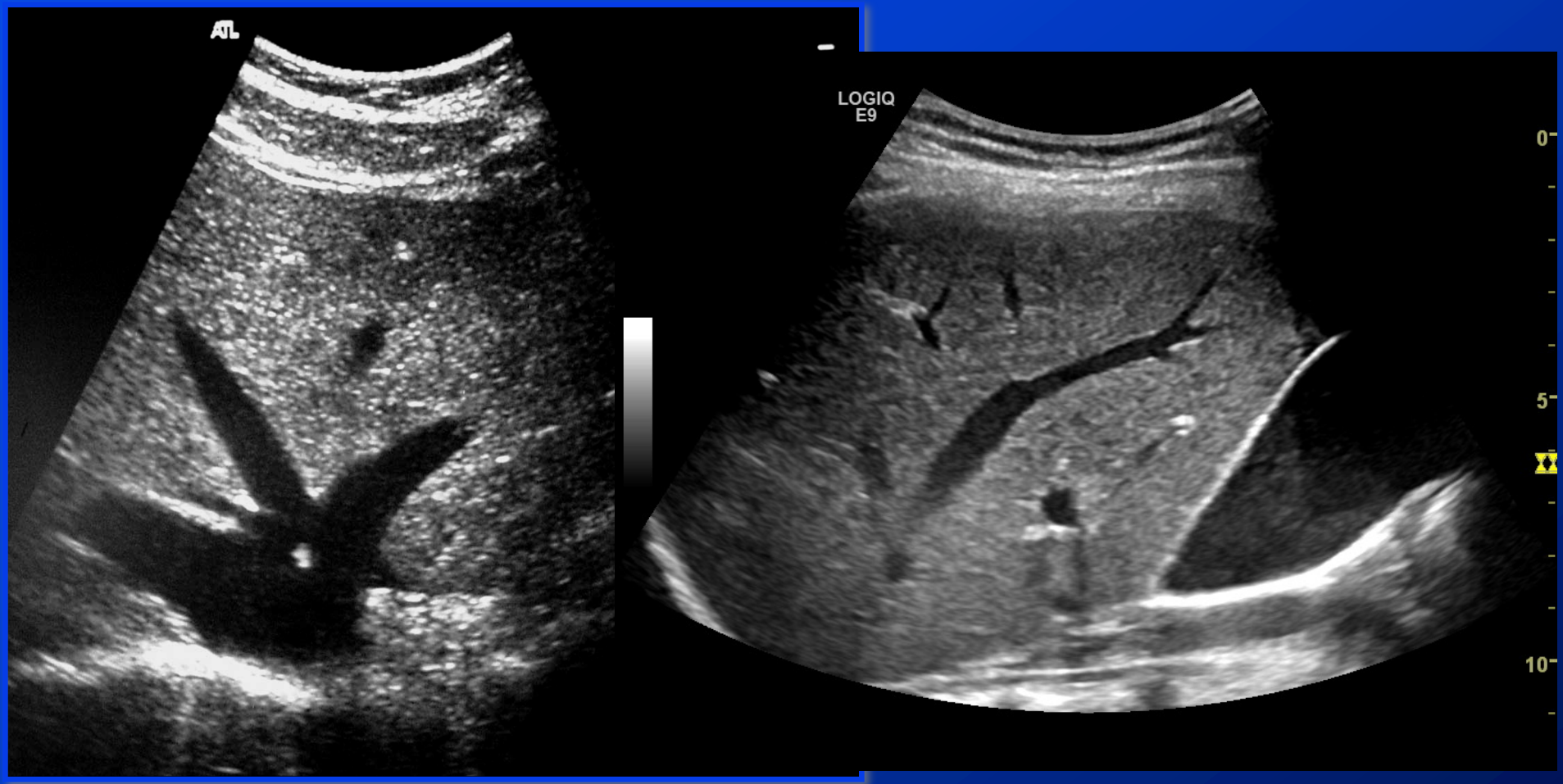

Haukeland US
09/29/10 09:20:35
ADM
MI 1.2
TIs 1.7
C1-5
GASTRO
FR 24
CHI
Frq 5.0
Gn 64
S/A 1/1
Map F/1
D 12.0
LOGIQ
E9


LOGIQ
E9
0
5
10
AC 34
40
20
cm/s

Color Doppler flow in real-time



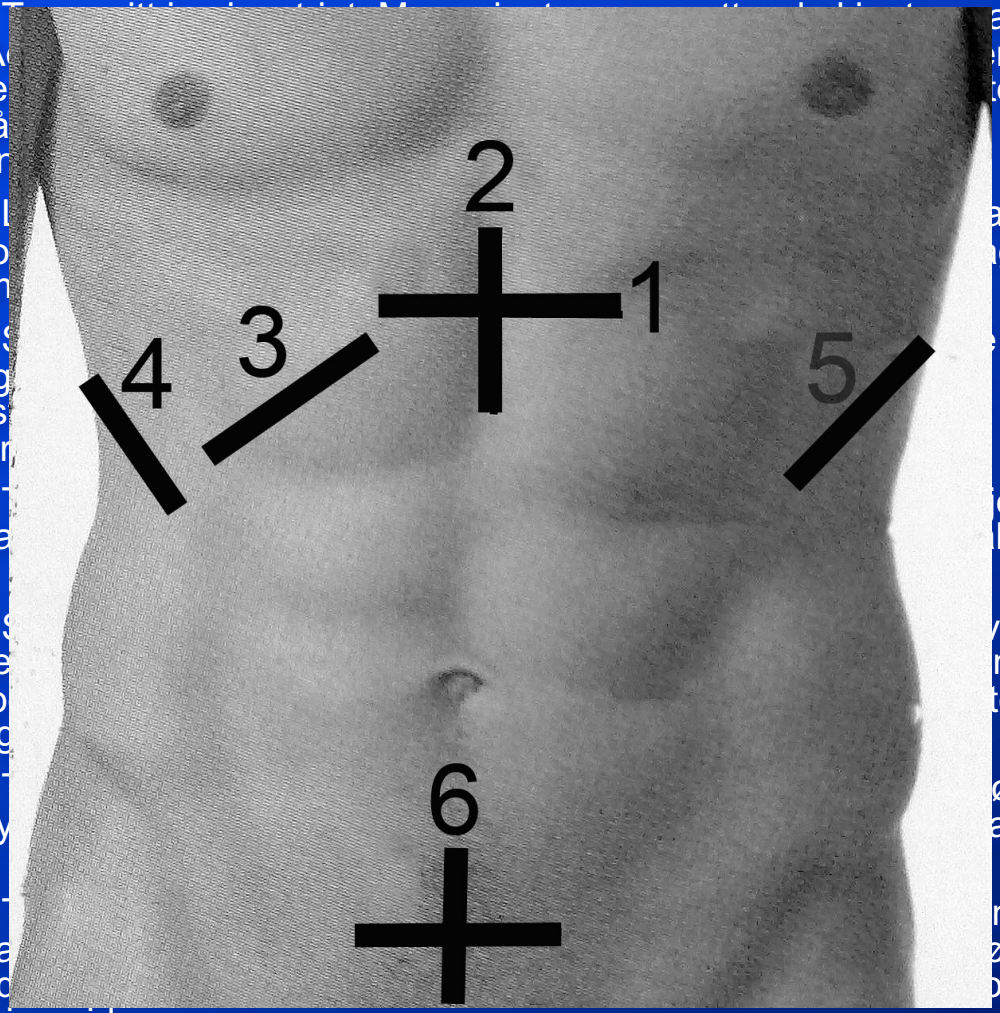
The hepatic veins



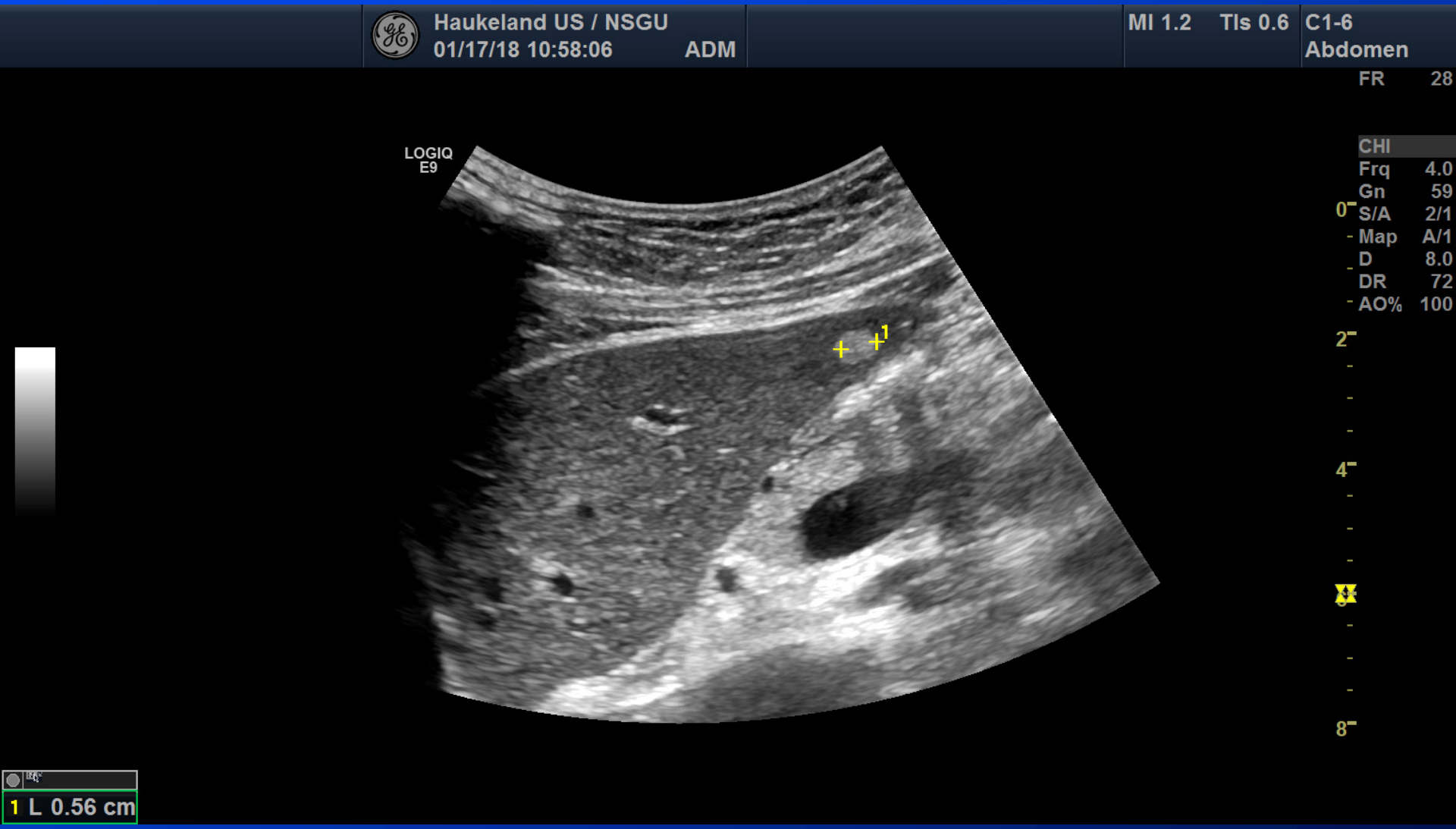
6+

A systematic examination of abdominal organs

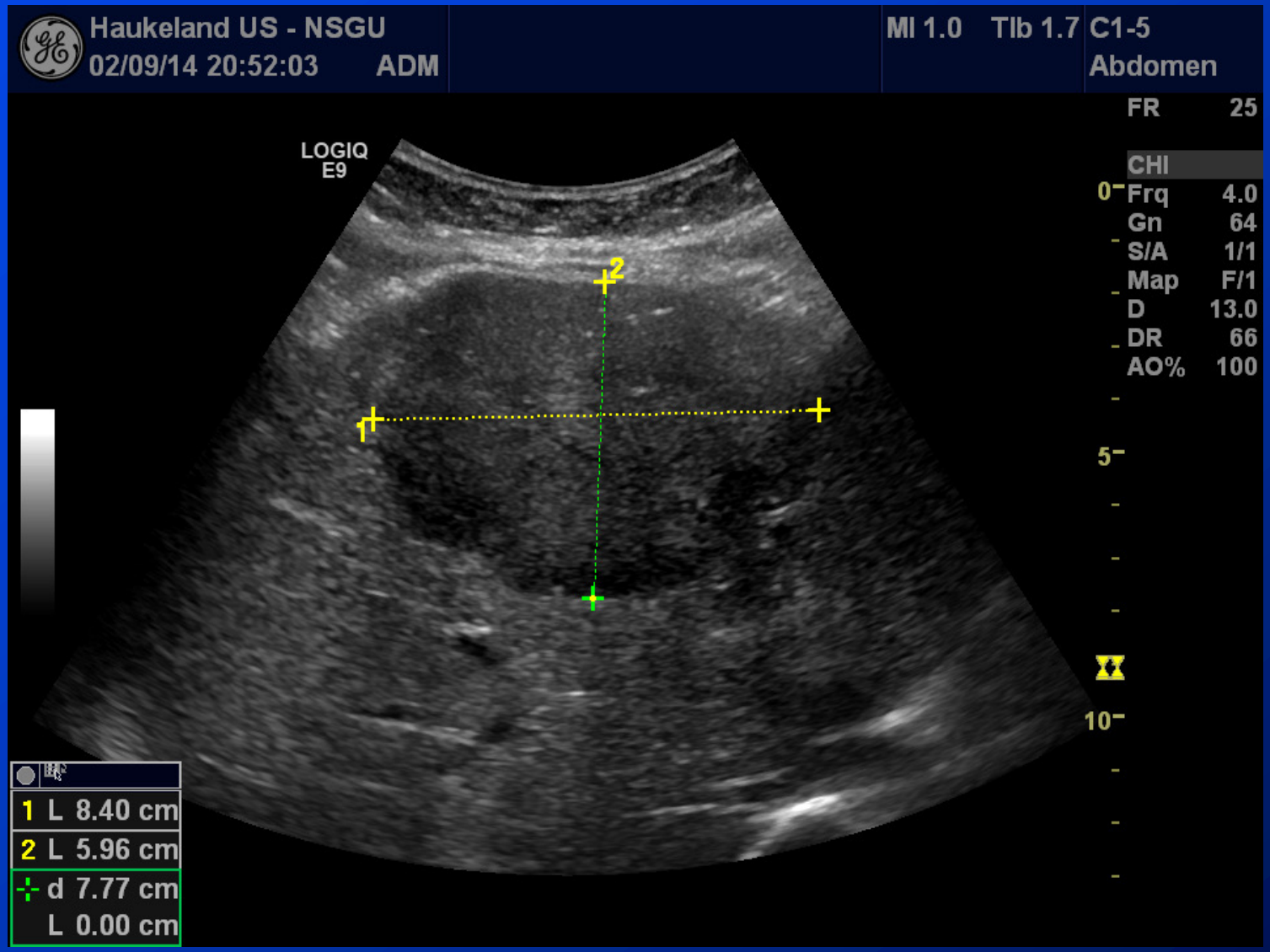
- **Stasjon 1** T… atomiske landemerker: A… r. Man skanner systematisk gje… ten til å puste dypt inn for å få… 2 glass vann å drikke kan noer…
- **Stasjon 2** L… avgående kar i lengderetning o… agesekken (antrum) i samm…
- **Stasjon 3** S… e som gjør at man noen gang… tilfelle undersøkes fas… subcostal vinkling og inter…
- **Stasjon 4** T… ion og grep om lydhodet og ska… lflaten samt intercostalt.
- **Stasjon 5** S… venstre flanke og lokaliserer milte… n fremstilling av nyre fra pol til p… te kunne sees fra venstre flanke g…
- **Stasjon 6** T… økes best når urinblæren er fy… a som regel sees.
- **Stasjon +** T… ning av tarmer for å se etter "ta… øyre fossa iliaca og identifisere c… ecum og i distal retning ned til sigmoideum.



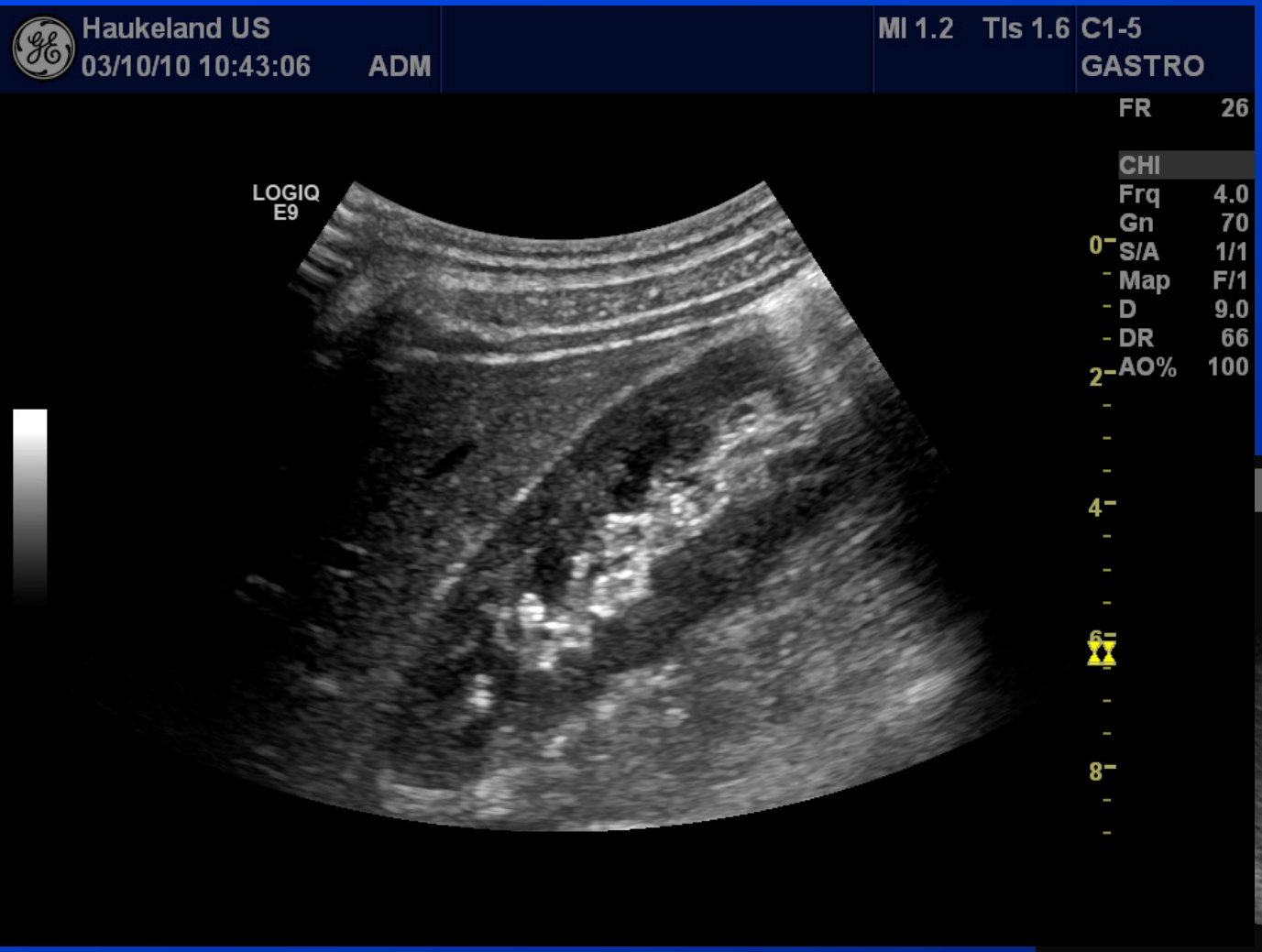
Stasjon 2 – Ve. lobe

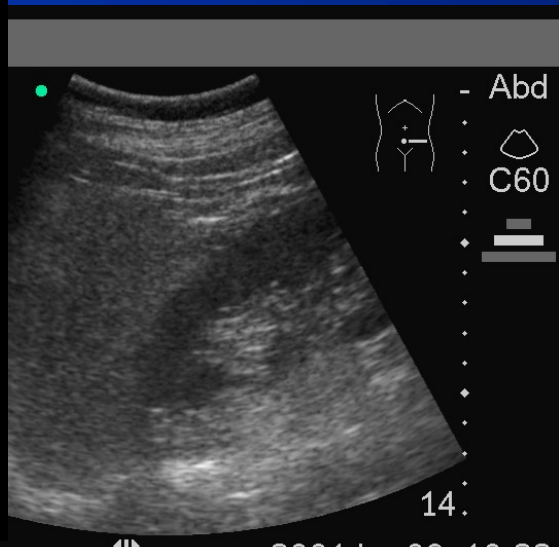


Stasjon 3 – Scanne for FLLs



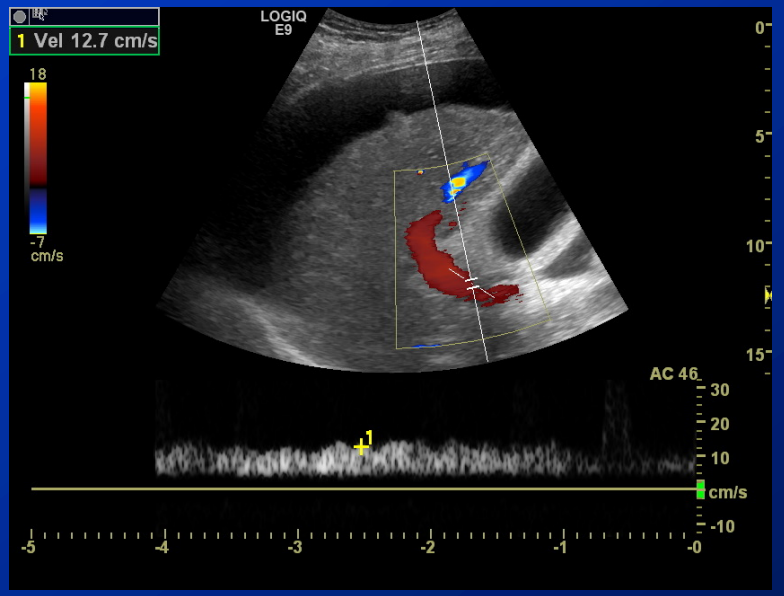
Stasjon 4 - Sammenligne ekkogenisitet lever-nyre





US better than CT

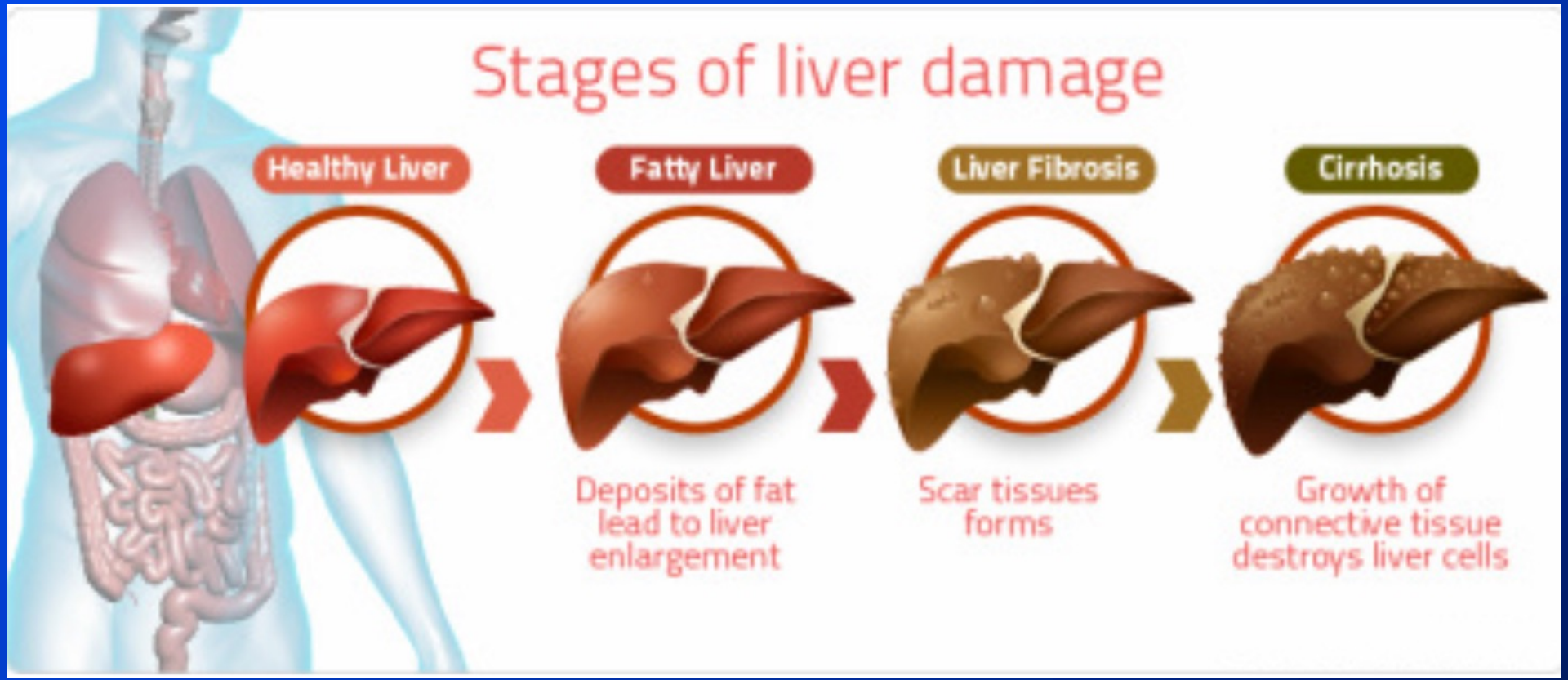
- Small and complex cysts
- Flow evaluation
  - Portal vein trombosis
  - Budd-Chiari
- Cirrhosis evaluation
  - Global liver assessment
  - Portal HT
  - TIPS



