MULTIPARAMETRIC US APPLICATION IN LIVER

ANJA BRODNJAK, MD
RADIOLOGY CONSULTANT
MARIBOR,SLOVENIA

Liver Imaging Workshop

June 27 - 28, 2024

Cluj-Napoca, Romania

I have no potential conflict of interest

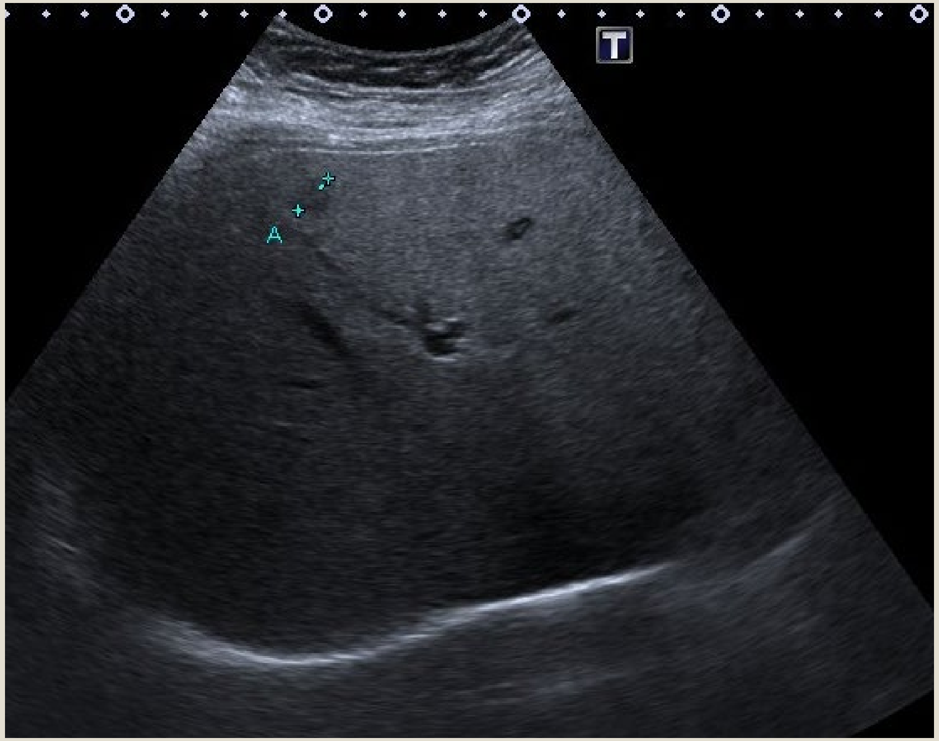
ANJA BRODNJAK, MD
RADIOLOGY CONSULTANT
MARIBOR, SLOVENIA