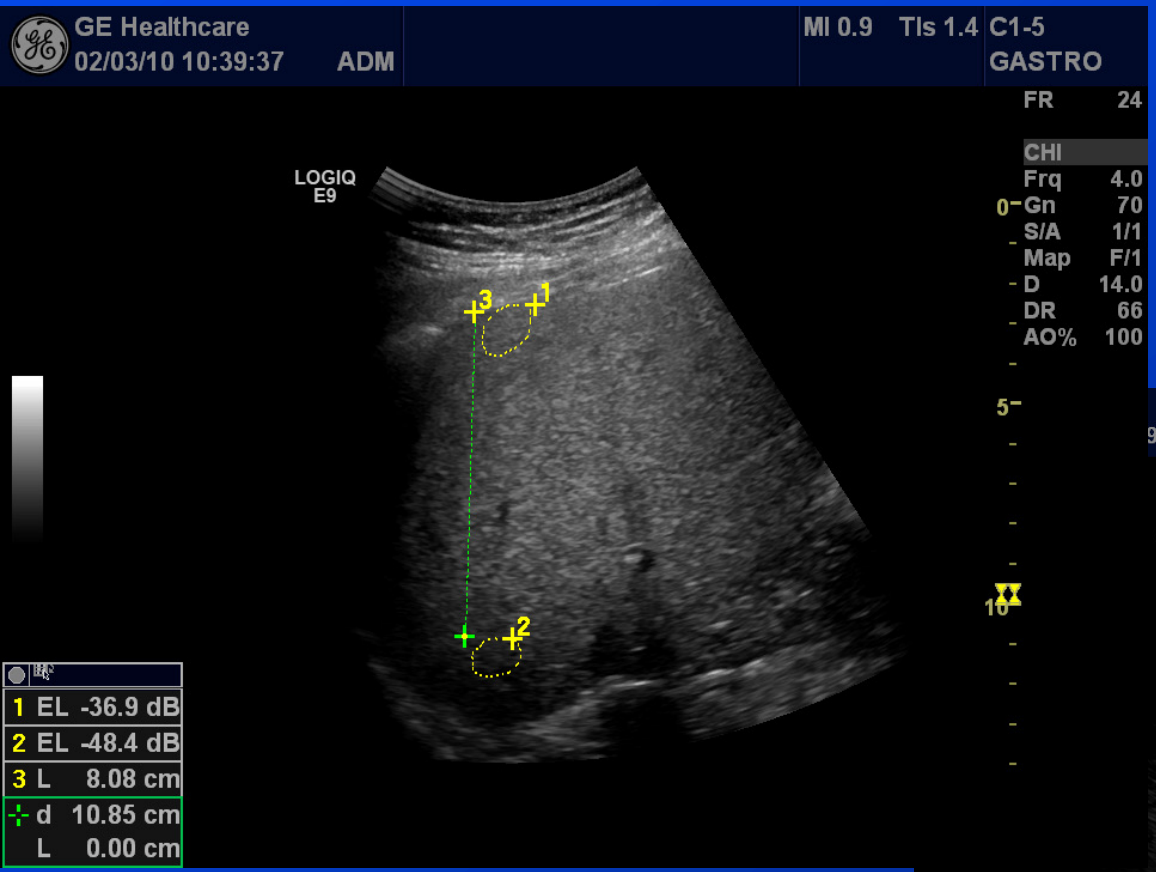
Diffuse Liver Diseases

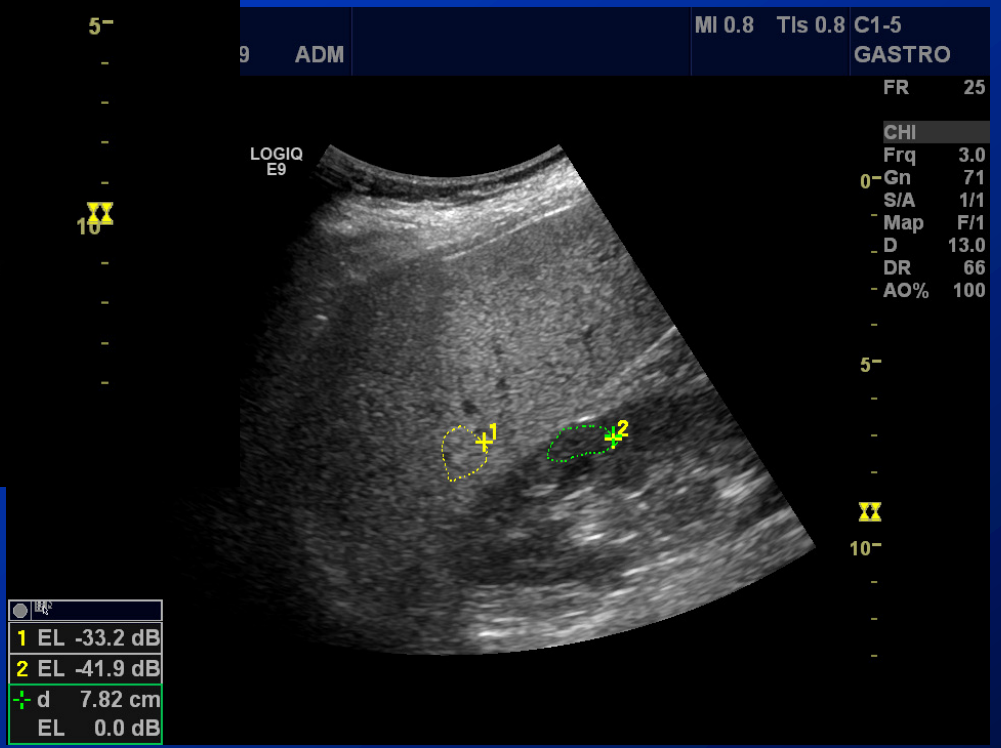
- Steatosis
- Fibrosis
- Cirrhosis

From a healthy liver to cirrhosis

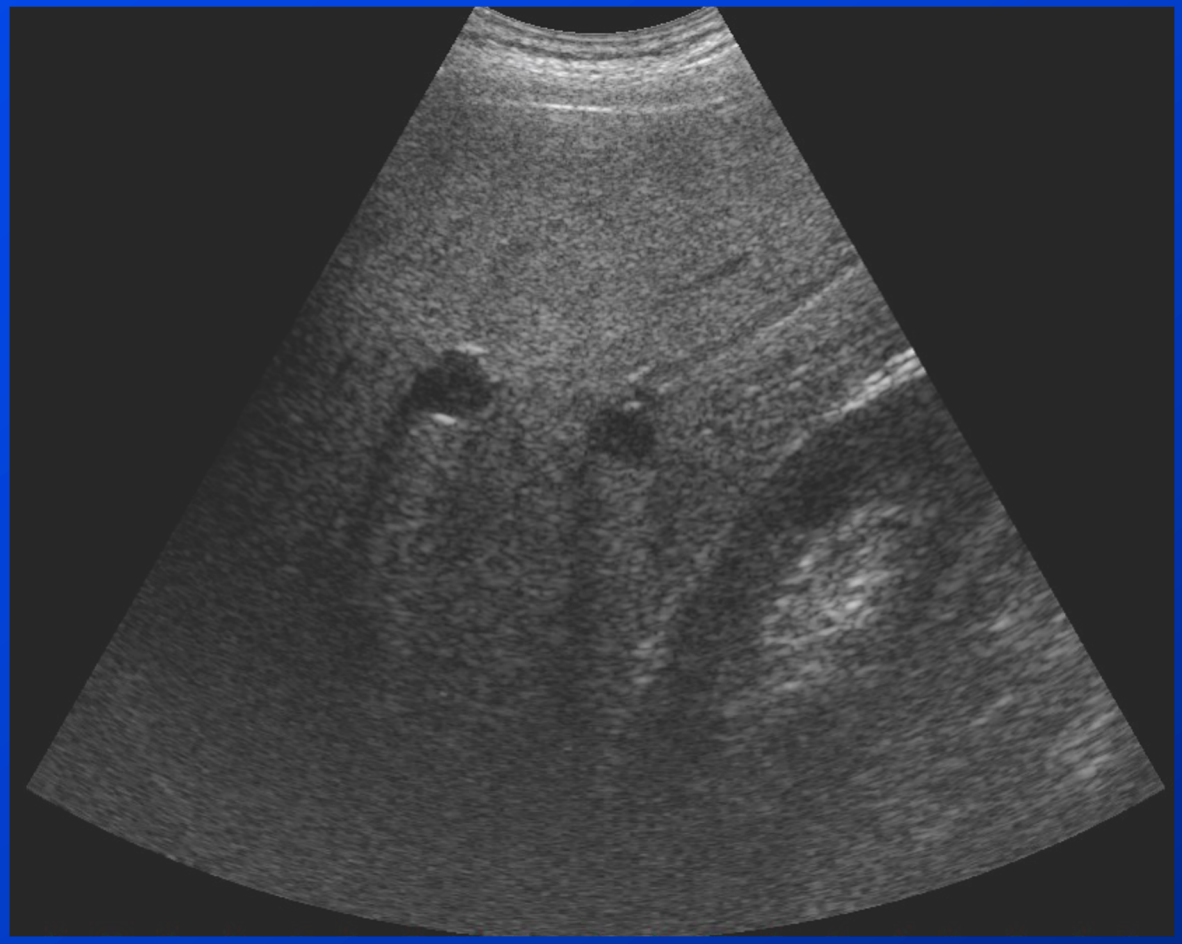


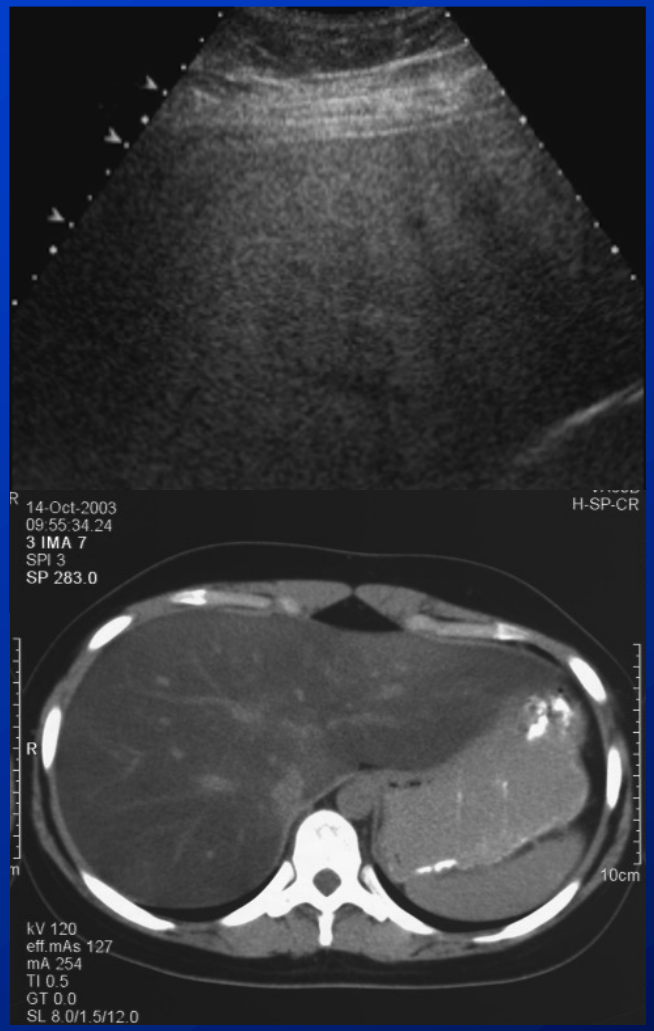
Steatosis with acoustic attenuation





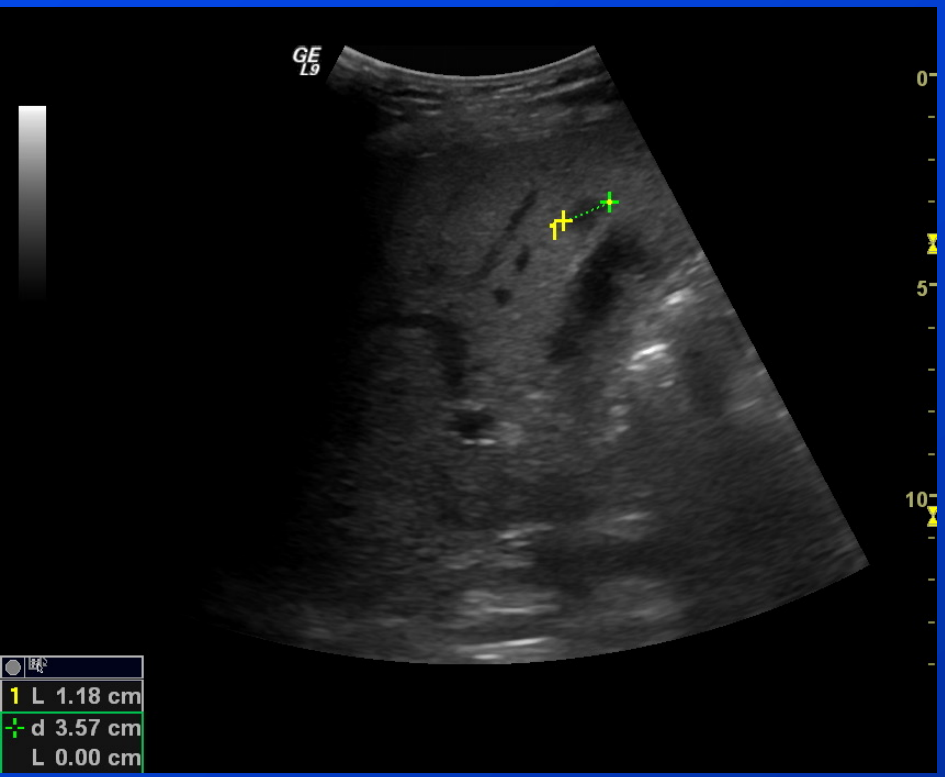
Steatosis grade 3

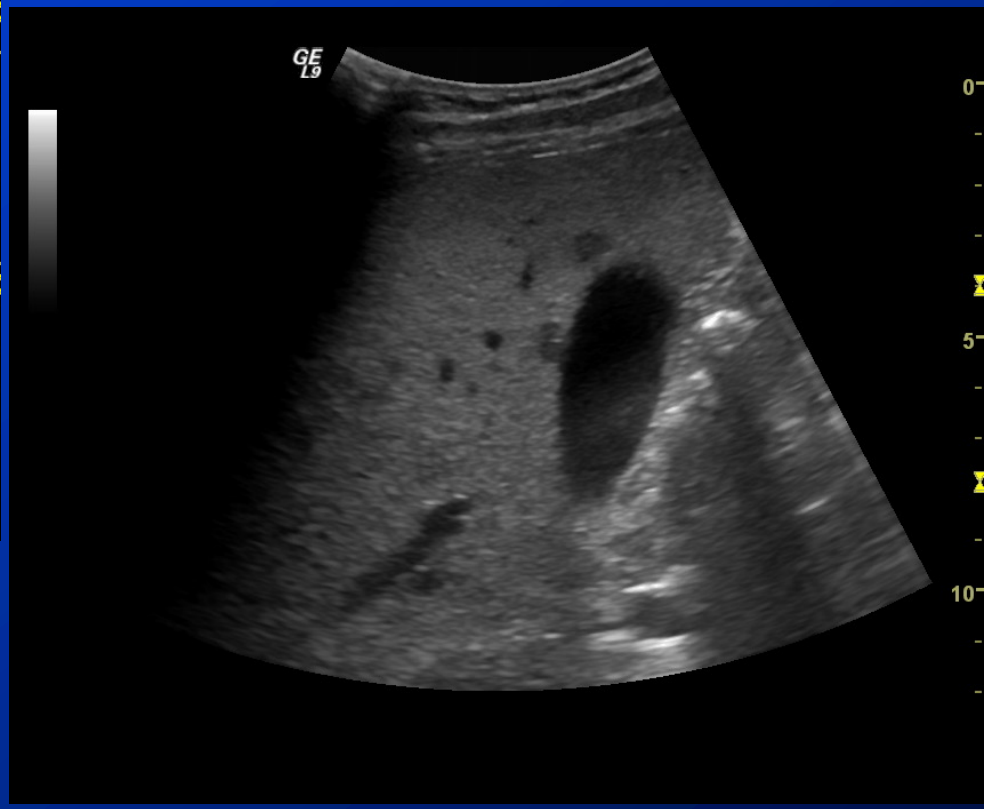




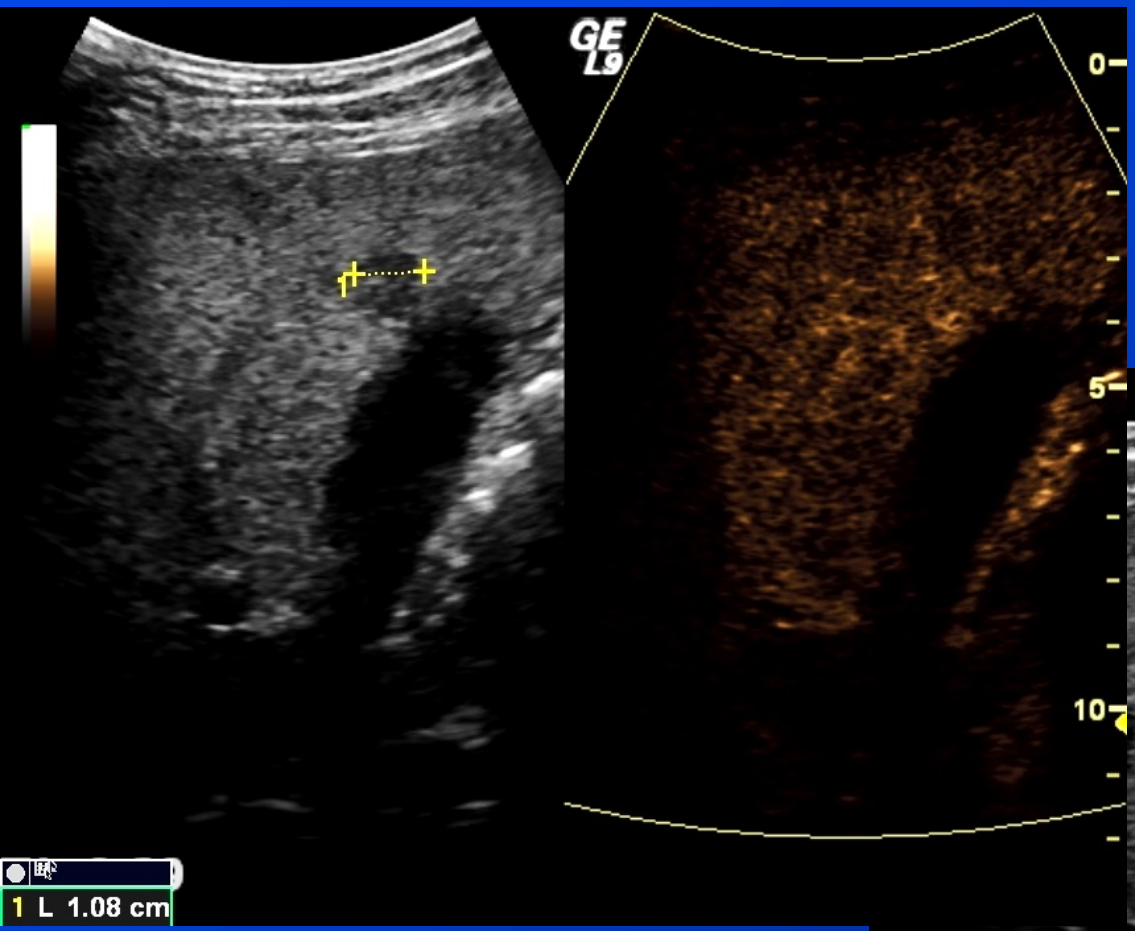
Fatty liver – Dangerous !

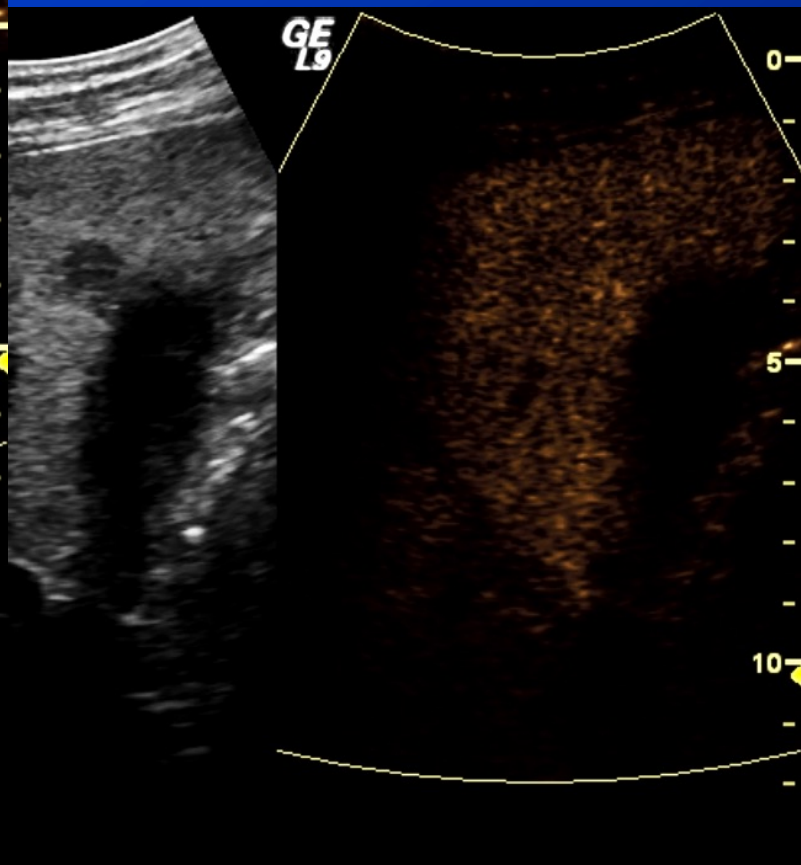
A common problem:
Focal Lesions in Fatty Livers



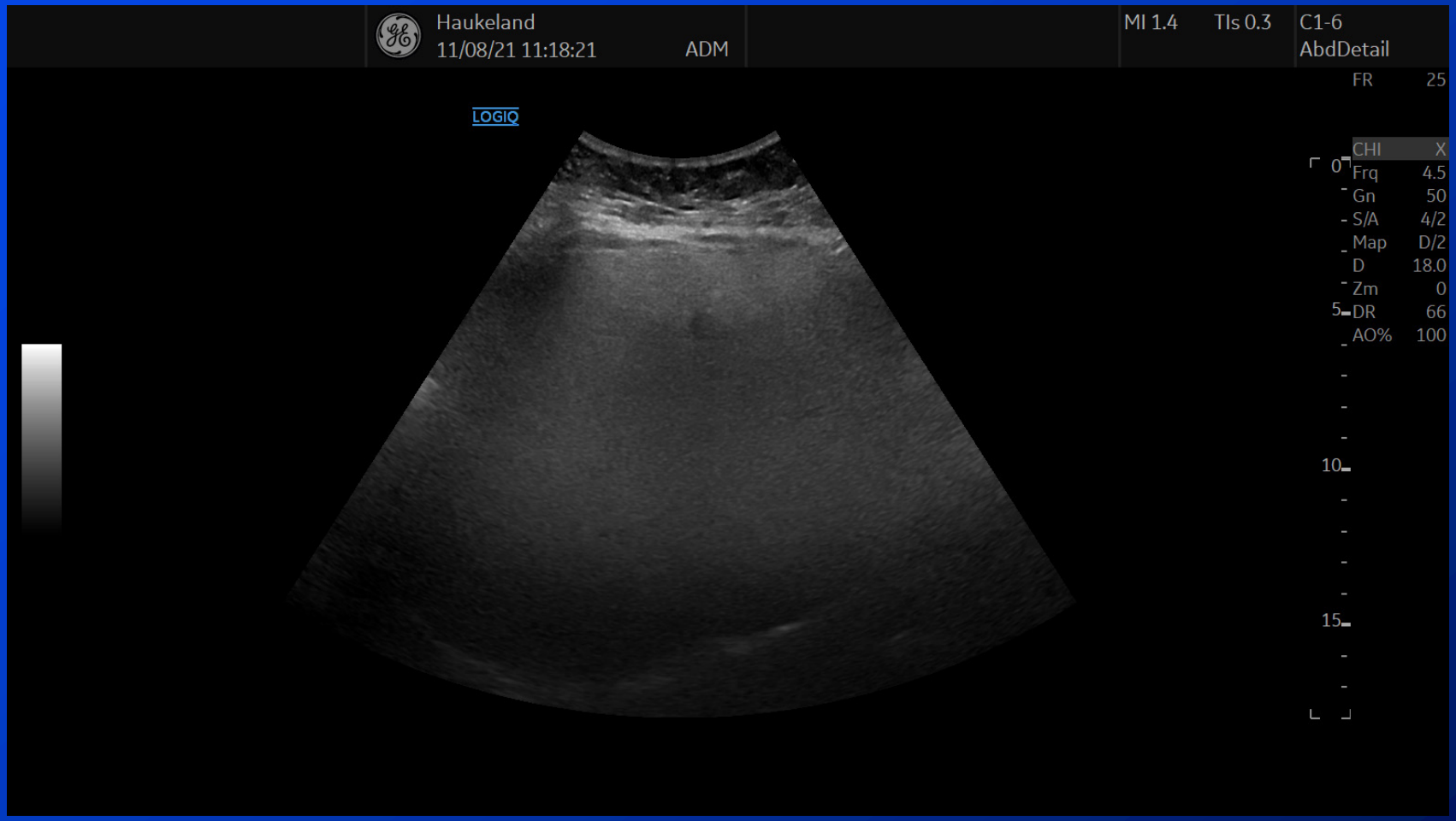


CEUS in Fatty liver





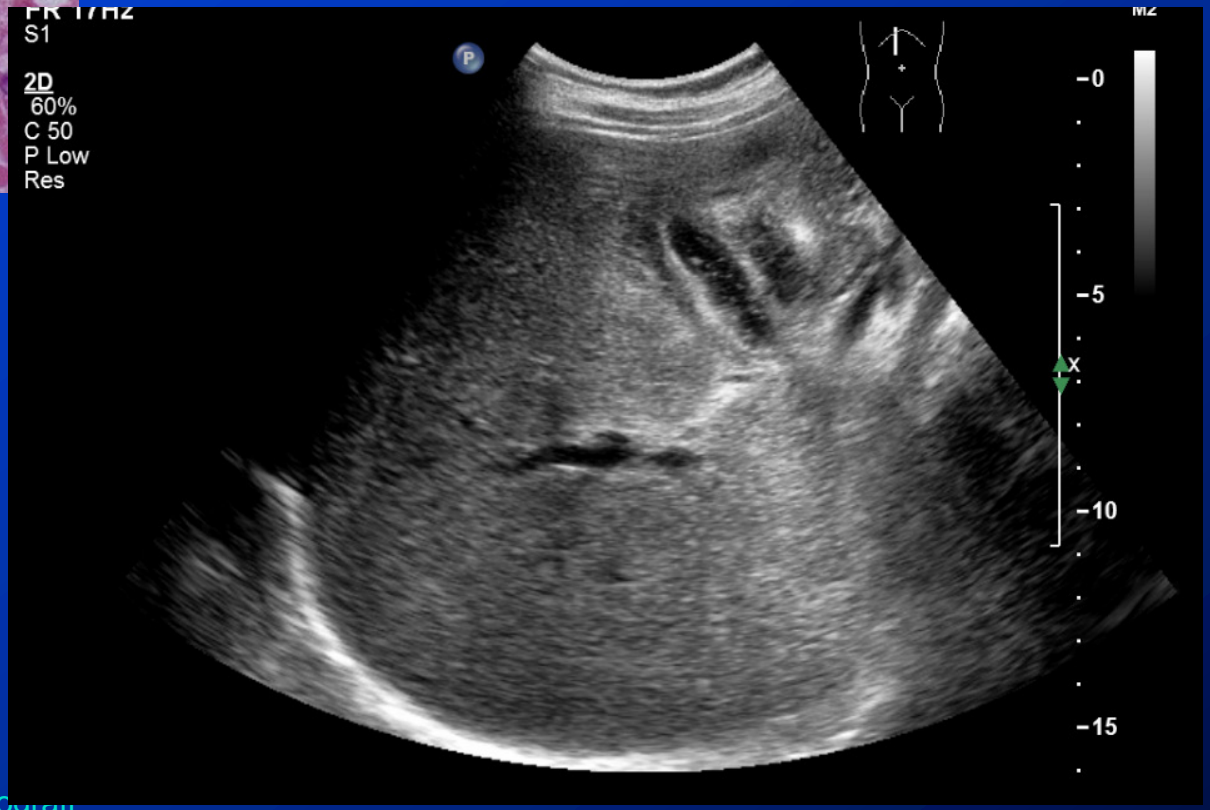
Alcoholic steatosis



Alkoholiske leversykdommer

- Generell parenchymaffeksjon
  - Steatose
  - Hepatitter
  - Fibrose – Cirrhose
- Fokale lesjoner
  - Regenerasjonsknuter - DN
  - HCC

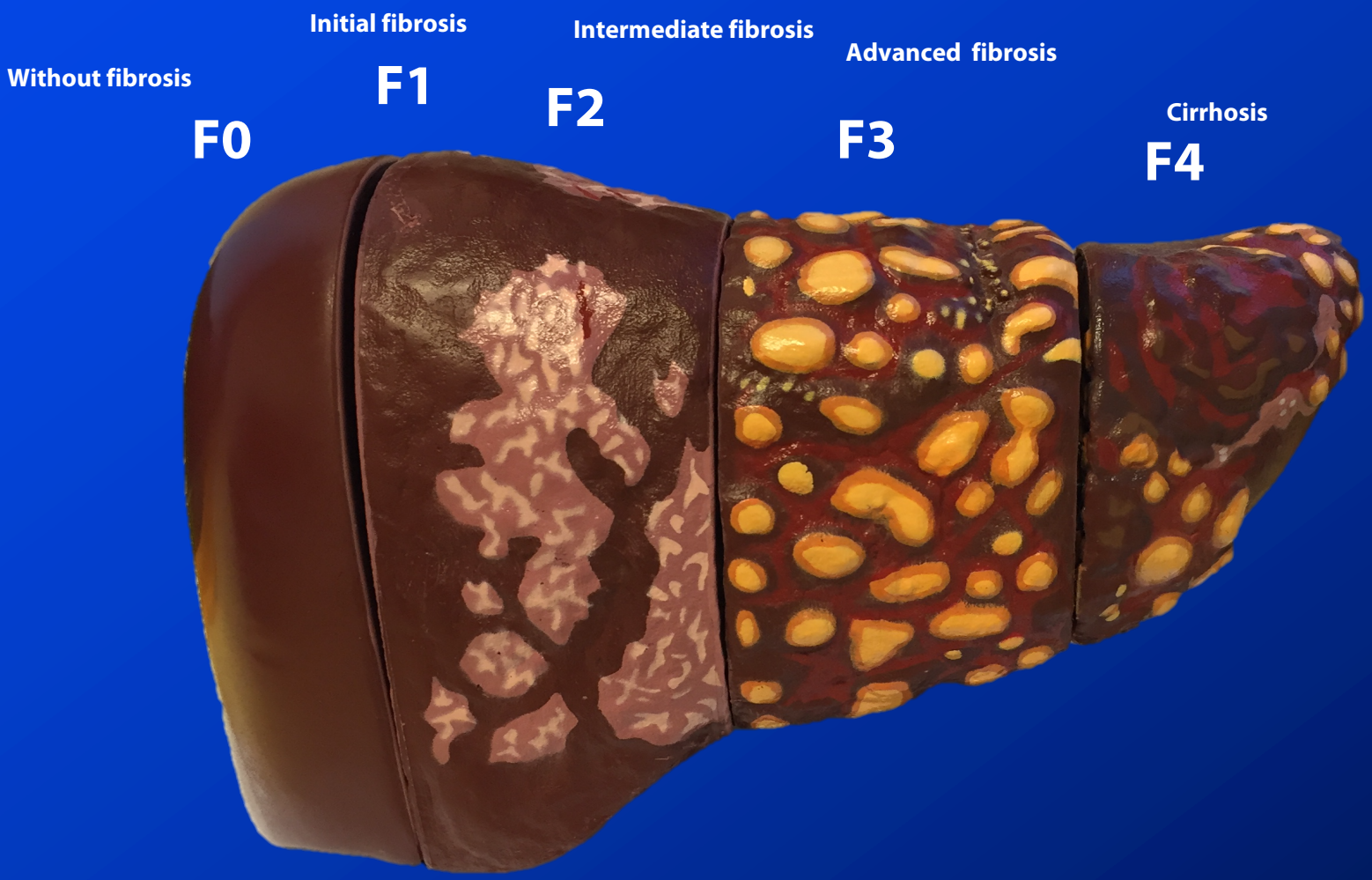
Alkoholisk Hepatitt



Hvordan spørre om Alkoholvaner?

”Jeg drikker bare et glass om dagen, doktor !”

Fibrosis staging
The Metavir Score

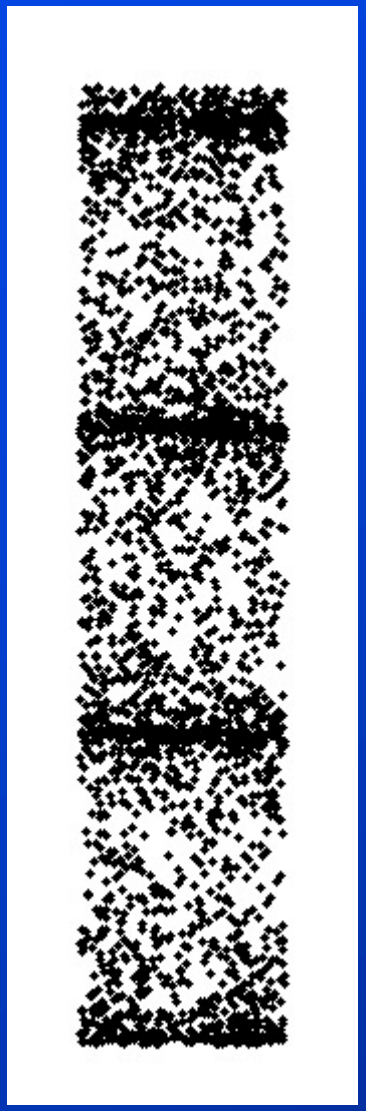


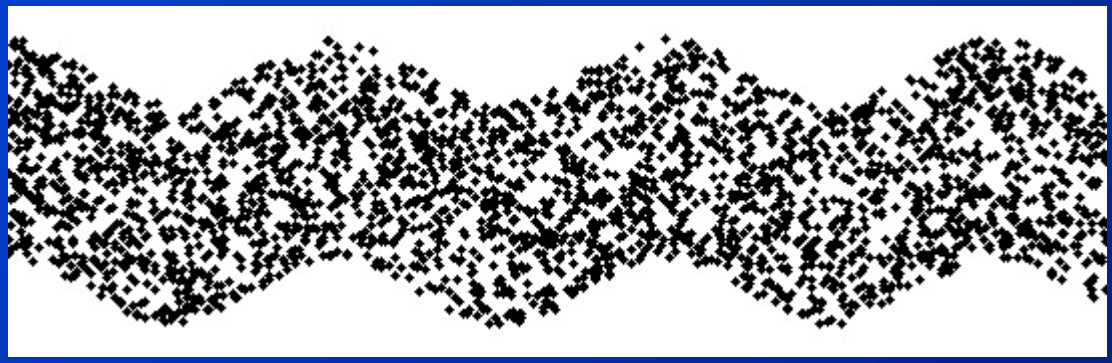
Longitudinal and Shear Waves

Ultrasound Wave

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

$c_l \sim 1540$ m/s in tissue



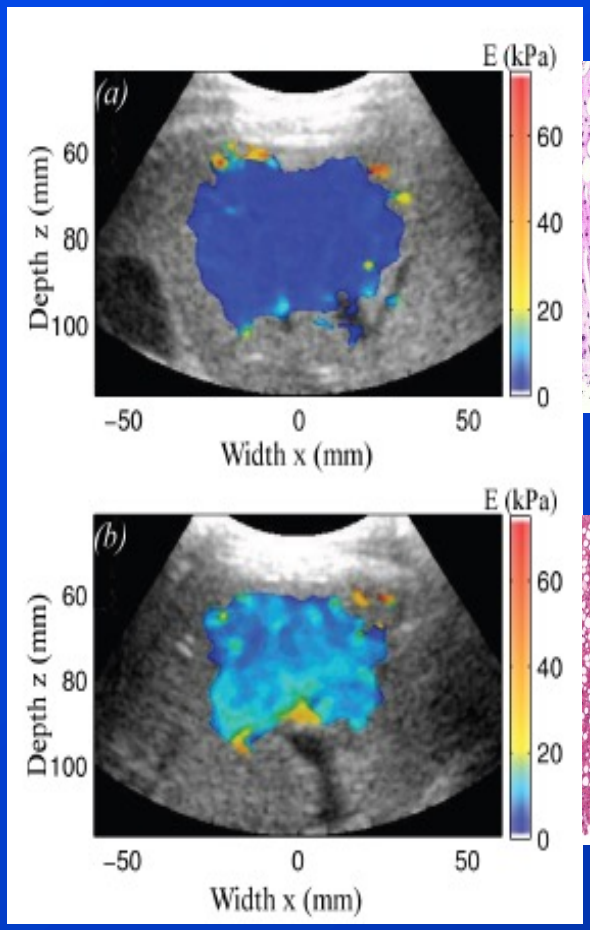


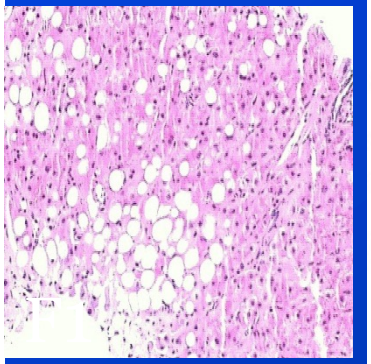
Shear Wave

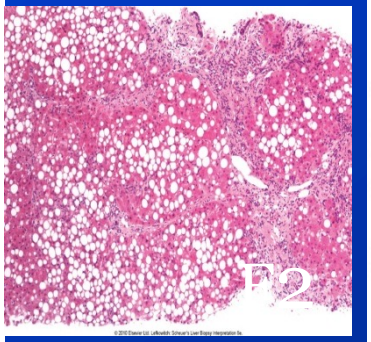
$$c_t = \sqrt{\frac{E}{3\rho}}$$

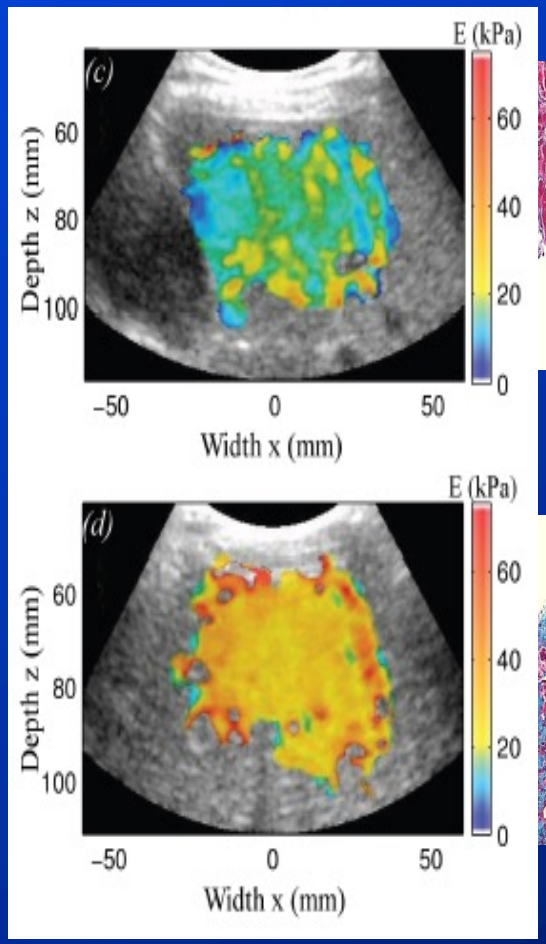
$c_t = 1\text{-}10$ m/s in tissue

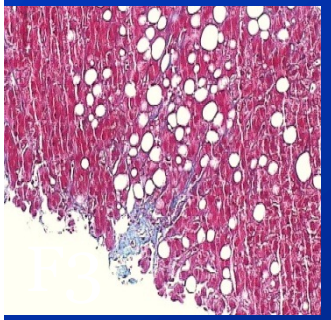
Shear Wave Elastography compared to histological findings and Liver Fibrosis

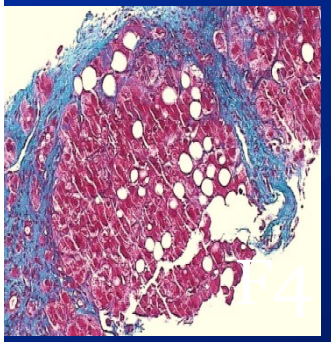












Ultrasound Med Biol. 2011 Sep;37(9):1361-73. Epub 2011 Jul 2011 Noninvasive in vivo liver fibrosis evaluation using supersonic shear imaging: a clinical study on 113 hepatitis C virus patients. Bavu E, Gennisson JL, Couade M, Bercoff J, Mallet V, Fink M, Badel A, Vallet-Pichard

New Guidelines 2017

Guidelines & Recommendations

29 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)

Authors

Christoph F. Dietrich[1, 2], Jeffrey Bamber[3], Annalisa Berzigotti[4], Simona Bota[5], Vito Cantisani[6], Laurent Castera[7], David Cosgrove[8], Giovanna Ferraioli[9], Mireen Friedrich-Rust[10], Odd Helge Gilja[11], Ruediger Stephan Goertz[12], Thomas Karlas[13], Robert de Knegt[14], Victor de Ledinghen[15], Fabio Piscaglia[16], Bogdan Procopet[17], Adrian Saftoiu[18], Paul S. Sidhu[19], Ioan Sporea[20], Maja Thiele[21]

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

Eur J Ultrasound, 2017

SWE in Hepatitis C and B

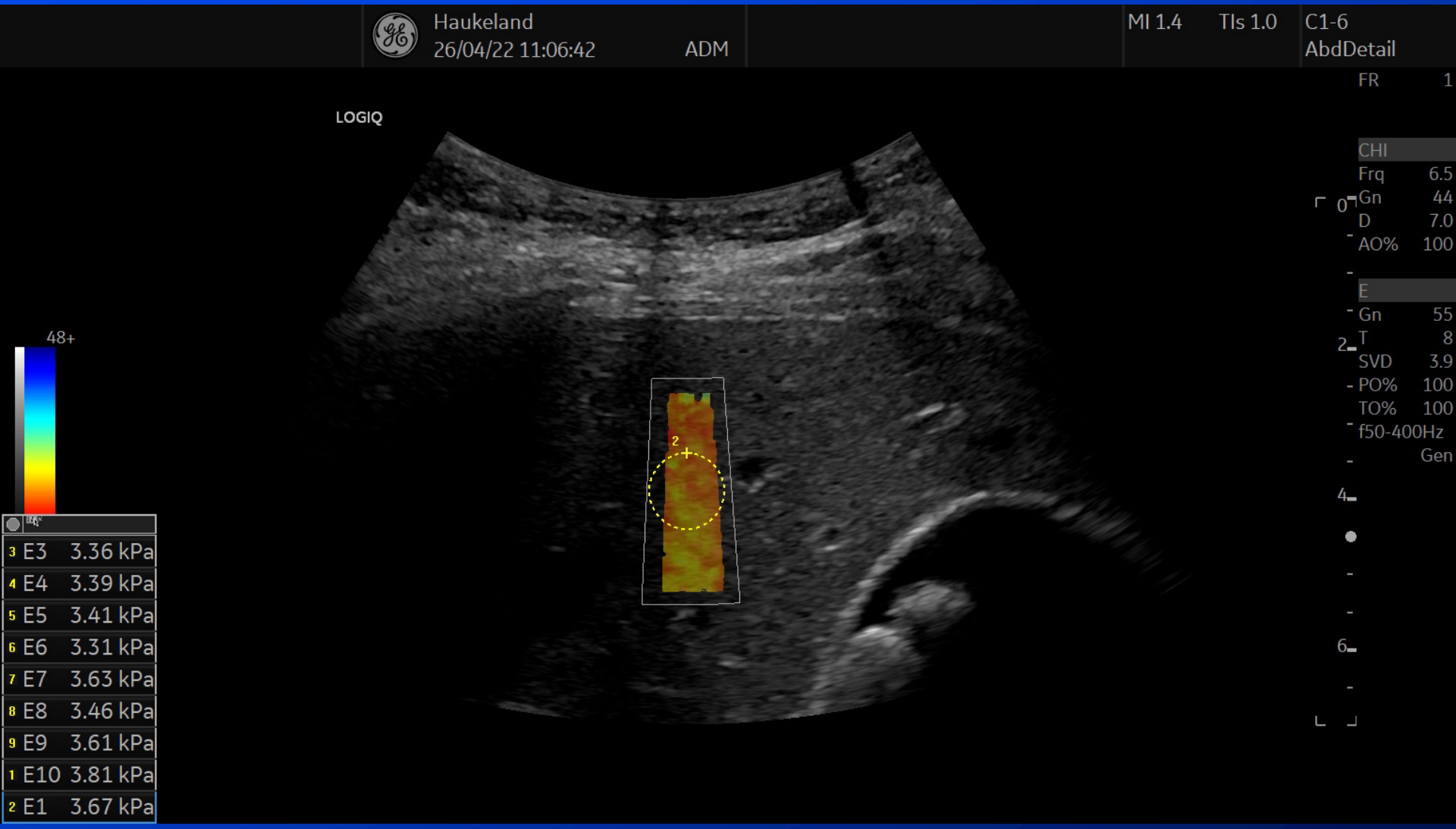
RECOMMENDATION 18

2D-SWE as demonstrated with SSI can be used as a first-line assessment for the severity of liver fibrosis in patients with chronic viral hepatitis C. It performs best with regard to the ruling out of cirrhosis (LoE 1b, GoR A) [139, 158, 159]. Broad consensus (17/0/1, 94 %)

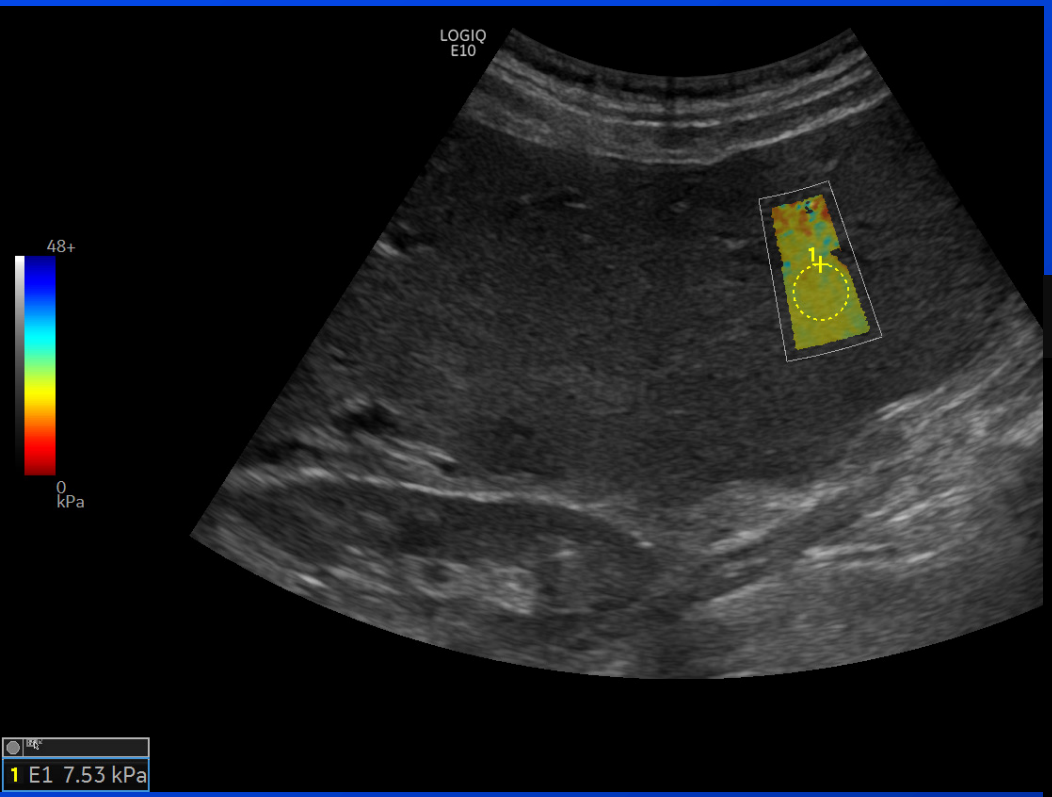
RECOMMENDATION 24

2D-SWE as demonstrated with SSI is useful in patients with CHB to identify those with cirrhosis (LoE 3a, GoR C) [196, 197]. Broad consensus (17/0/1, 94 %)