Learning objectives

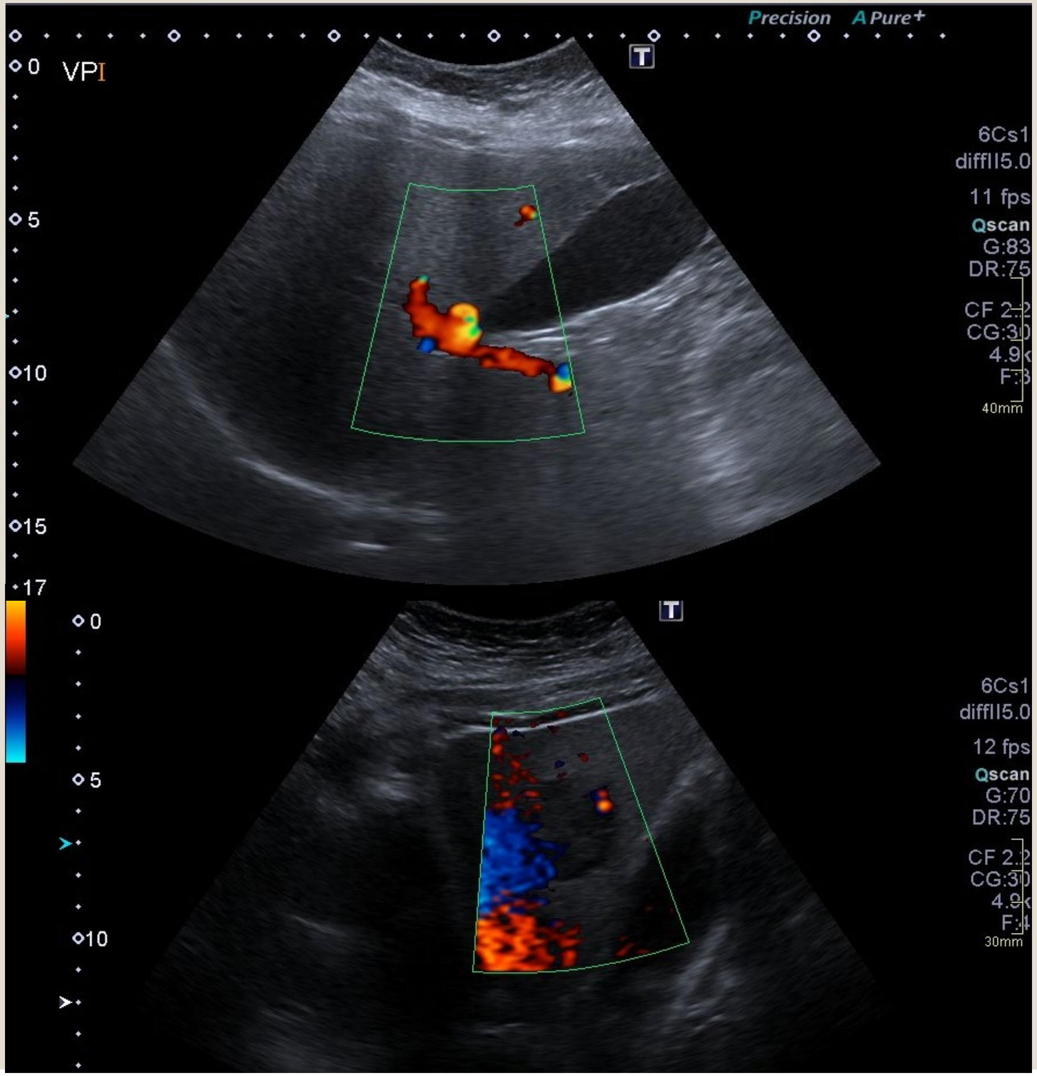
- 1) Basic principles and physics of low mechanical index
- CEUS
- 2) Technique used to image the liver in different vascular
- phases
- 3) The European Federation of Societies for Ultrasound in
- Medicine and Biology (EFSUMB) guidelines regarding
- liver CEUS.
- 4) Examples of liver CEUS through recorded clips.
- 5) Different types of US Elastography, and the current role
- in diagnosing liver fibrosis.
- 6) Technique of estimation of liver elasticity through shear
- wave elastography (SWE).
- 7) Steatosis quantification by US.

Multiparametric US technique

- Clinical setting
- Patient preparation
- Conventional B-mode technique



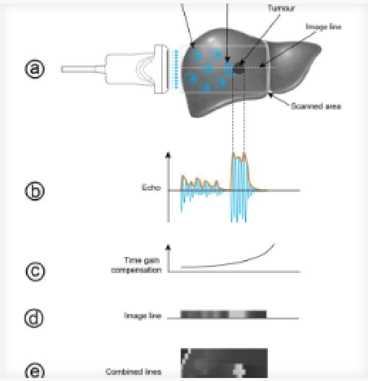
- Doppler ultrasound techniqe



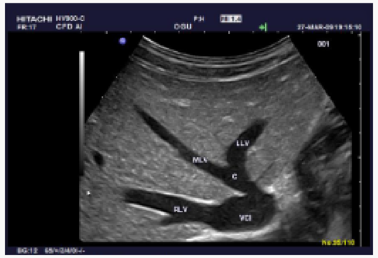
EFSUMB Course Book 2nd Edition is released as individual chapters for publication on our website.

Each chapter is available to download completely free.