Elastography – F0 - normal



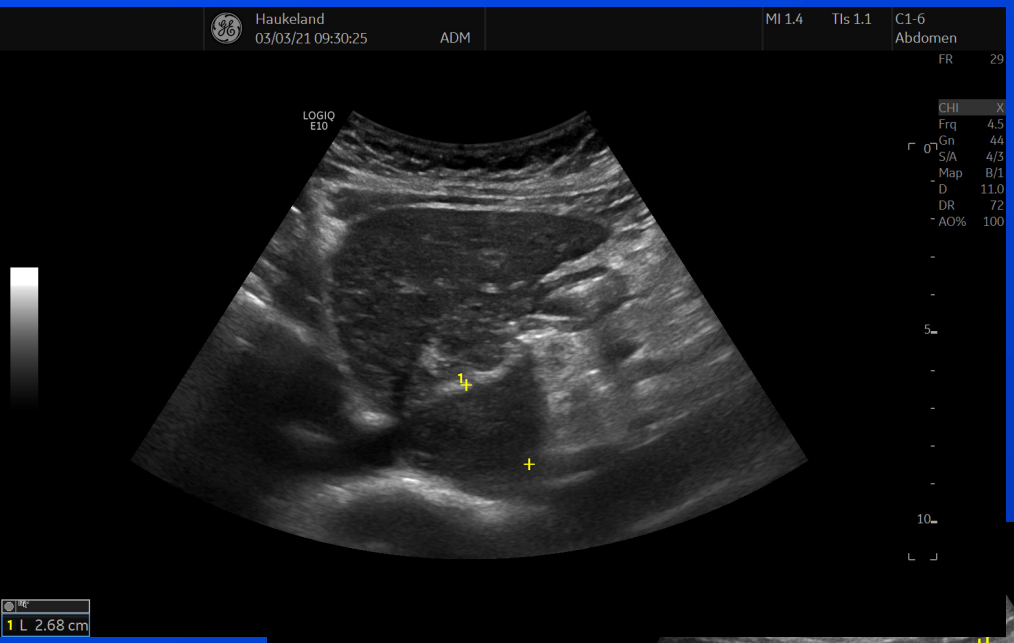
Elastography – F1



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 %			

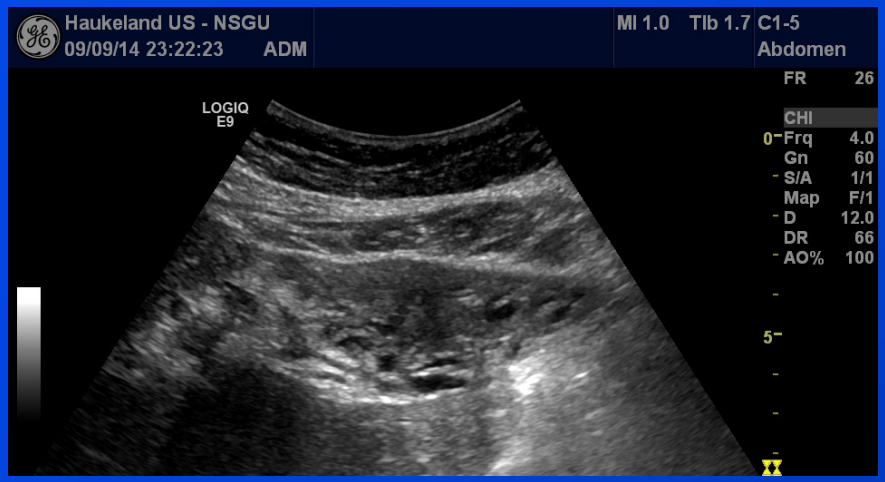
Liver fibrosis - F3

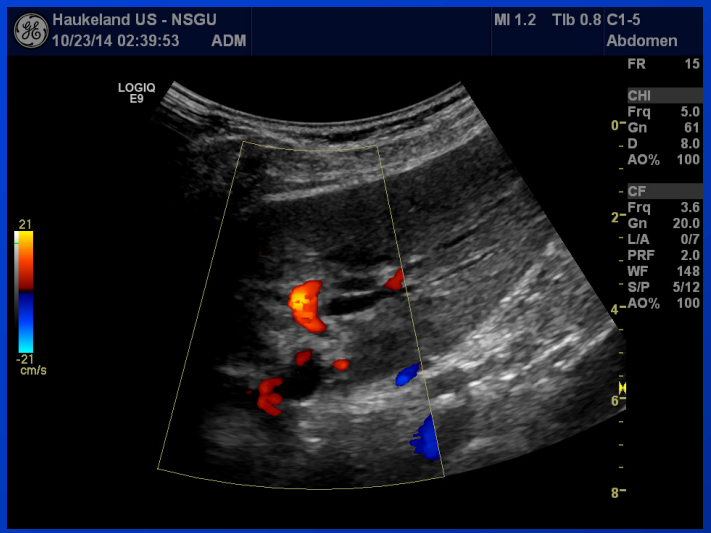


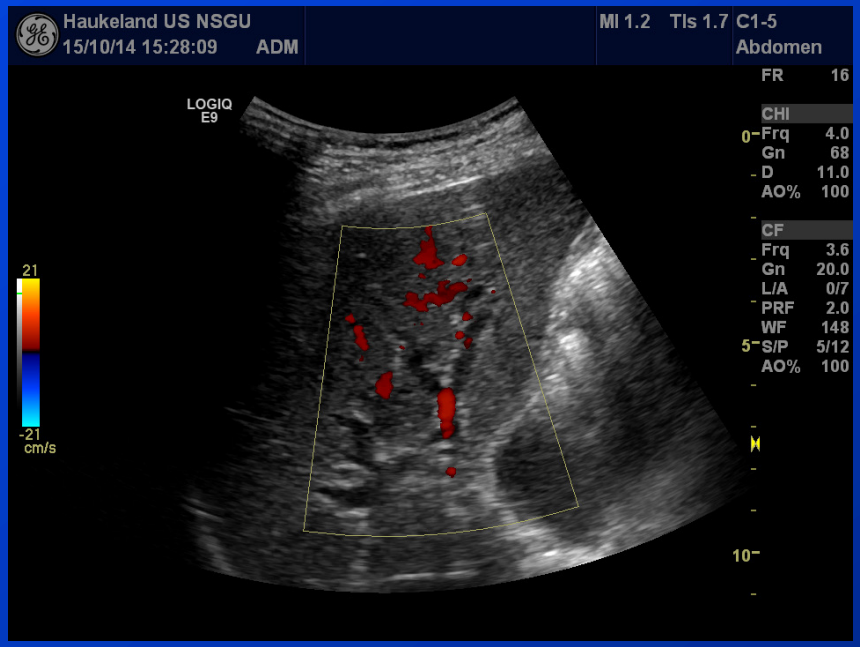
Haukeland
03/03/21 09:25:03 ADM

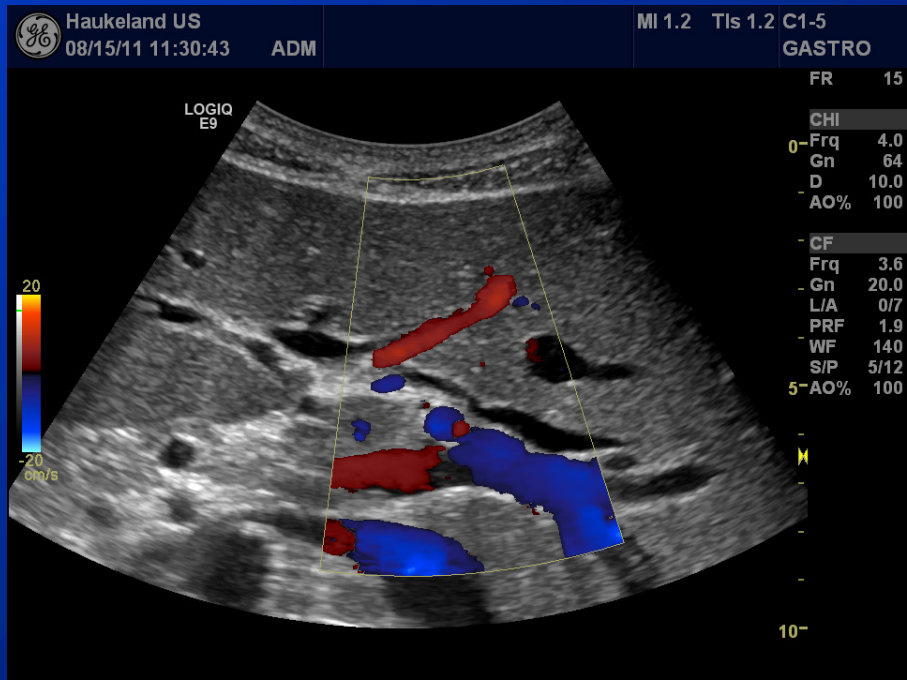
Parameter	Value	m1
B Mode Measurements		
Stiffness,kPa		
E1	9.24 kPa	11.45
E2	7.46 kPa	7.46
E3	10.90 kPa	10.90
E4	11.87 kPa	11.87
E5	10.11 kPa	10.11
E6	10.93 kPa	10.93
E7	11.86 kPa	11.86
E8	11.18 kPa	11.18
E9	8.72 kPa	8.72
E10	11.25 kPa	11.25
E Median	10.91 kPa	
E IQR	1.78 kPa	
E IQR/Median	16.3 %	

PSC: Primary Sclerosing Cholangitis

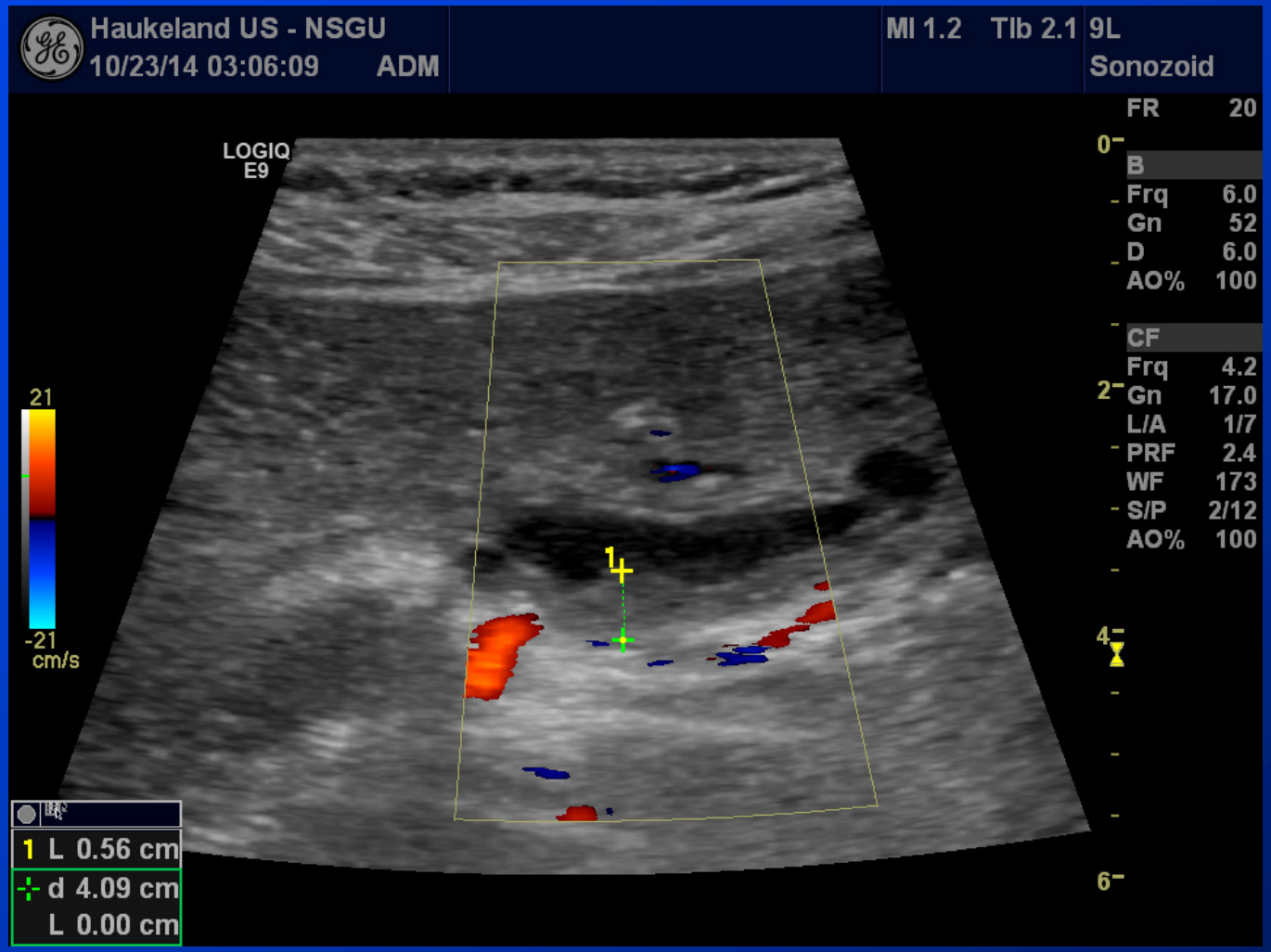




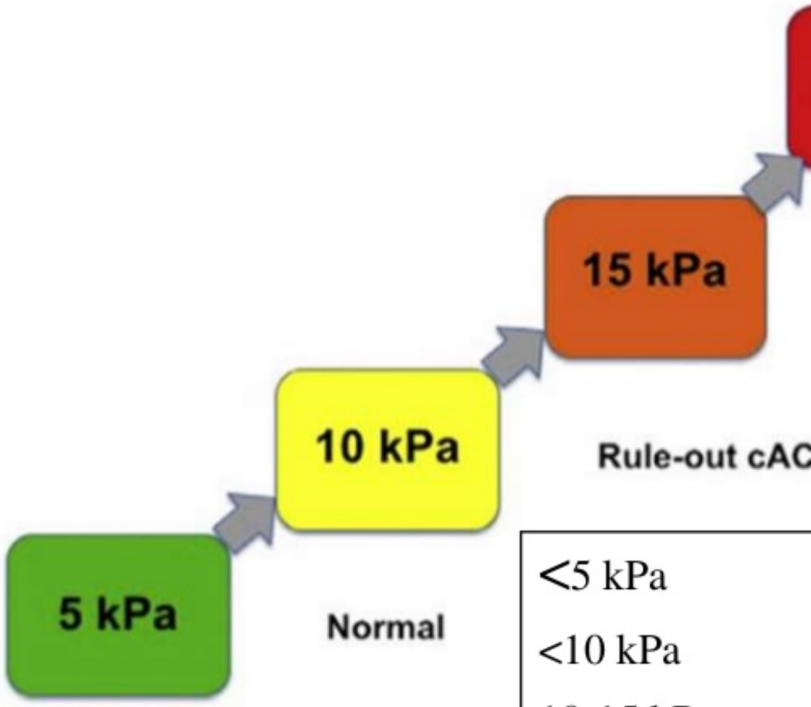




Intraductal growth: Inflammation, fibrosis or neoplasia ?



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.

SWE guidelines

Table 2: Recommendation for Interpretation of Liver Stiffness Values Obtained with ARFI Techniques in Patients with Viral Hepatitis and NAFLD

Liver Stiffness Value	Recommendation
≤5 kPa (1.3 m/sec)	High probability of being normal
<9 kPa (1.7 m/sec)	In the absence of other known clinical signs, rules out cACLD. If there are known clinical signs, may need further test for confirmation
9–13 kPa (1.7–2.1 m/sec)	Suggestive of cACLD but need further test for confirmation
>13 kPa (2.1 m/sec)	Rules in cACLD
>17 kPa (2.4 m/sec)	Suggestive of CSPH

Note.—ARFI = acoustic radiation force impulse, cACLD = compensated advanced chronic liver disease, CSPH = clinically significant portal hypertension, NAFLD = non-alcoholic fatty liver disease.

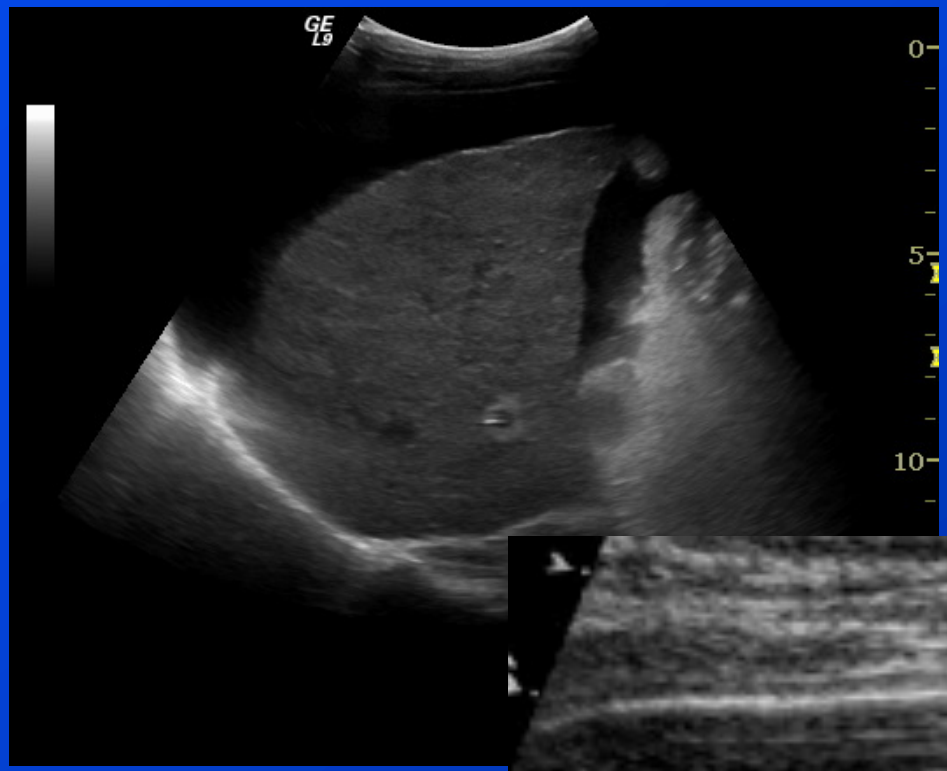
Barr et al., Radiology 2020; 296

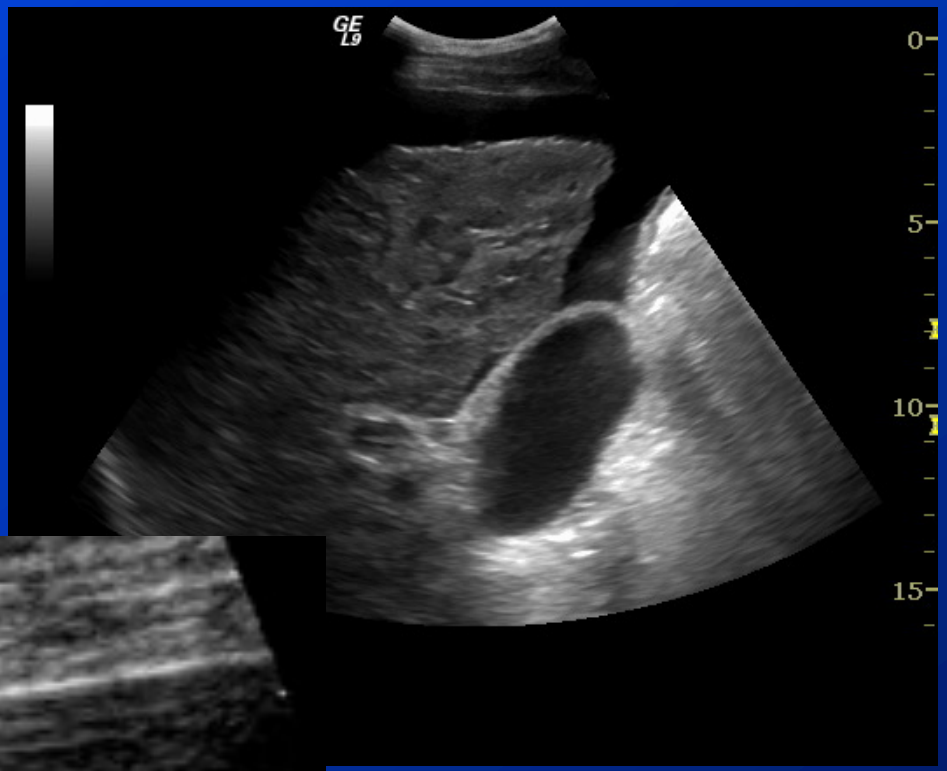
Ultrasound elastography

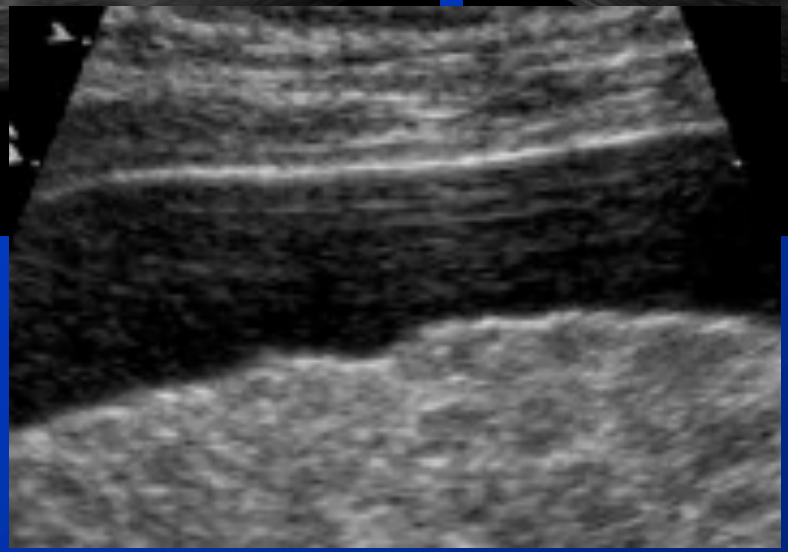
- Correlates well with histology regarding fibrosis
- Easy to perform
- Prolongs the US exam only with 2 min
- Provides valuable information to the clinician

- CT does not give data on liver stiffness
- MR elastography has low availability, is expensive and time consuming

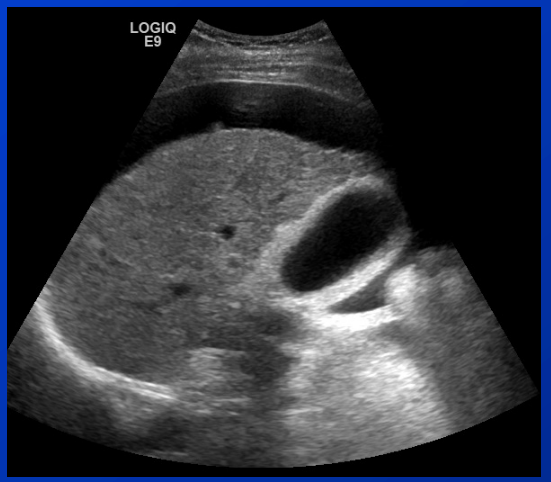
Liver cirrhosis





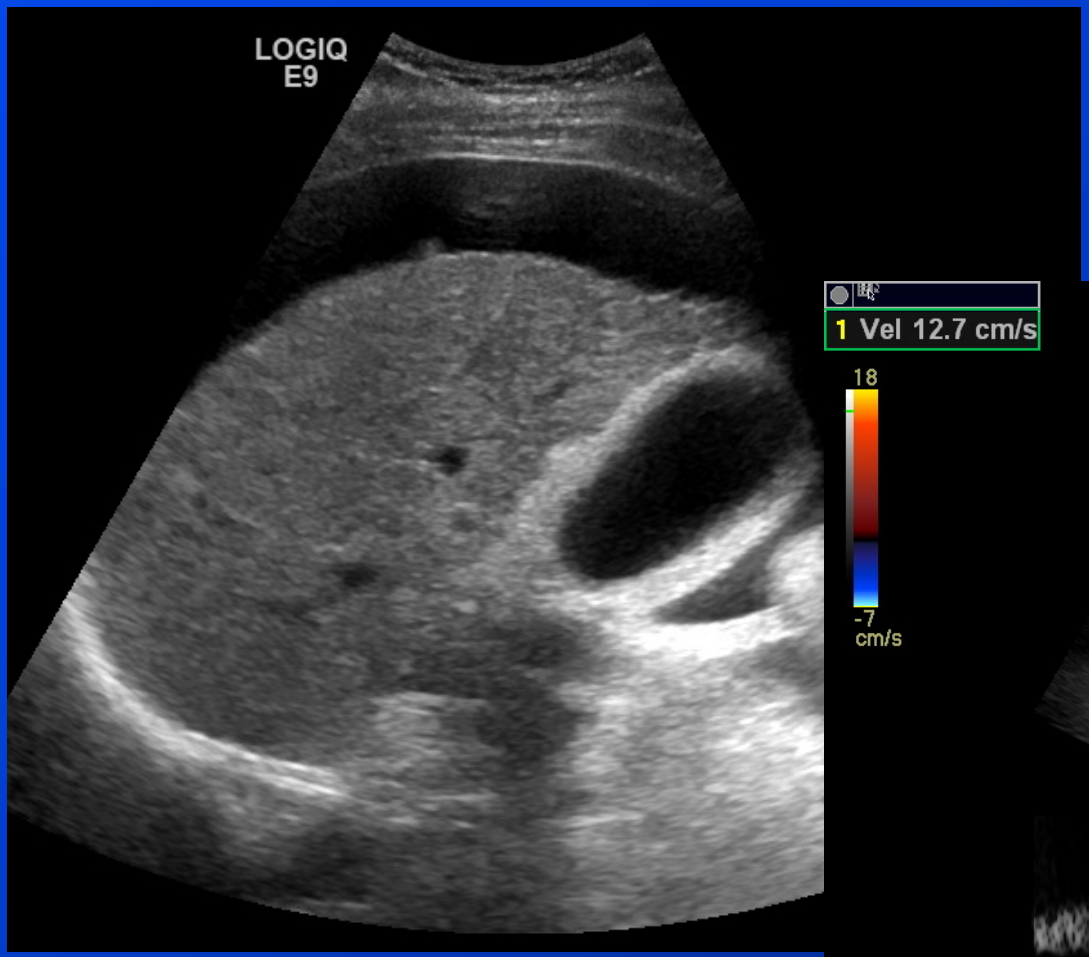


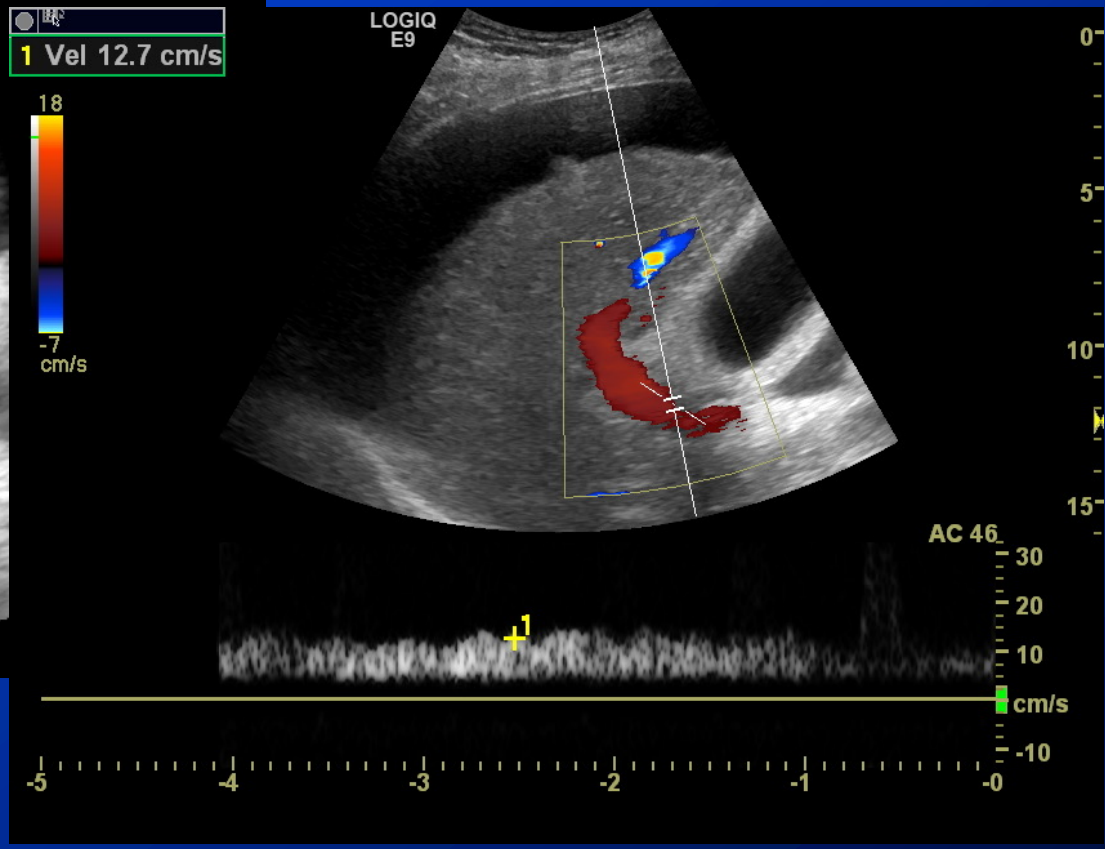
Ultrasound in the evaluation of cirrhotic livers



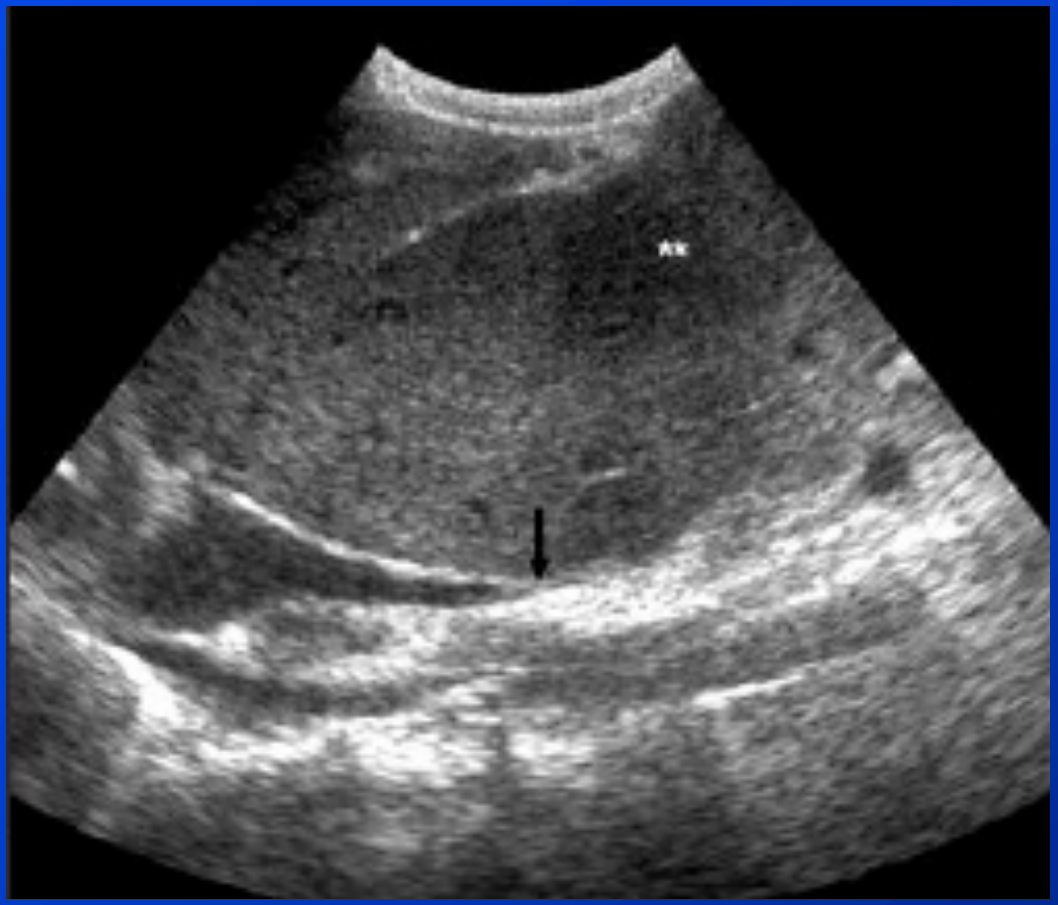
- Size of liver
- Size of left lobe and caudate lobe
- Capsule smoothness
- Ascites
- Echogenicity, homogenicity, nodularity, focal lesions
- Bile ducts and gallbladder
- Diameter of portal vein (+ splenic vein and spleen)
- Doppler measurements:
  - Color and pulsed Doppler of portal and hepatic veins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

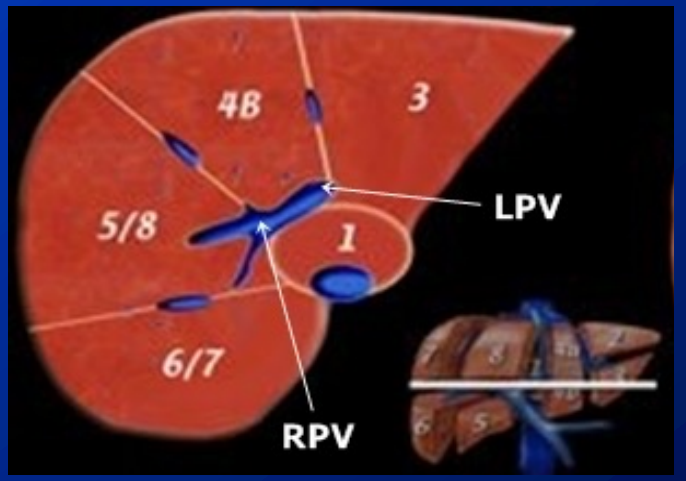
Lever Cirrhose





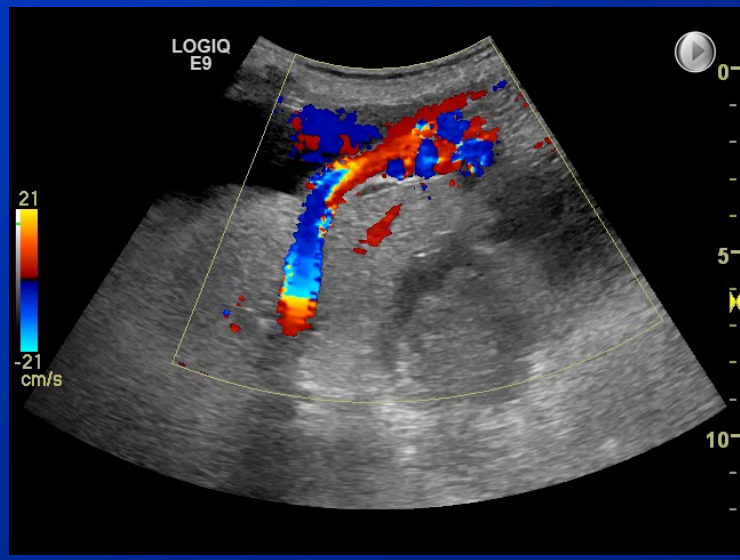
Enlarged caudate lobe



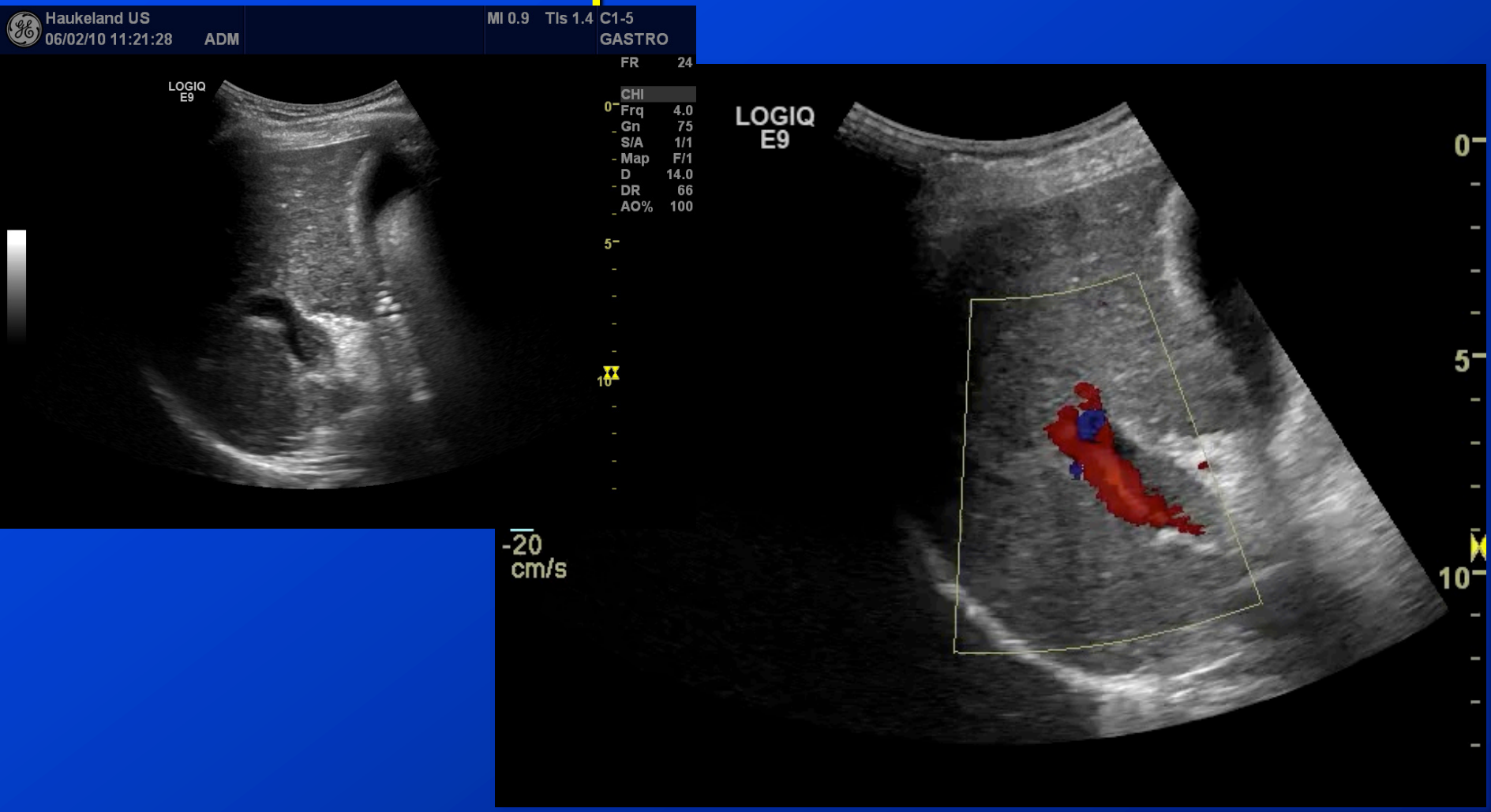


Signs (indirect) of portal hypertension seen by US

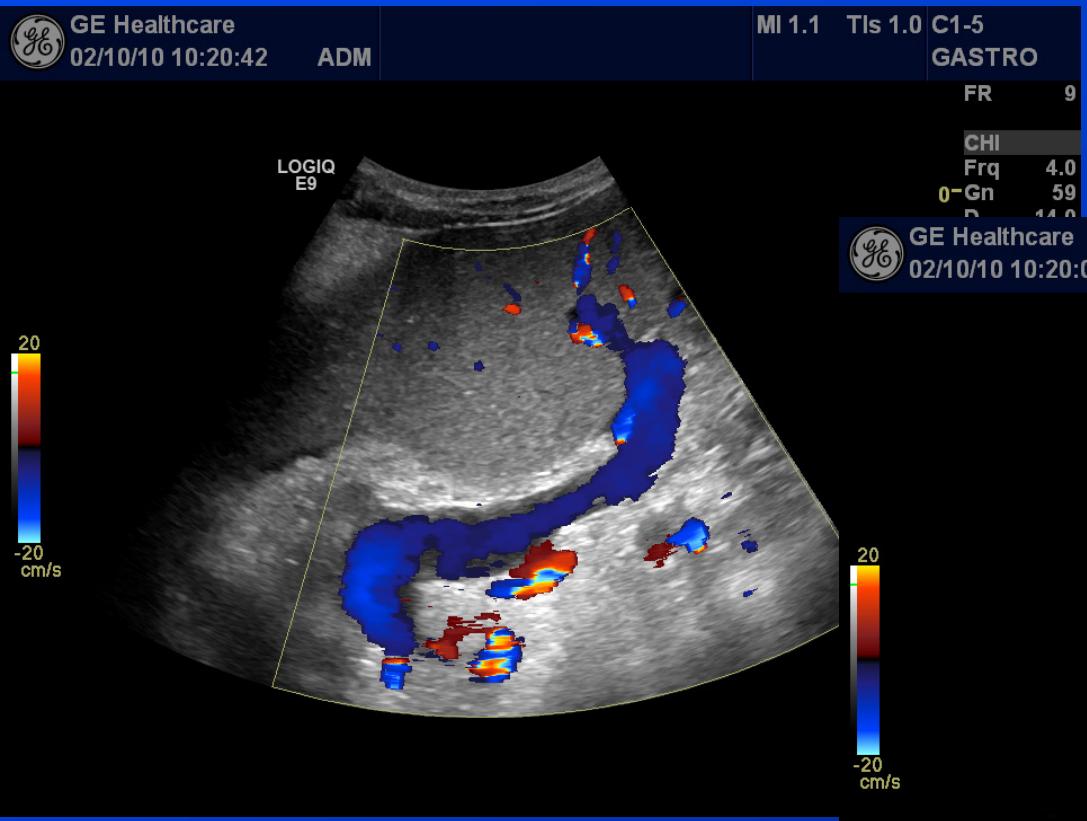
- Dilated portal vein (>13 mm)
- Decreased velocity in portal vein (<13 cm/sec)
- Reversed flow in portal vein
- Dilated splenic vein (> 10 mm)
- Shunts in the splenic hilum
- Recanalization of umbilical vein
- Enlarged spleen
- Esophageal varices
- Hypertensive gastropathy

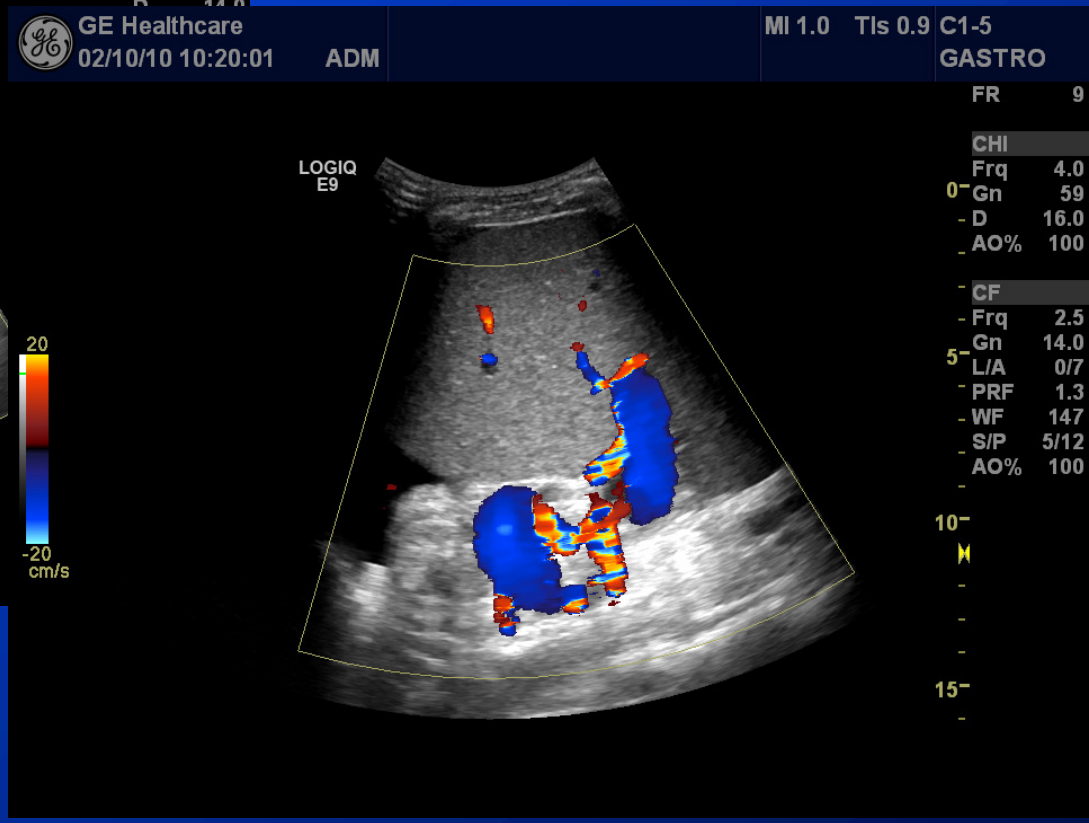


Use Color Doppler flow in real-time for portal thrombosis

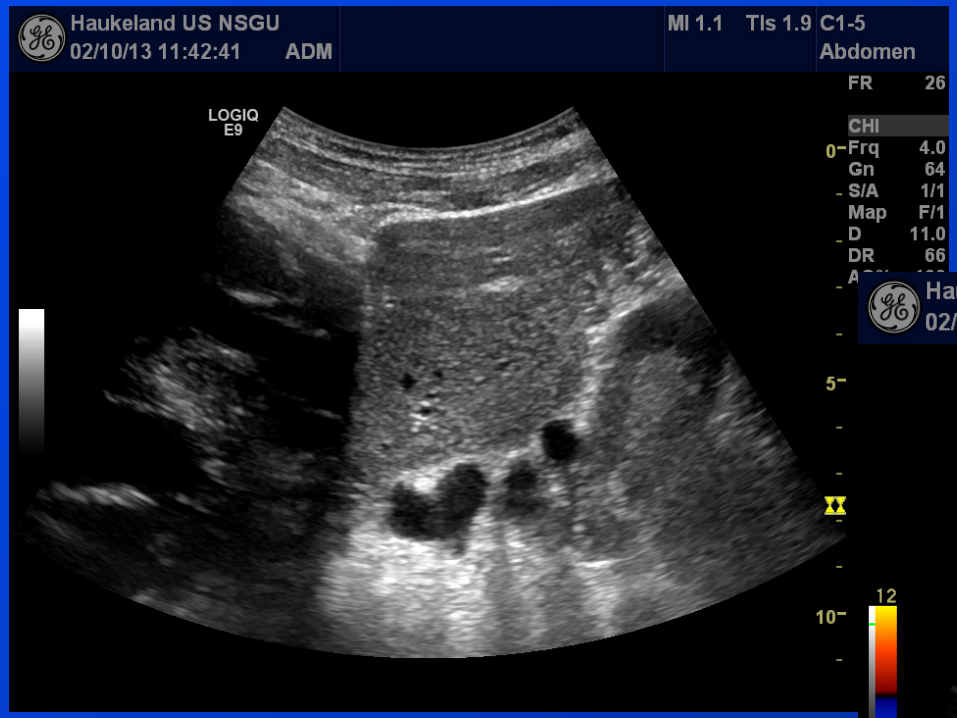


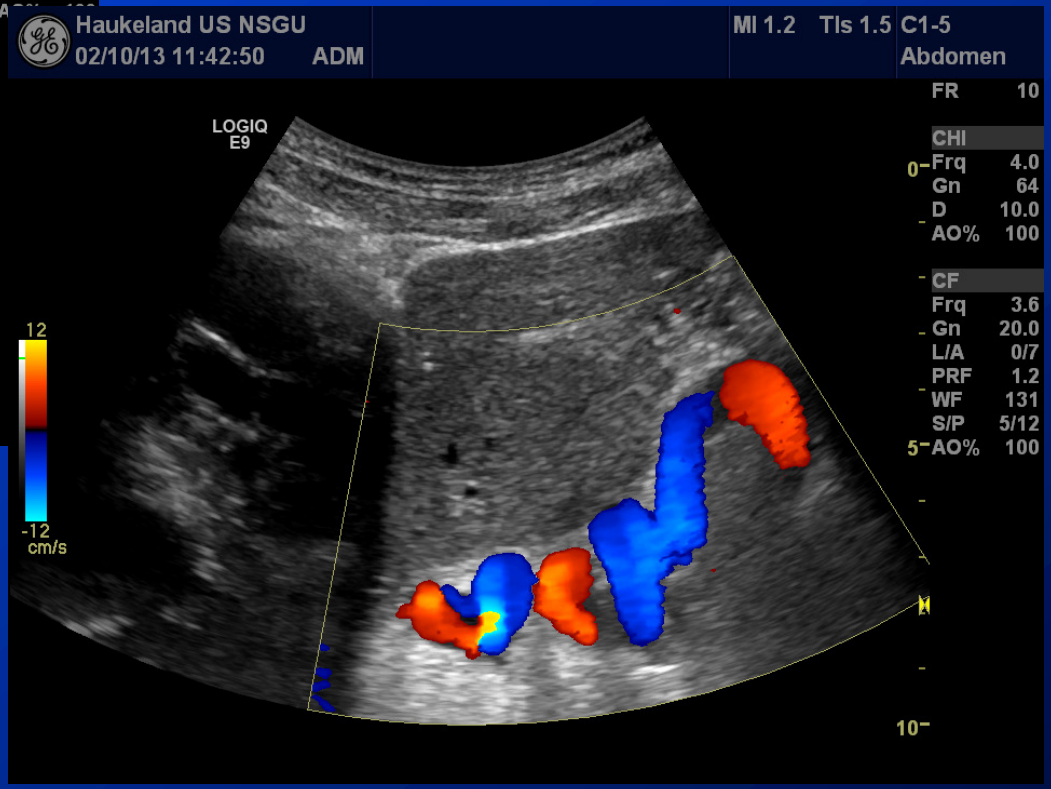
Dilated splenic vein in Portal HT



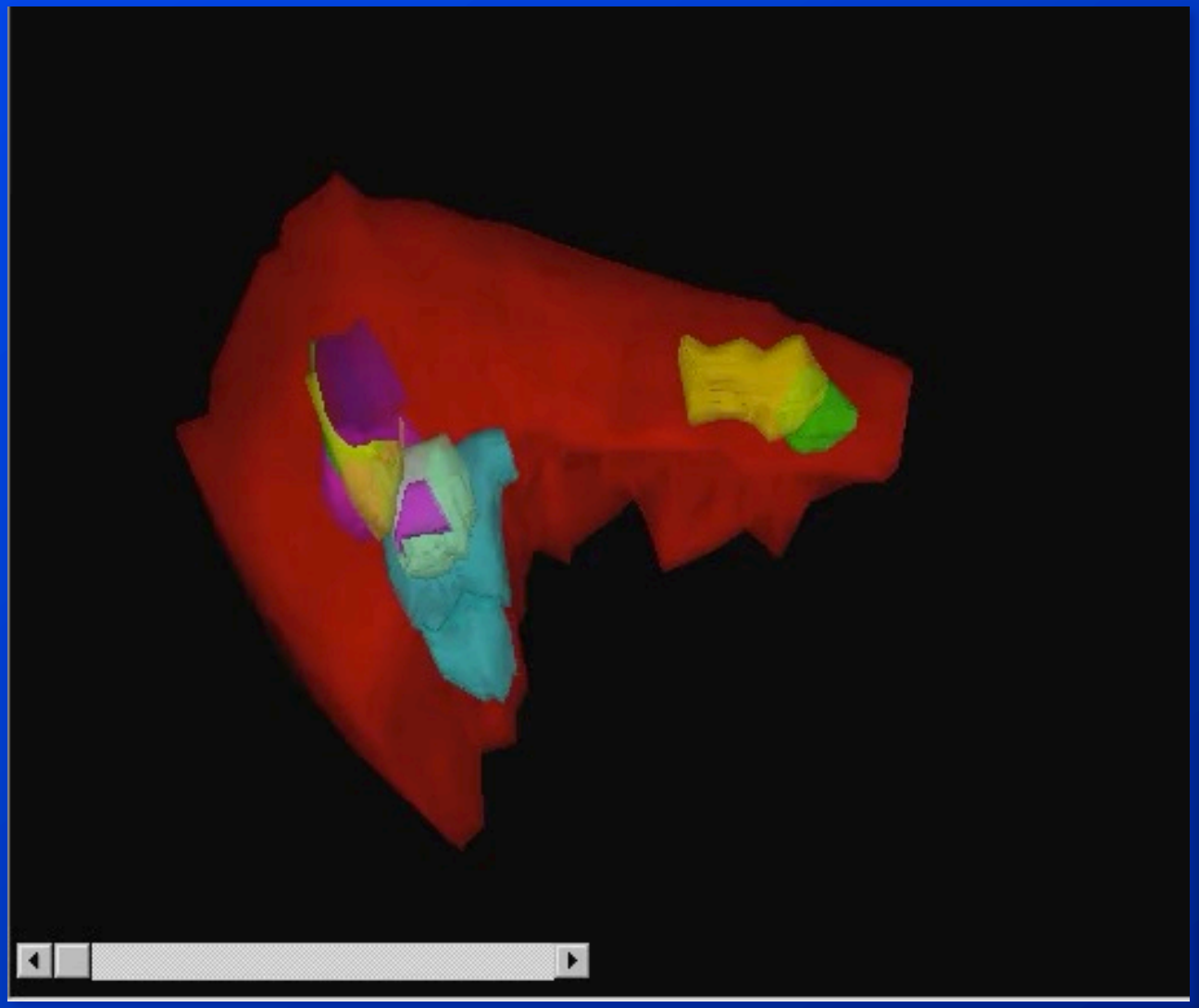


Esophageal Varices





Detection of Focal Liver Lesions

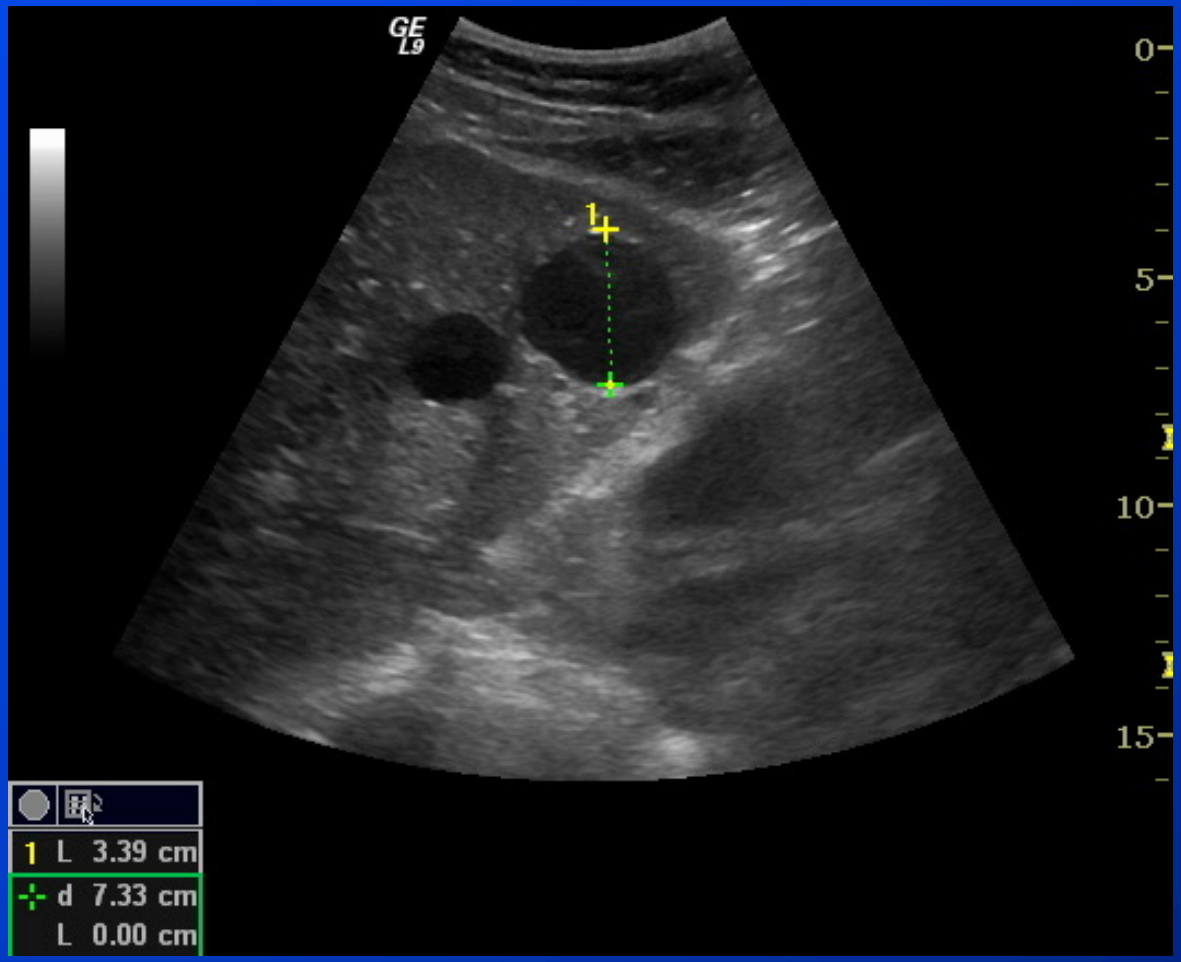


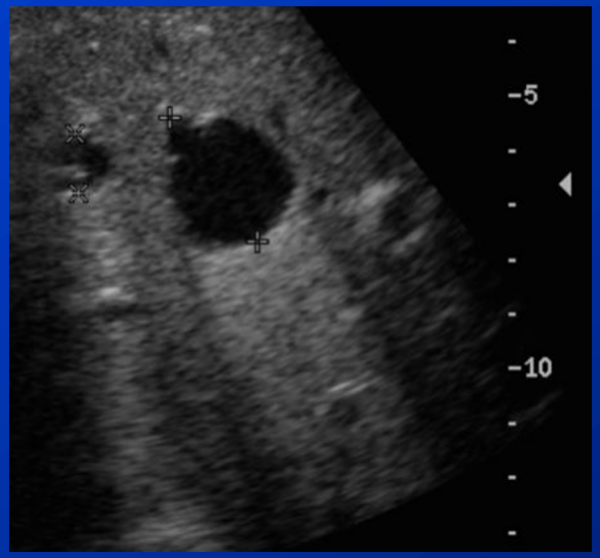
Hausken, Gilja et al., 1999

FLL Classification

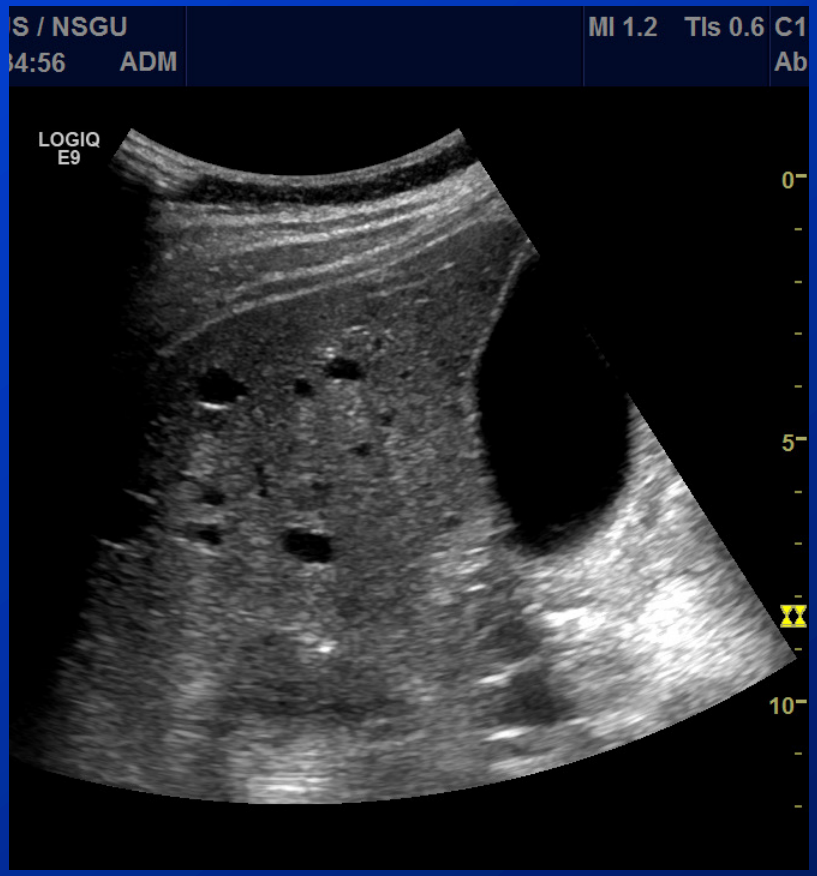
Benign	Malignant
Hepatocellular	Hepatocellular
Adenoma	Hepatocellular Carcinoma
Focal Nodular Hyperplasia	(Hcc) and its variants
Diffuse Nodular Hyperplasia	Fibrolamellar Carcinoma
Macroregenerative Nodules	Hepatocholangiocarcinoma
Dysplastic Nodules	Hepatoblastoma
	Carcinosarcoma
Biliary Epithelium	Biliary Epithelium
Bile Duct Cyst	Cystadenocarcinoma
Biliary Duct -Adenoma	Cholangiocarcinoma
Mucinous Cystic Neoplasm	
Peribiliary Gland Hamartoma	
von Meyenburg Complex	
Biliary Cystadenoma	
Biliary Papillomatosis	
Vascular	Vascular
Cavernous Hemangioma	Angiosarcoma
Infantile Hemangioendothelioma	Epithelioid
	Hemangioendothelioma
Others	Others
Angiomyolipoma	Primary Lymphomas
Mesenchymal Hamartoma	Sarcomas
Solitary Fibrous Tumor	
Inflammatory Pseudotumor	