The following 43 chapters are currently live:

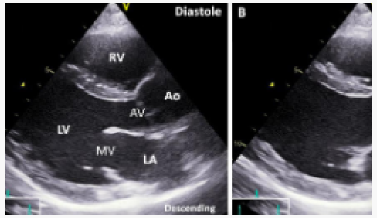


(Ch:01) Physical Principles of Medical

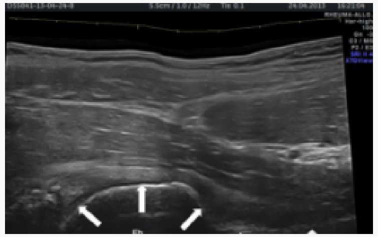


(Ch:02) Ultrasound of the Liver

(Ch:03) Liver Elastography



(Ch:04) Basics in Transthoracic Echocardiography and Standard Documentation



(Ch:05) Musculoskeletal Ultrasound

Diffuse parenchymal disease

- **HEPATIC STEATOSIS** – most common liver pathology
- Sensitivity and specificity for the detection of steatosis by B mode US is very high in the hands of expert investigator
- Steatosis is characterized by increased echogenicity (often compared with kidney or spleen parenchyma at the same depth)
- It is belived that the presence of focal hypoechoic areas – areas with normal or near normal fat content in steatotic parenchyma, are relatively specific to hepatic steatosis and may be helpful

https://efsumb.org/efsumb-course-book/

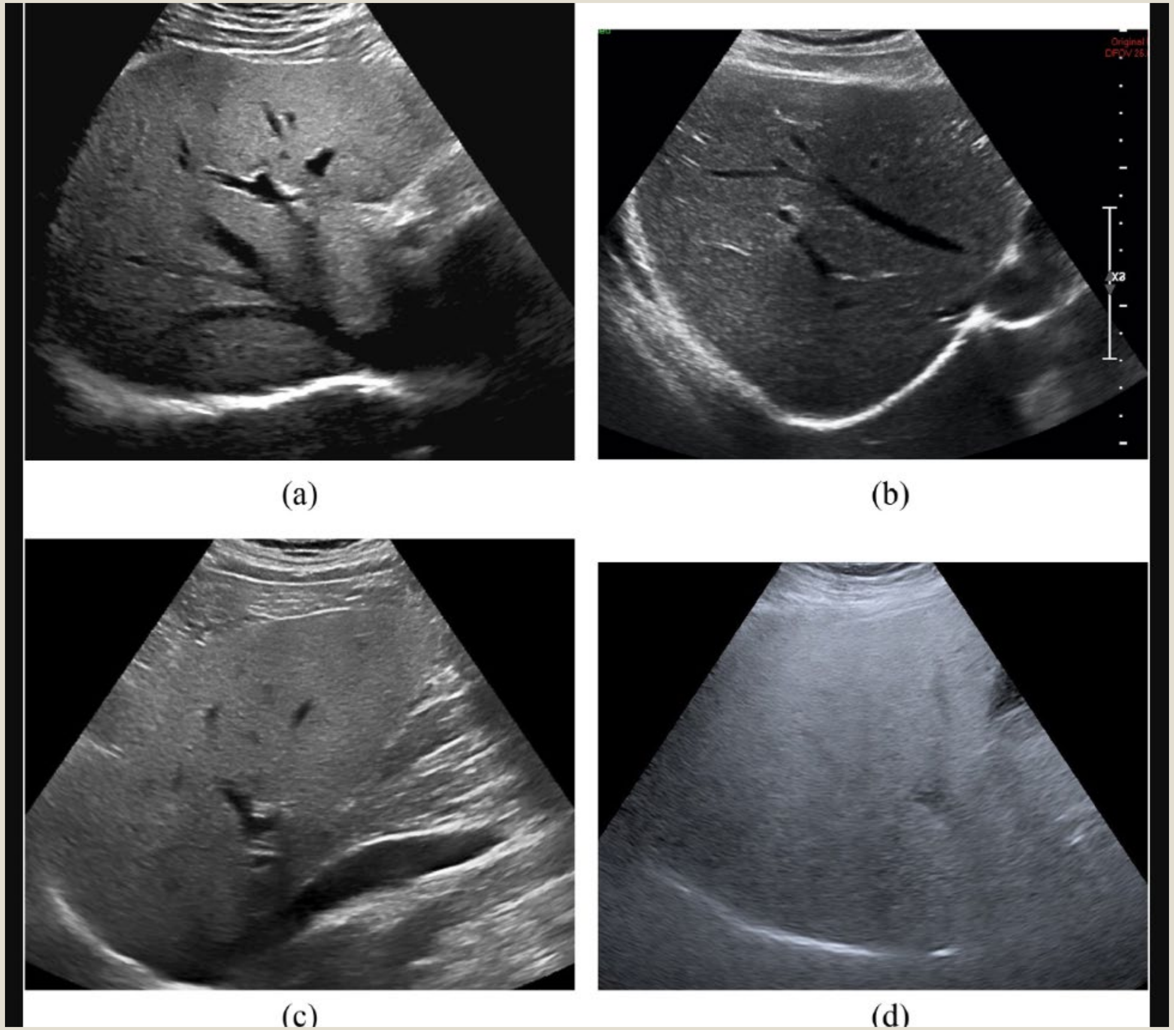
Table 1. Histological grading of steatosis and staging of steatohepatitis