Liver cysts

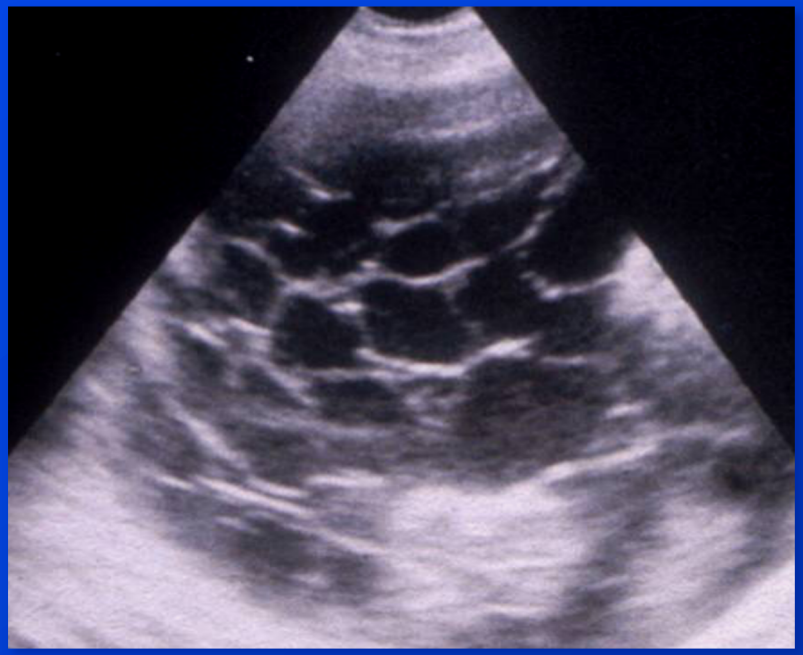


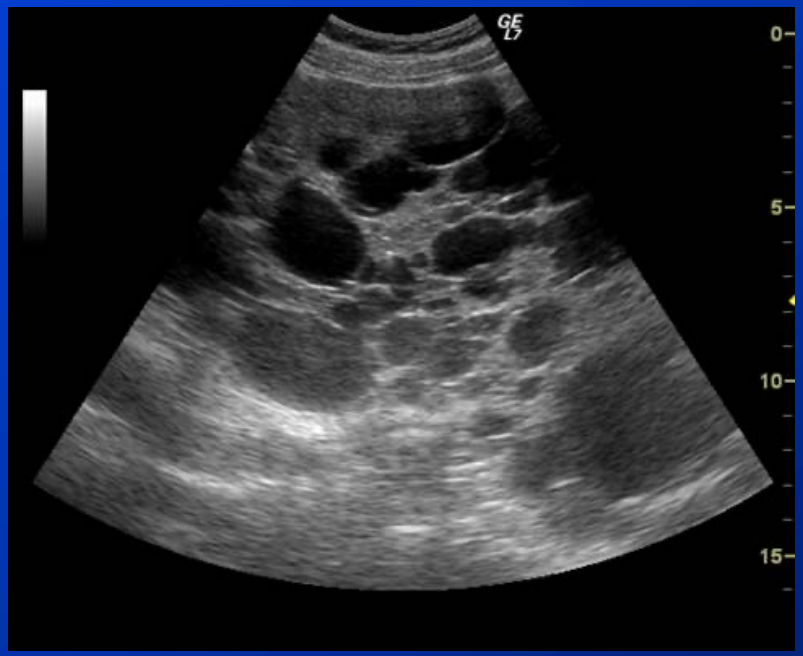


Ultrasound better than CT in small and complex cysts



Polycystic liver disease



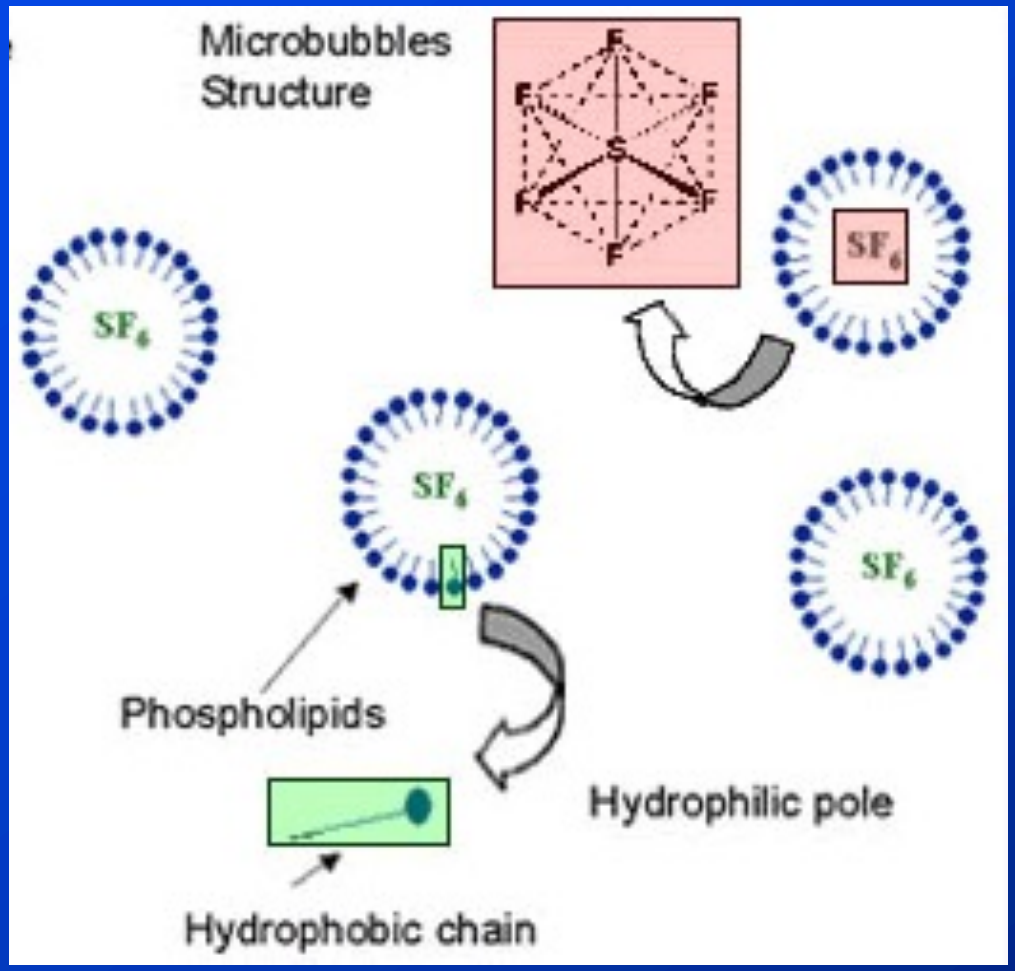


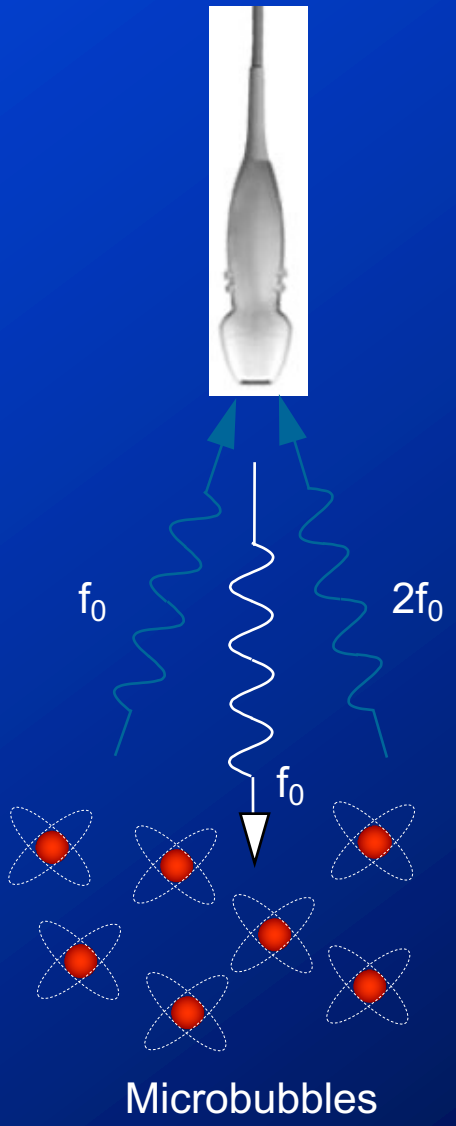
SONOVue®

Sulphur Hexafluoride

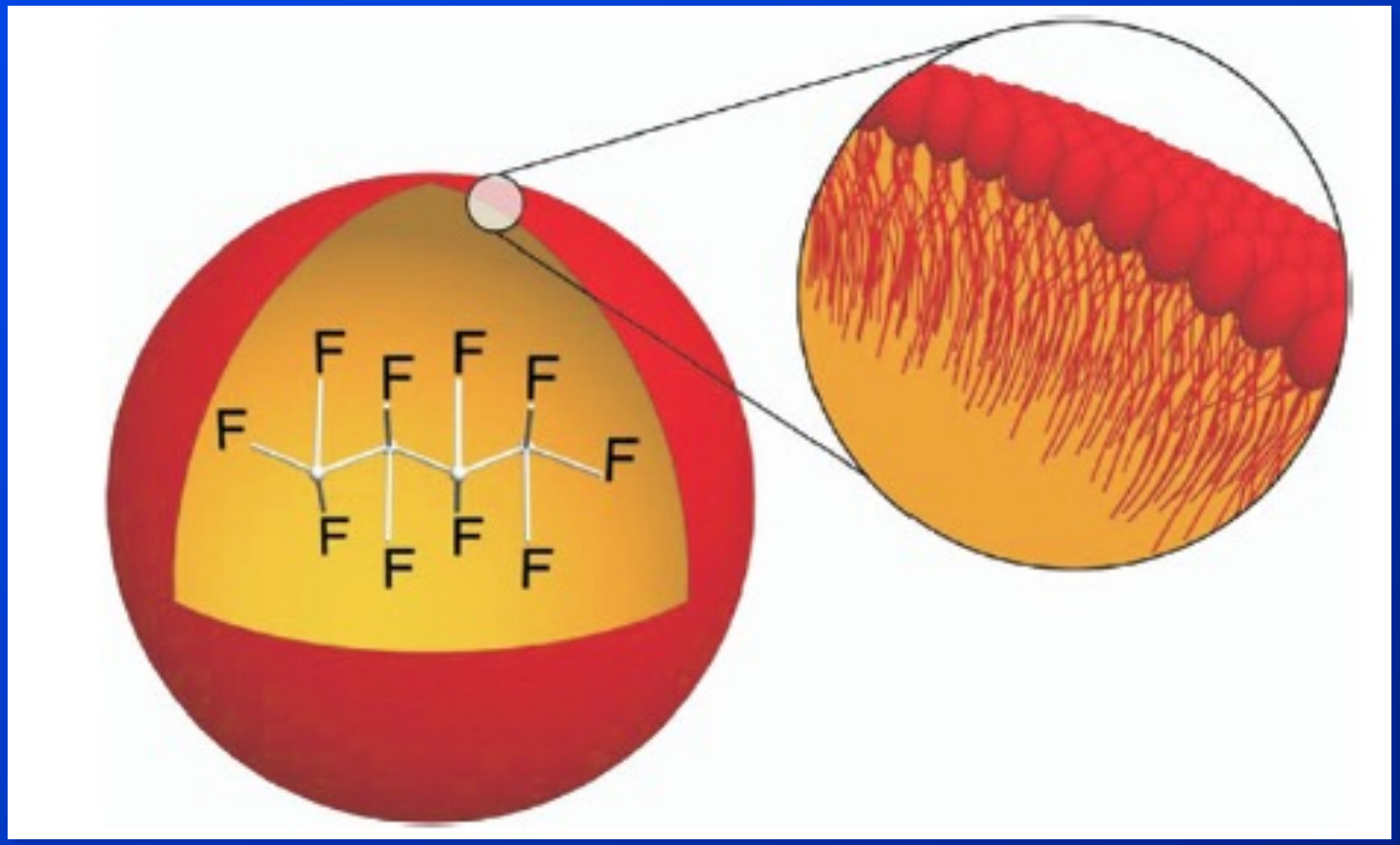
BRACCO

the Image of Innovation





Sonazoid



- Membrane is hydrogenated egg phosphatidylserine sodium (HEPSNa)
- The gas is perfluorobutane (PFB)

New Guidelines for CEUS 2011

The EFSUMB Guidelines and Recommendations on the Clinical Practice of Contrast Enhanced Ultrasound (CEUS): Update 2011 on non-hepatic applications

Authors F. Piscaglia[1], C. Nolsøe[2], C. F. Dietrich[3], D. O. Cosgrove[4], O. H. Gilja[5], M. Bachmann Nielsen[6], T. Albrecht[7], L. Barozzi[8], M. Bertolotto[9], O. Catalano[10], M. Claudon[11], D. A. Clevert[12], J. M. Correas[13], M. D'Onofrio[14], F. M. Drudi[15], J. Eyding[16], M. Giovannini[17], M. Hocke[18], A. Ignee[19], E. M. Jung[20], A. S. Klauser[21], N. Lassau[22], E. Leen[23], G. Mathis[24], A. Saftoiu[25], G. Seidel[26], P. S. Sidhu[27], G. ter. Haar[28], D. Timmerman[29], H. P. Weskott[30]

Affiliations Affiliation addresses are listed at the end of the article.

Bibliography
DOI http://dx.doi.org/10.1055/s-0031-1281676

Published online 2011
Ultraschall in Med © Georg Thieme Verlag KG Stuttgart · New York · ISSN 0172-4614

Correspondence

Thematic sections

	Thematic Section	Chairperson
1	Introduction	F. Piscaglia – C. Nolsøe
2	Generalities	D. Cosgrove
3	Equipment	H. P. Weskott
4	Investigator's training	O. H. Gilja

List of Abbreviations

AAA = Abdominal Aortic Aneurysm
AUC = Area Under the Curve
CE = Contrast Enhanced
CECT = Contrast Enhanced Computed Tomography
CEMRI = Contrast Enhanced Magnetic Resonance Imaging

Cited 1343 times as per 20/11-22

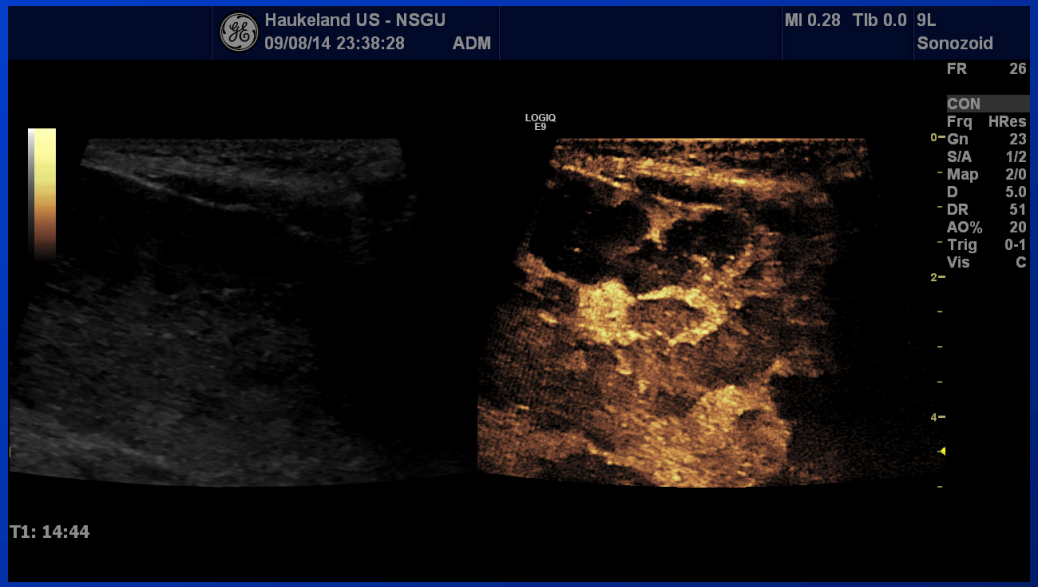
Ultraschall Med / EJU Aug. 2011

Indications - Liver

- Characterization of benign FLLs
  - FNH, hemangiomas, adenomas
- Detection of focal lesions
  - Metastasis
- Study FLL in cirrhosis
- Guiding of biopsies
- Guiding of intervention,- e.g. ablation

3 (4) Phases in liver perfusion

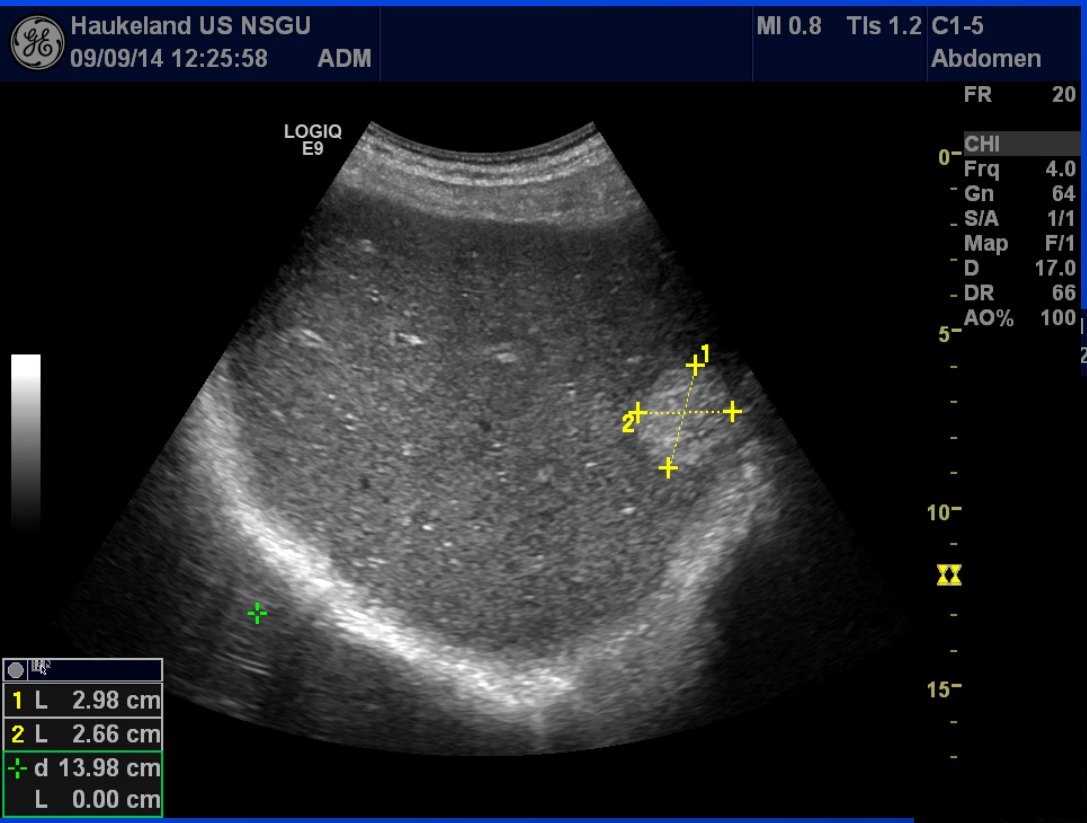
- Arterial phase
  - 0-30 sec.
- Portal phase
  - 30-120 sec.
- Sinusoidal phase
  - 2-4 min
- Post-vascular phase
  - 4-30 min

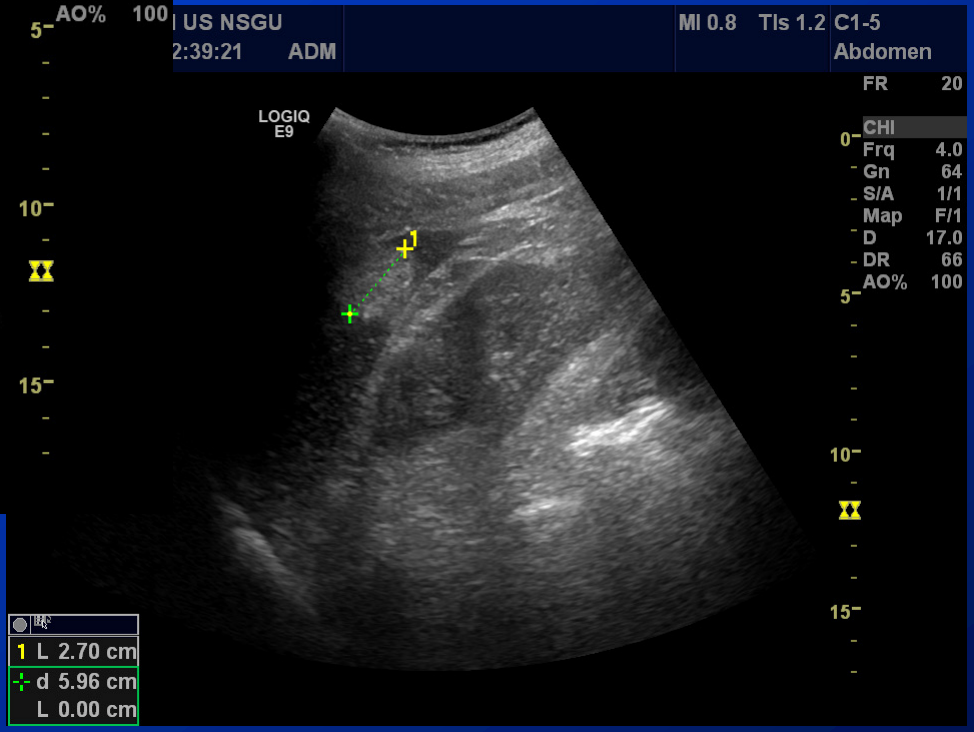


Focal Liver Lesions

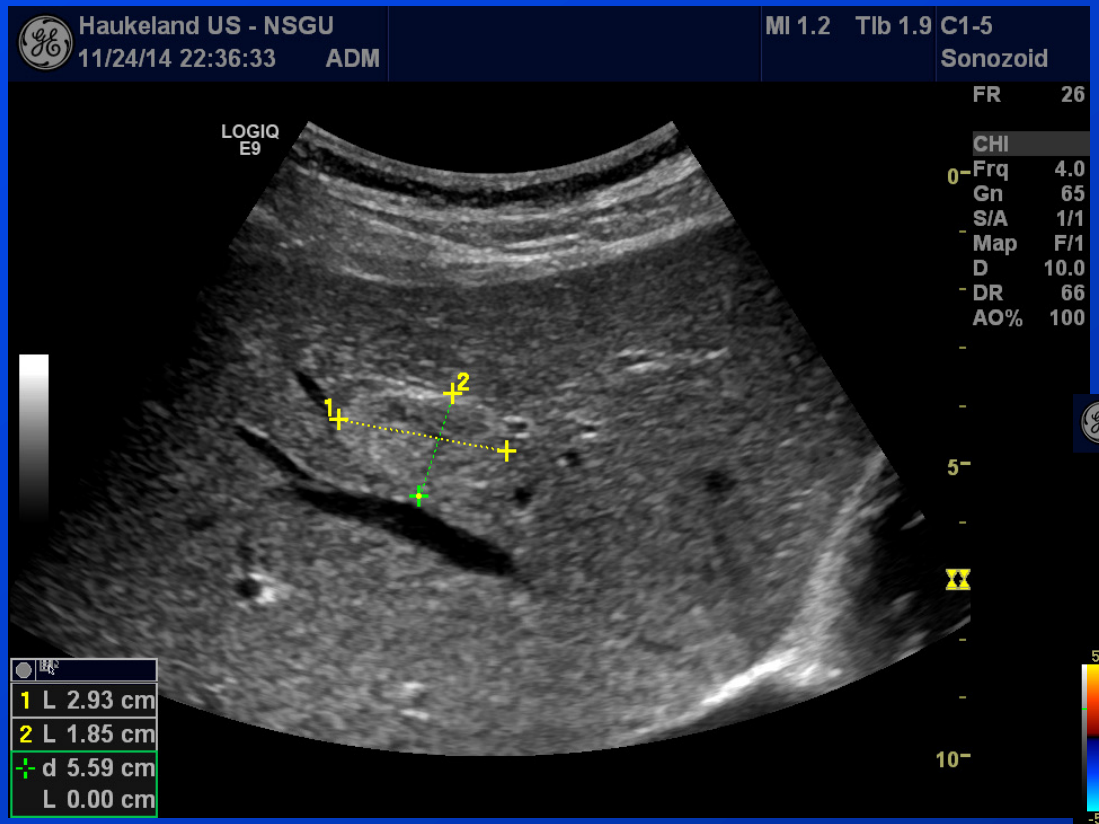
	Type of lesion	Arterial phase	Portal phase	Sinusoidal phase (parenchimal)
Benign	Haemangioma	Globular enhancement from the periphery	Centripetal filling	Progressive enhancement (iso to hyperechoic)
	Focal Nodular Hyperplasia	1. Strongly hyperechoic 2. In 40% of cases spoke and wheel pattern	Moderately hyperechoic or Isoechoic	Moderately hyperechoic or Isoechoic (central scar visible in 40% of cases)
	Adenoma	Strong homogeneous enhancement of short duration (capsular vessels)	Isoechoic	Isoechoic
Malignant	Hepato-cellular Carcinoma	Enhancement 1.Homogeneous 2.Inhomogeneous	Slightly hypoechoic	Slightly or strongly hypoechoic
	Hypervascular Metastases	1. Hyperechoic 2. Possible central area of necrosis in large lesions	Slightly hypoechoic	Strongly hypoechoic
	Hypovascular Metastases	1.No enhancement 2.Peripheral rim	Slightly hypoechoic	Strongly hypoechoic

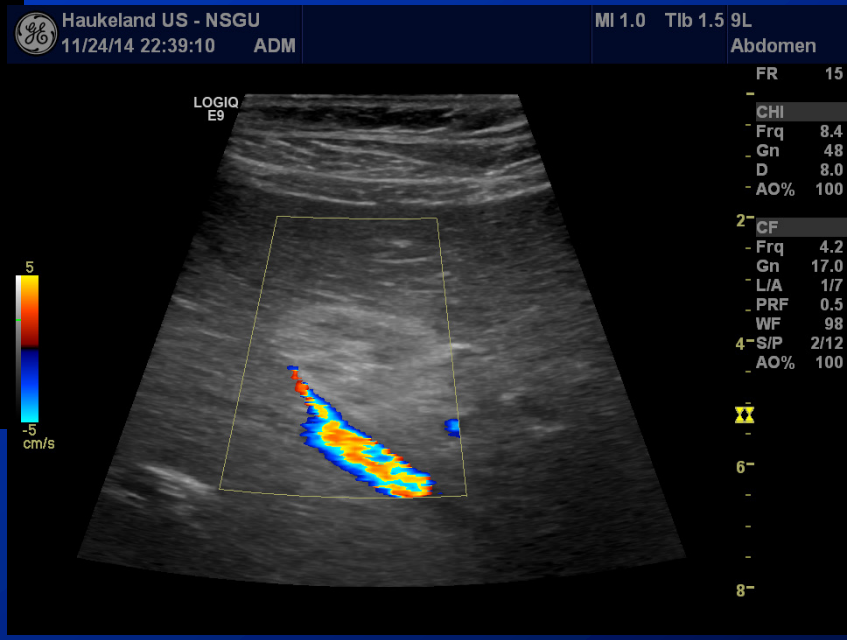
Lesion in Liver – S7



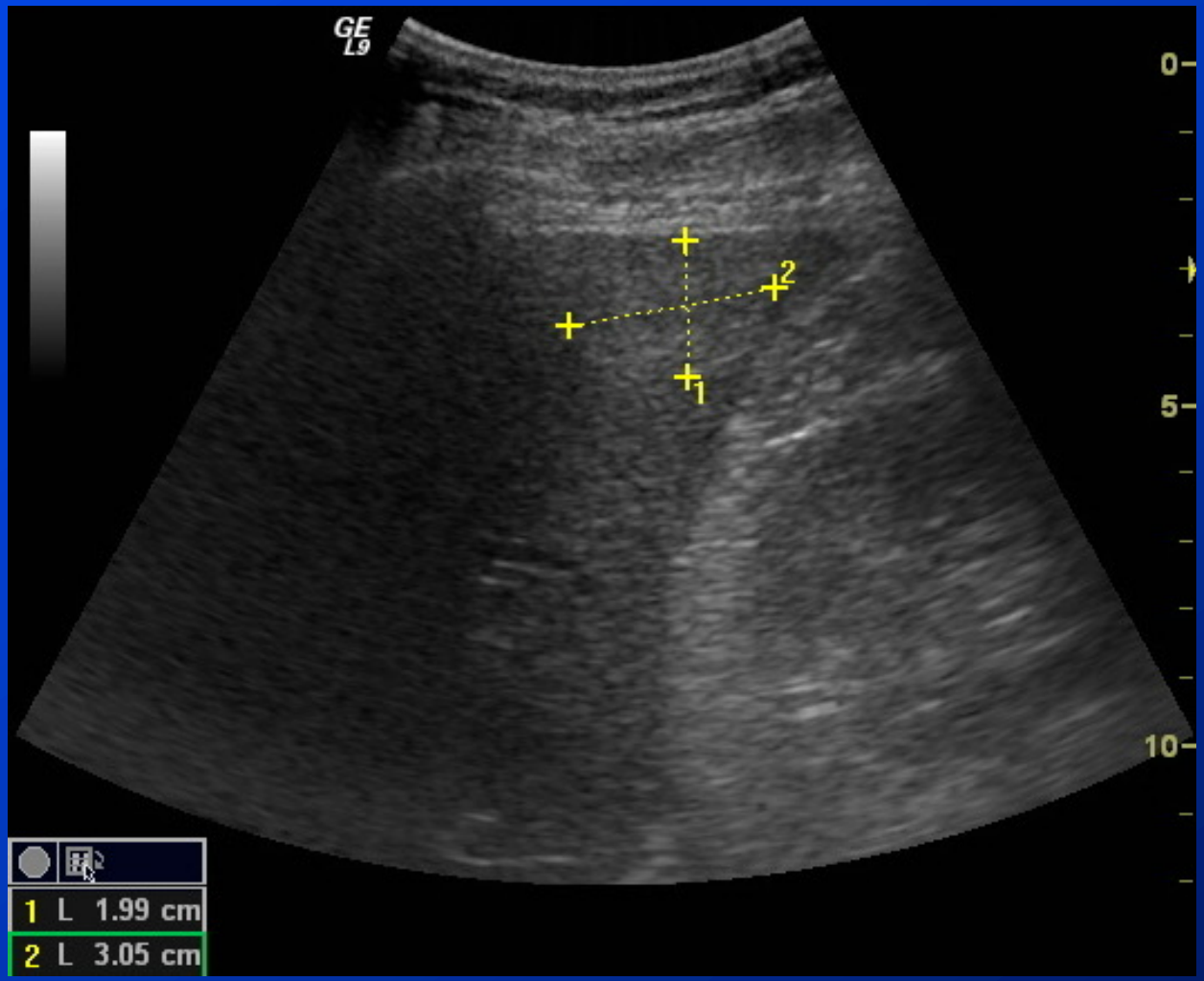


Hyper-echoic Tumor

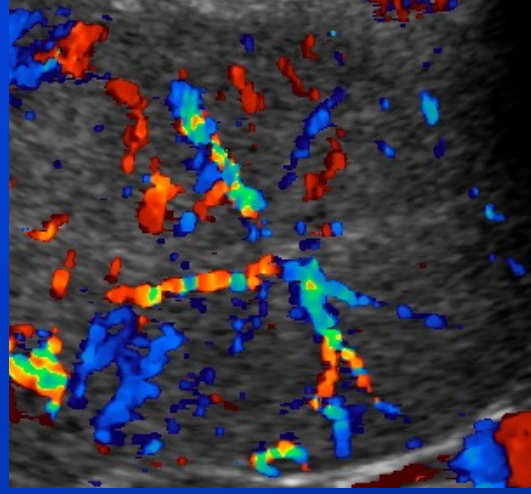




Typical location: By the capsule or by an hepatic vein

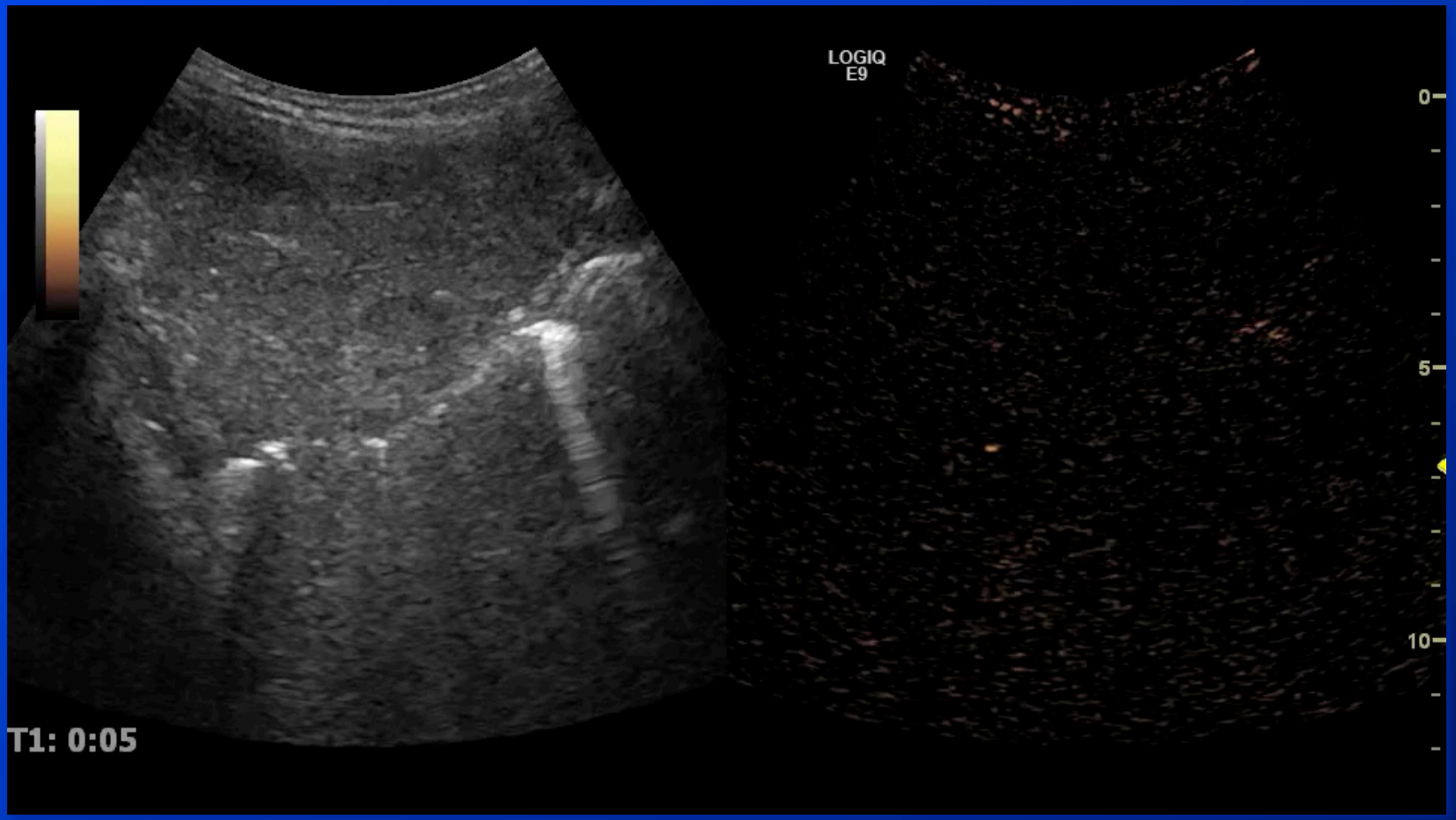


Focal Nodular Hyperplasia - FNH

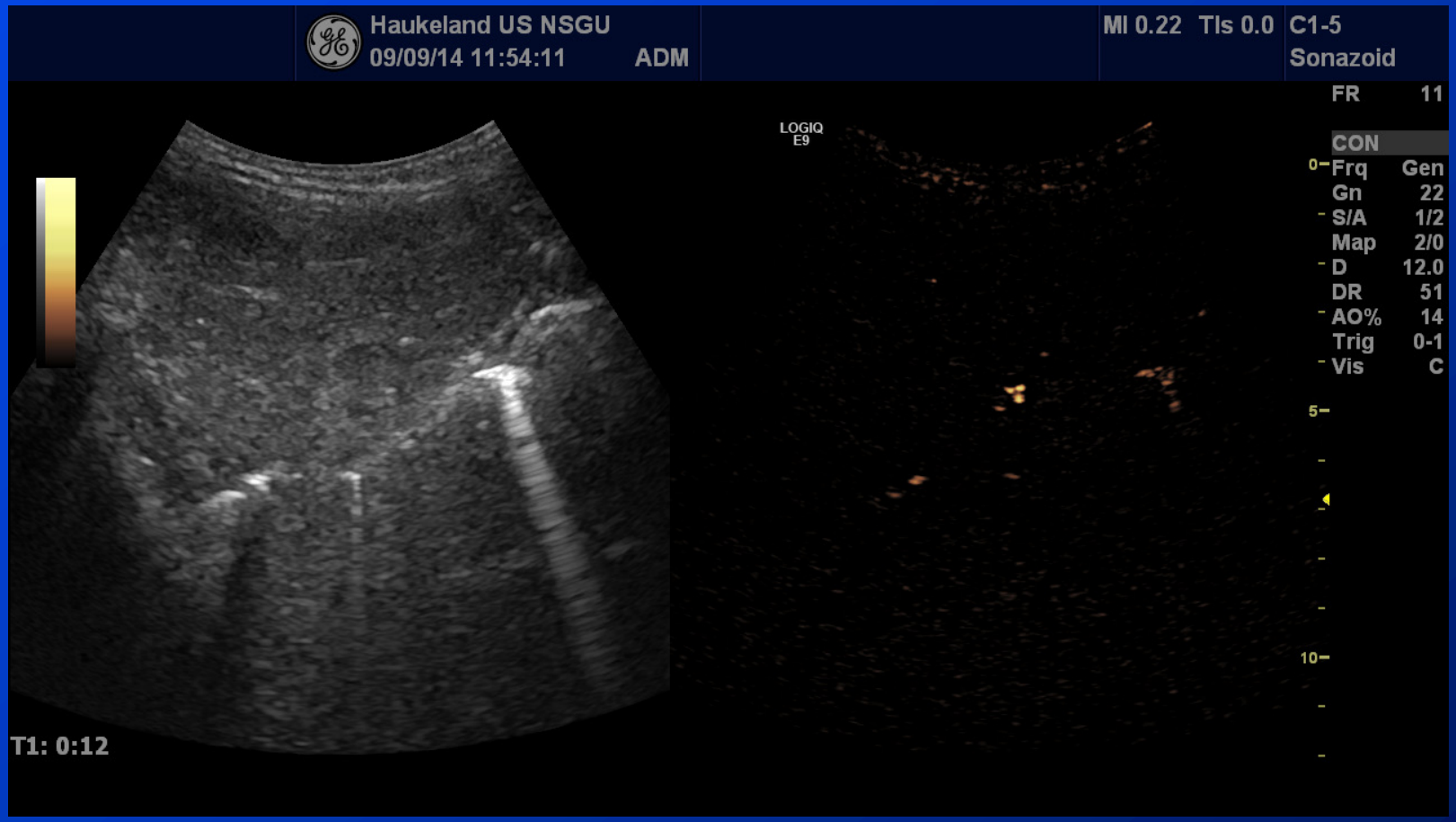


- FNH- a centrifugal stellate branching in early arterial phase
- Spoke wheel pattern in approx 40%
- Intense homogenous uptake
- Iso- or hyperechoic lesion is seen in portal venous phase.
- With these characteristic features:
  - sensitivity and specificity of contrast-enhanced low MI real-time US are 87.6% and 94.5%, respectively
    - Di Stasi 1996

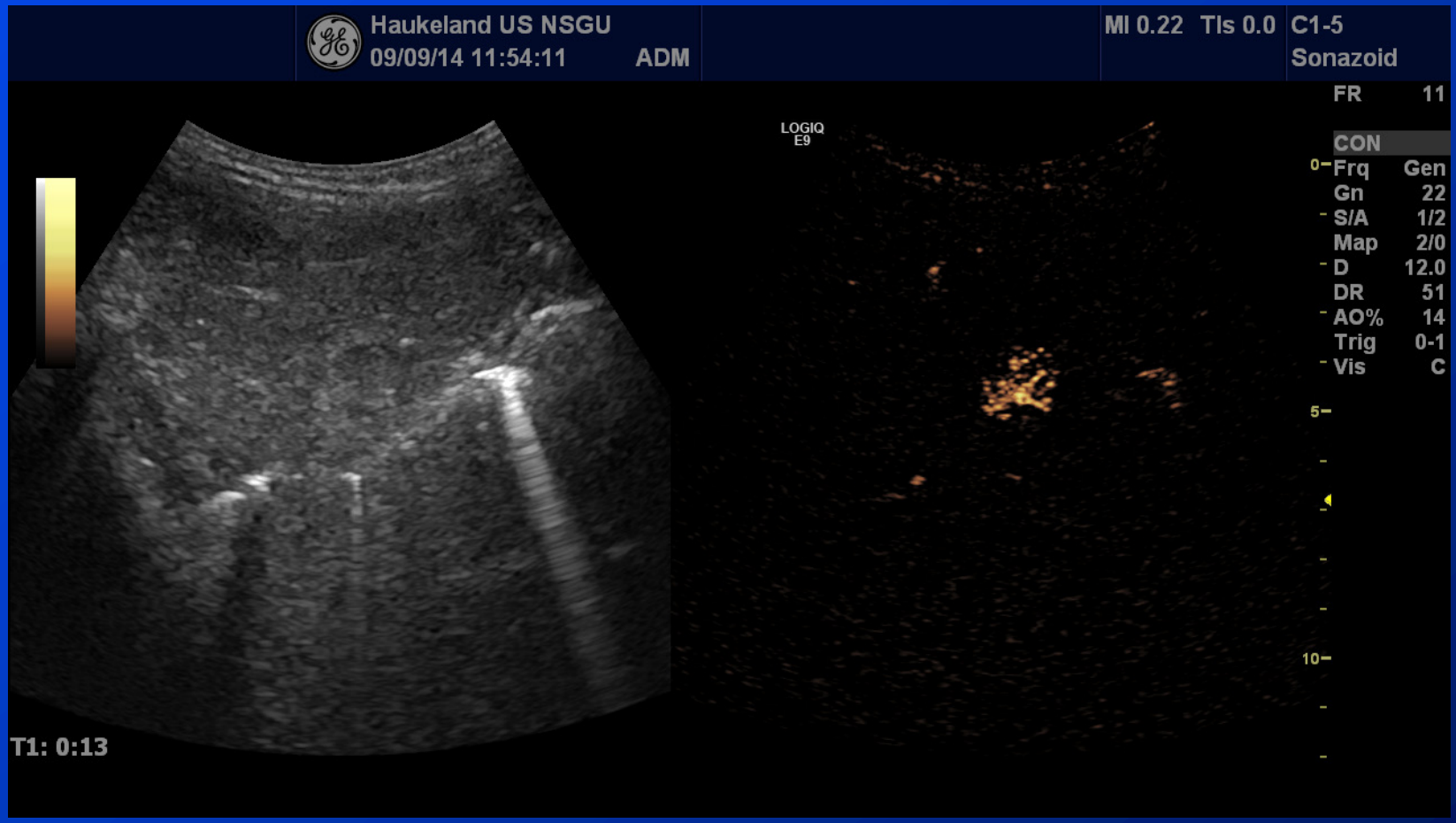
CEUS – Sonazoid - FNH



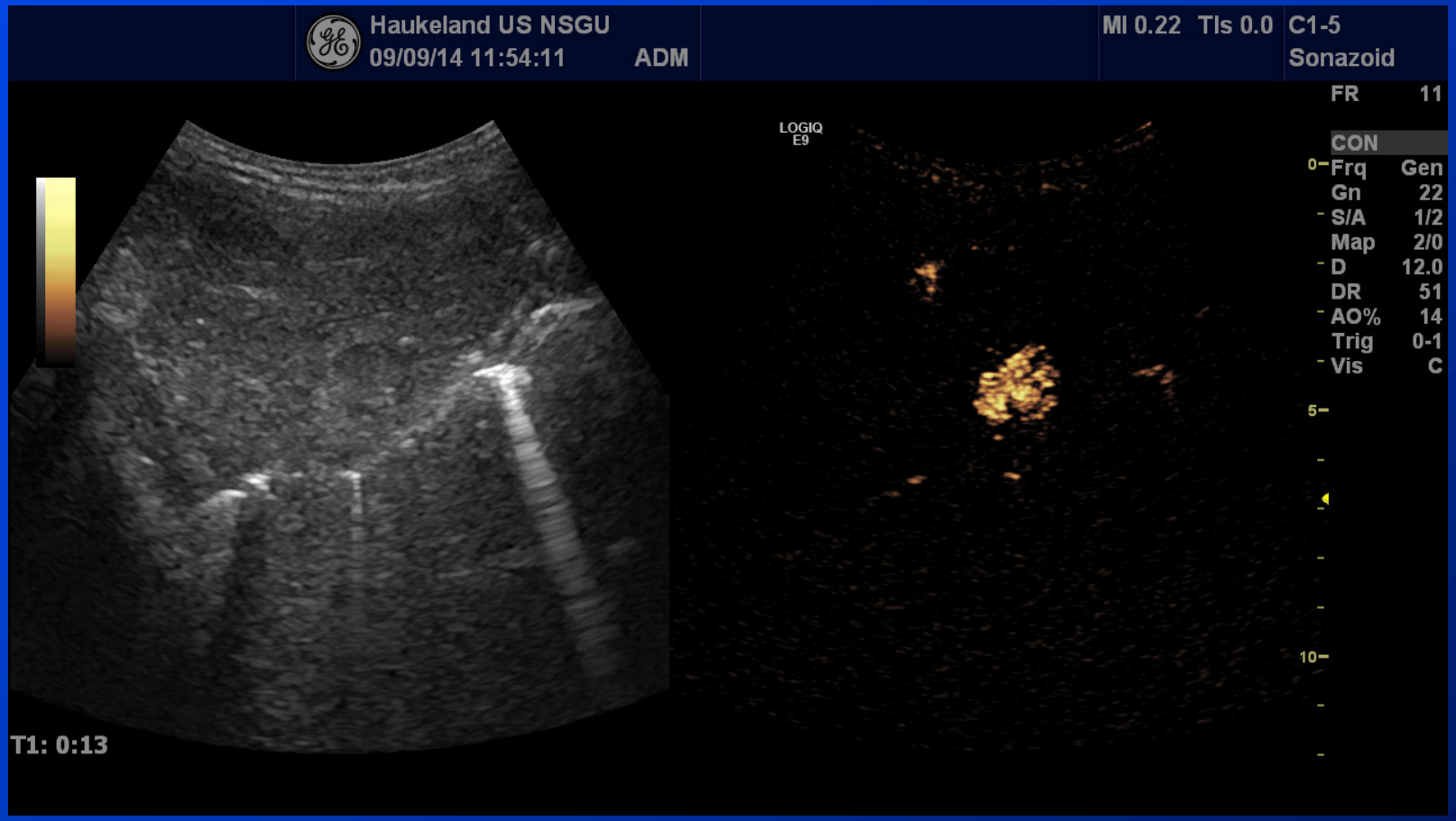
Arterial Phase: 12 sec.