NAS components Item	Score	Extent
Steatosis	0	<5%
	1	5%–33%
	2	>33%–66%
	3	>66%
Lobular inflammation	0	No foci
	1	<2 foci/200 ×
	2	2–4 foci/200 ×
	3	>4 foci/200 ×
Hepatocyte ballooning	0	None
	1	Few balloon cells
	2	Many cells/prominent ballooning
Fibrosis stage (not part of NAS)		
Item	Score	Extent
Fibrosis	0	None
	1	Perisinusoidal or periportal
	1A	Mild, zone 3, perisinusoidal
	1B	Moderate, zone 3, perisinusoidal
	1C	Portal/periportal
	2	Perisinusoidal and portal/periportal
	3	Bridging fibrosis
	4	Cirrhosis

NAS score = non-alcoholic fatty liver disease activity score.
The total NAS score is the sum of scores for steatosis, parenchymal (lobular) inflammation and ballooning, and ranges from 0 to 8. Fibrosis is evaluated separately.

- MASLD (metabolic associated steatotic liver disease) is defined by the presence of hepatic fat content (steatosis) in ≥5% of hepatocytes and is currently the most common liver disease worldwide.
- Prevalence is proportional to obesity and components of metabolic syndrome
- Estimated prevalence of 5%-30% in the general population depending on geographical area and around 55%-80% in patients with type 2 diabetes (European Association for the Study of the Liver et al. 2016; Chalasani et al. 2018; Younossi 2019), resulting in more than 1 billion individuals being affected (Loomba and Sanyal 2013).
- Steatosis is a dynamic process in liver that changes during time.

Diffuse parenchymal disease
Hepatic steatosis



- Assessment of liver fat with MR (magnetic resonance), which is currently an accepted reference standard
- New US methods able to quantitatively assess liver fat content (QUS) have recently been developed.
- QUS has lower-cost, more available, and more tolerable to a broader range of patients than MRI.
- QUS is non-invasive technique that can be repeated multiple times to accurately assess progression or regression of disease (MASLD).
- Monitoring patients non-invasively, to identify those who are or are not improving after lifestyle changes and/ or upcoming pharmacological therapies for MASH

Quantification of liver fat content: WFUMB position paper • G. Ferraioli *et al.*

Steatosis quantification by US (QUS)

- Ultrasound attenuation = the decrease in intensity as sound travels through a material, caused by absorption, scattering and beam divergence
- Higher the attenuation, higher the intrahepatic fat
- The spectral-based techniques that have been used in clinical studies are those estimating the attenuation coefficient and those estimating the backscatter coefficient.

ELSEVIER

Check for updates

Ultrasound in Med. & Biol., Vol. 47, No. 10, pp. 2803–2820, 2021

0301-5629/$ - see front matter

https://doi.org/10.1016/j.ultrasmedbio.2021.06.002

● *Review*

QUANTIFICATION OF LIVER FAT CONTENT WITH ULTRASOUND: A WFUMB POSITION PAPER

Giovanna Ferraioli,* Annalisa Berzigotti,[†] Richard G. Barr,[‡] Byung I. Choi,[§] Xin Wu Cui,[¶] Yi Dong,[‖] Odd Helge Gilja,[#] Jae Young Lee,** Dong Ho Lee,[††] Fuminori Moriyasu,[‡‡] Fabio Piscaglia,[§§] Katsutoshi Sugimoto,[¶¶] Grace Lai-Hung Wong,[‖‖] Vincent Wai-Sun Wong,[##] and Christoph F. Dietrich***

Quantification of liver fat content: WFUMB position paper • G. Ferraioli *et al.*

Ultrasound Med Biol. 2021 Oct;47(10):2803-2820.