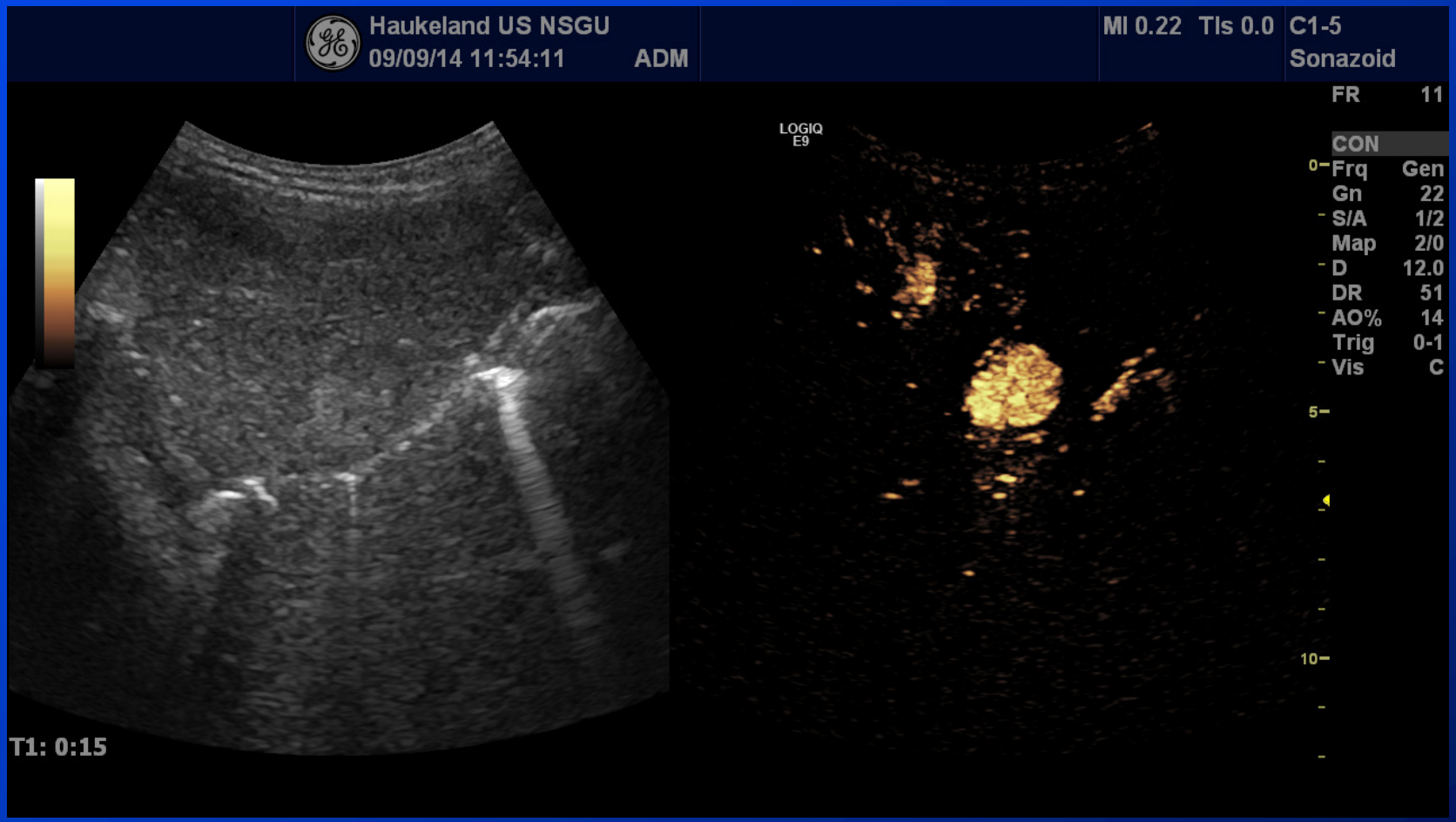
Arterial Phase: 13 sec

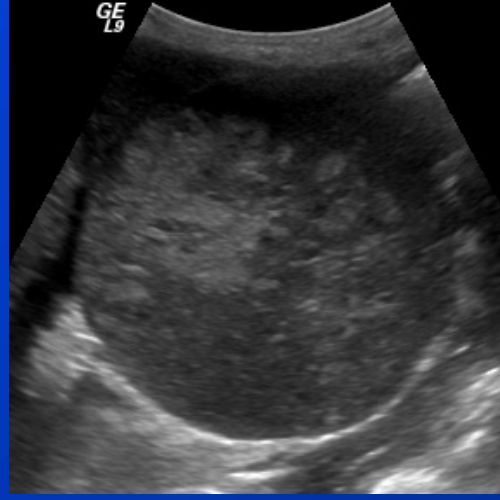


Arterial Phase: 13 sec



Arterial Phase: 15 sec

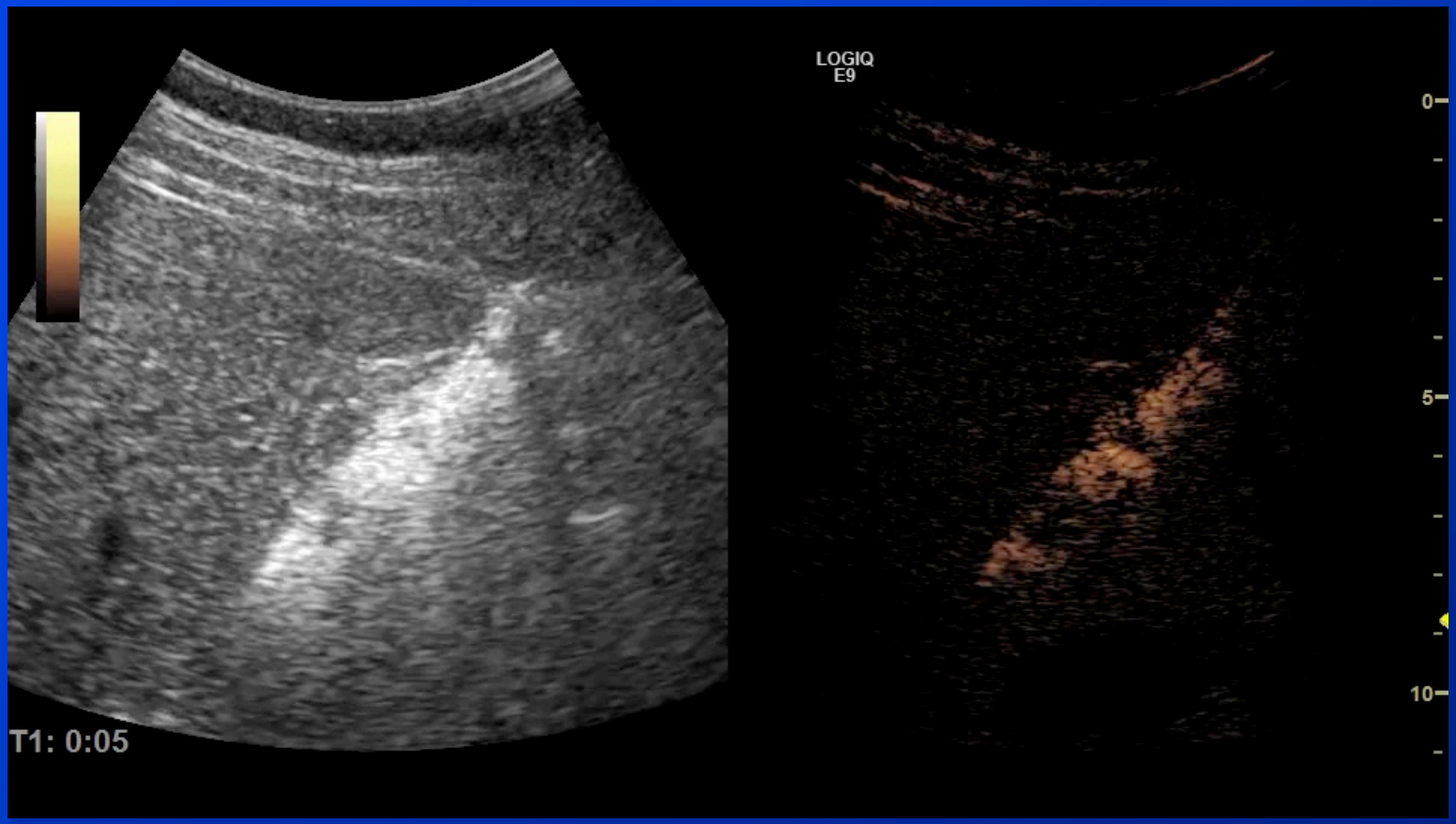




Liver cell adenoma

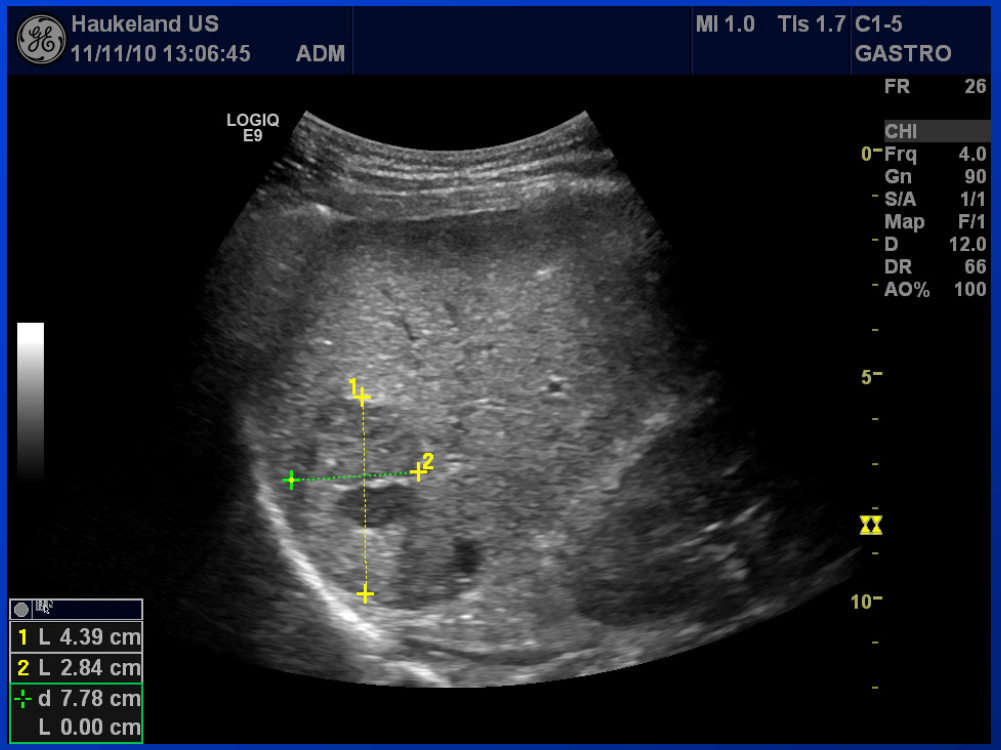
- Liver cell adenoma (LCA) is a rare primary benign neoplasm found mainly in young women with a history of oral contraceptive use
- The hypervascularity of adenomas can be demonstrated on Doppler,- sentripetal
- CEUS identification of the early and homogeneous hyperechoic enhancement in the periphery of the tumor, reflecting the presence of the subcapsular feeding arteries.
- The enhancement of LCA in the portal and late phases is nearly comparable with that of liver parenchyma, but LCA can remain slightly hypoechoic in relation to the adjacent liver

CEUS - Real-time Perfusion



Dynamic abilities outperforms CT and MR

Ultrasound in HCC

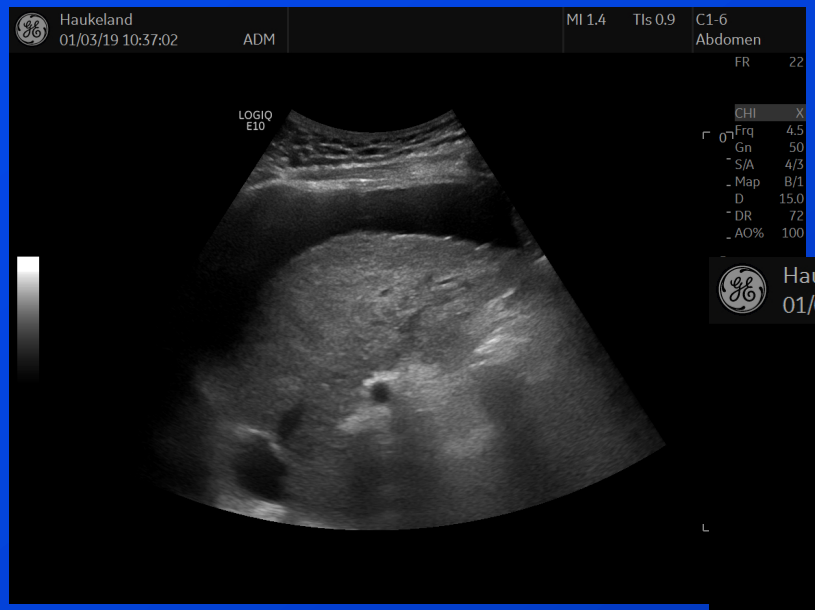


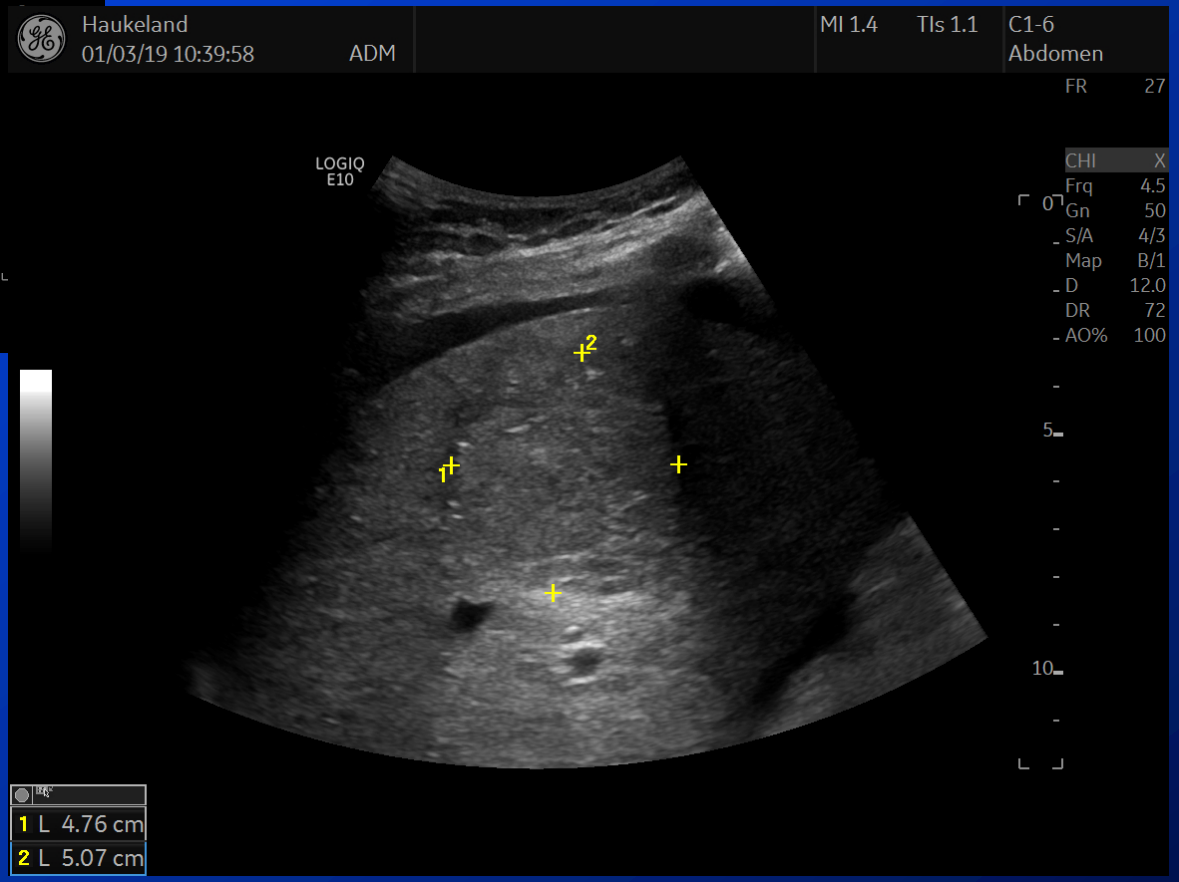
- Diagnosis
  - B-mode
  - Doppler
  - CEUS
- US-guided biopsy
- Per-operative guiding of ablation
- Follow-up and monitoring of treatment
- Surveillance / Screening

HCC facts
HCC – The great imitator

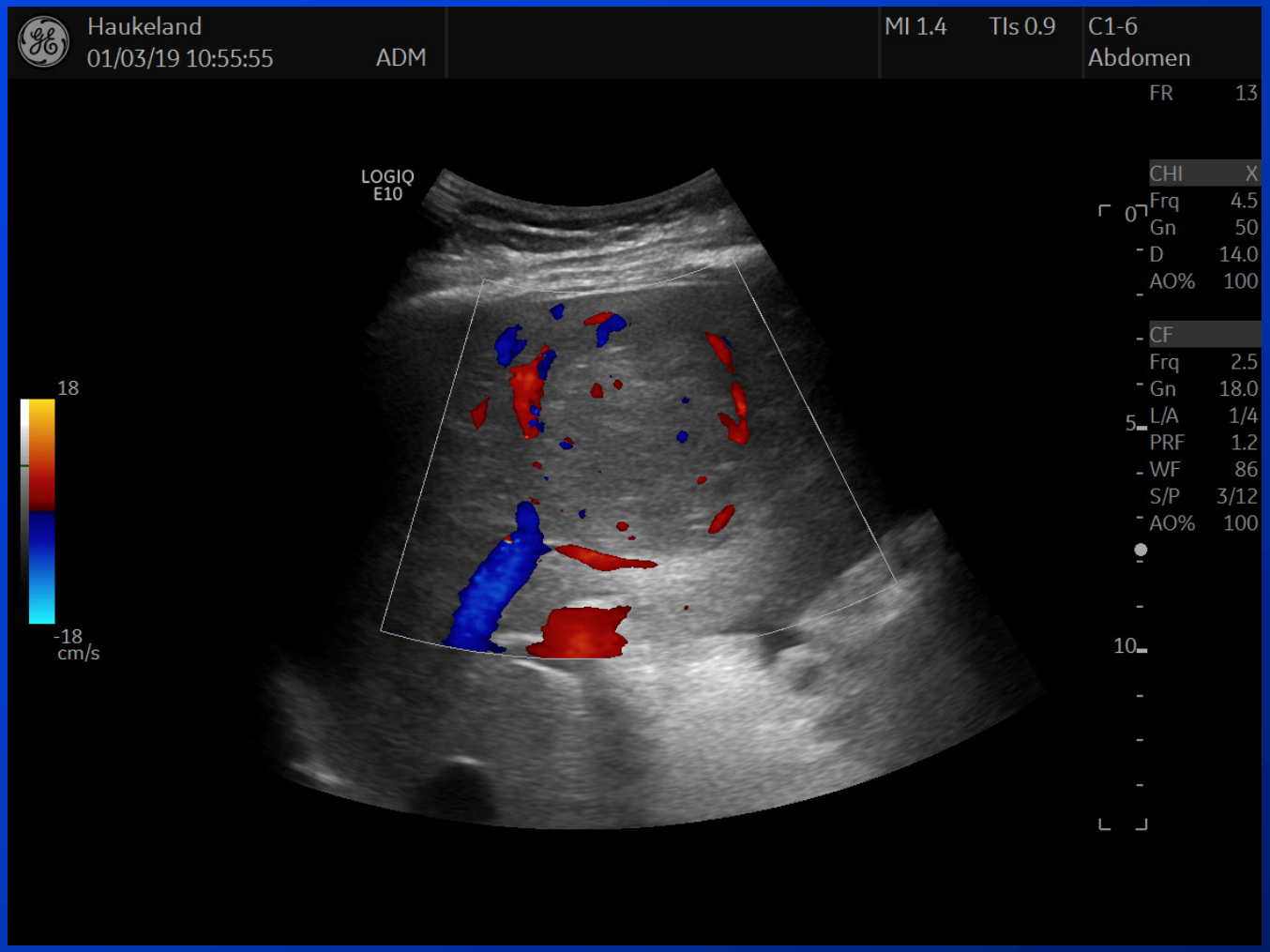
- Increasing incidence world-wide
- 90% has known ethiology
- AFP has limited sensitivity (approx. 60%)
- Most frequent: Alcohol (25%) and HCV
- NASH is increasing in incidence, thus feeding the HCC growth
- Barcelona criteria: 2 independant imaging methods are needed to avoid biopsy

A patient with cirrhosis

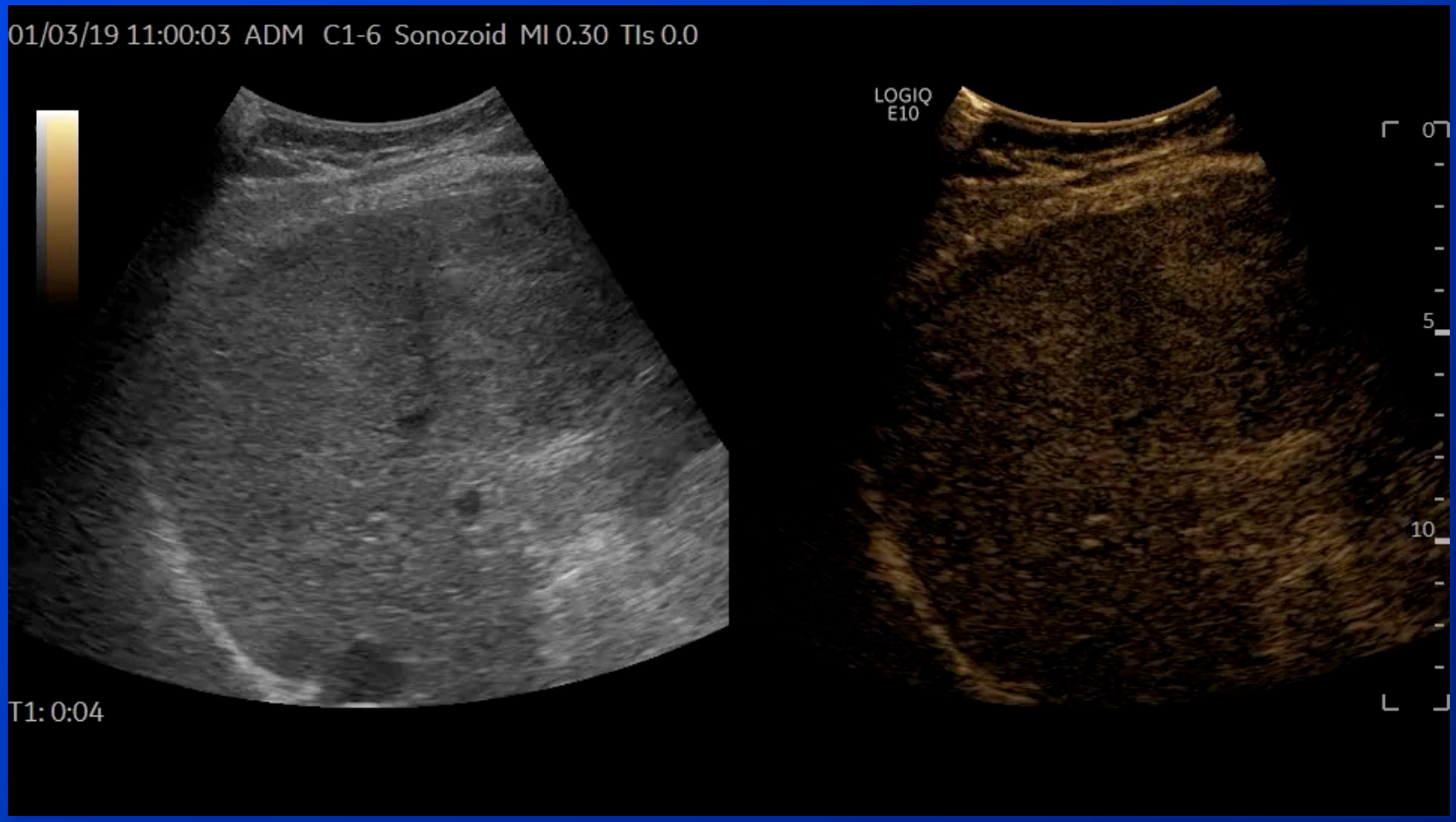




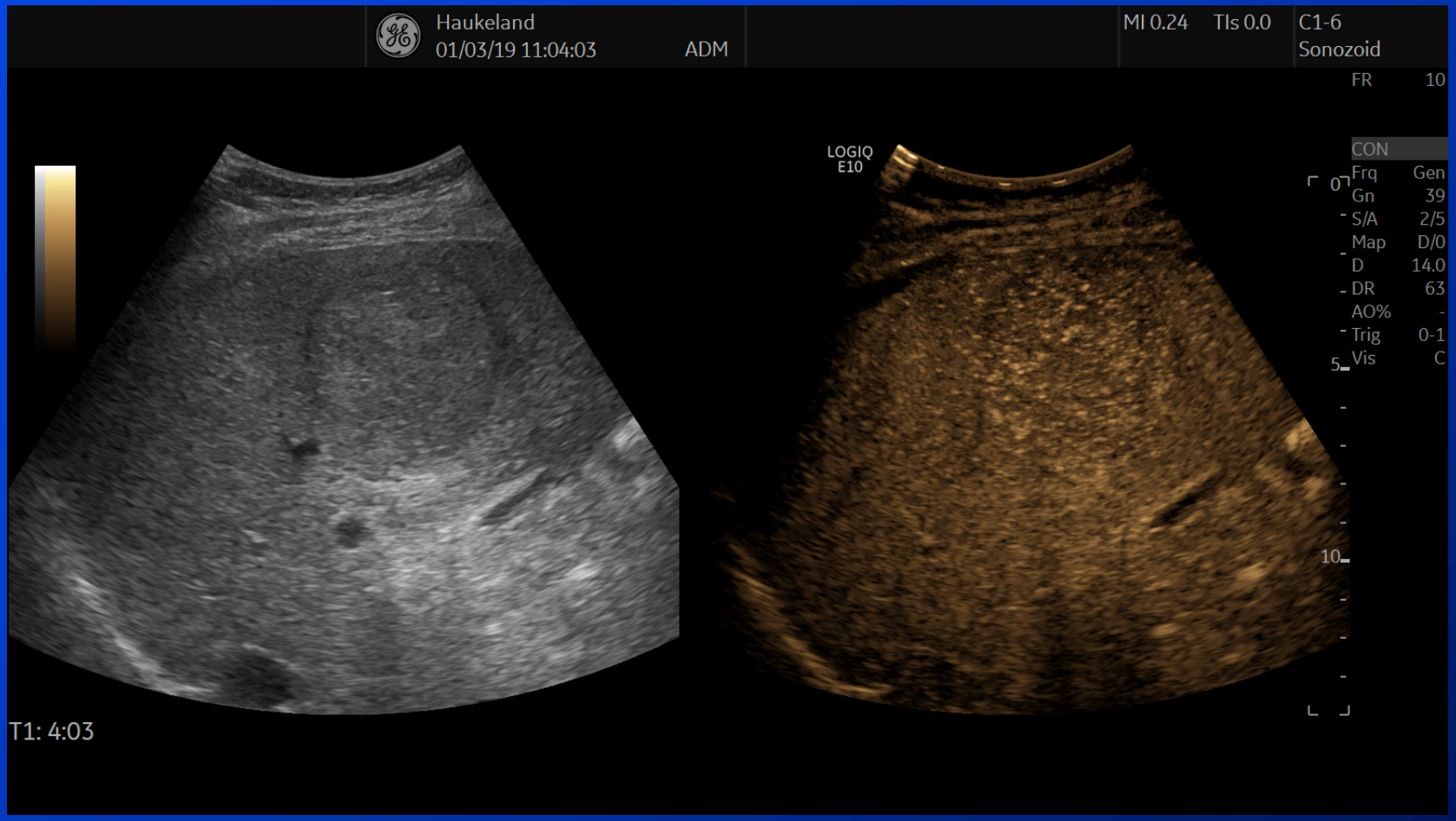
«The Basket Sign»



CEUS of tumor



Any wash-out in late phase ?



FNH versus HCC

FNH

HCC

One stop shopping

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