Diffuse parenchymal disease
US elastography

Year (Archive)

2017

Ultraschall Med 2017; 38(04): e16-e47
DOI: 10.1055/s-0043-103952

Download PDF

Guidelines & Recommendations

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)

Christoph F. Dietrich , Jeffrey Bamber , Annalisa Berzigotti , Simona Bota , Vito Cantisani , Laurent Castera , David Cosgrove , Giovanna Ferraioli , Mireen Friedrich-Rust , Odd Helge Gilja , Ruediger Stephan Goertz , Thomas Karlas , Robert de Knegt , Victor de Ledinghen , Fabio Piscaglia , Bogdan Procopet , Adrian Saftoiu , Paul S. Sidhu , Ioan Sporea , Maja Thiele

- Elastography – type of **remote palpation that allows measurement and display of bimechanical properties** associated with **the elastic restoring forces in the tissue that act against shear deformation**

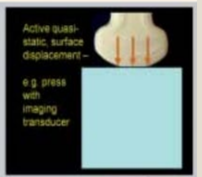
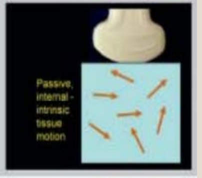
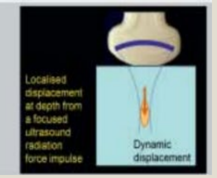
- Elastogram – **any image** of any elastic property of tissue

- Elastometry – **is the measurement of an elastic characteristic of tissue**, which may be obtained from either imaging or nonimaging methods

Different types of elastography

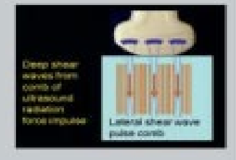
They all display images with contrast to obtain the same underlying information, associated with the shear elastic modulus

DISPLACEMENT OR STRAIN IMAGING

	method	type of force	applied force	property displayed/ measured	qualitative or quantitative	imaging or measure-ment	commercial implementation	illustration
displacement or strain imaging	strain elasto-graphy (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	 
	acoustic radiation force impulse (ARFI) imaging		ultrasound induced – focused radiation force impulse at depth	displace-ment	qualitative	single image within a box	Siemens	

SHEAR WAVE ELASTOGRAPHY (SWE)

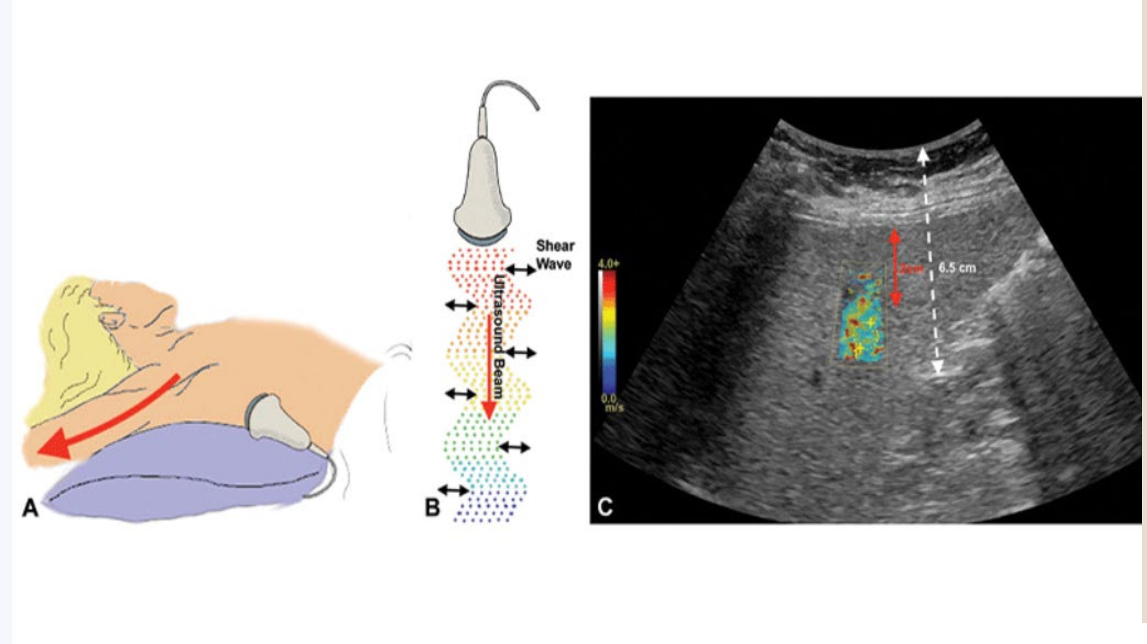
Shear wave speed imaging and/or measurement

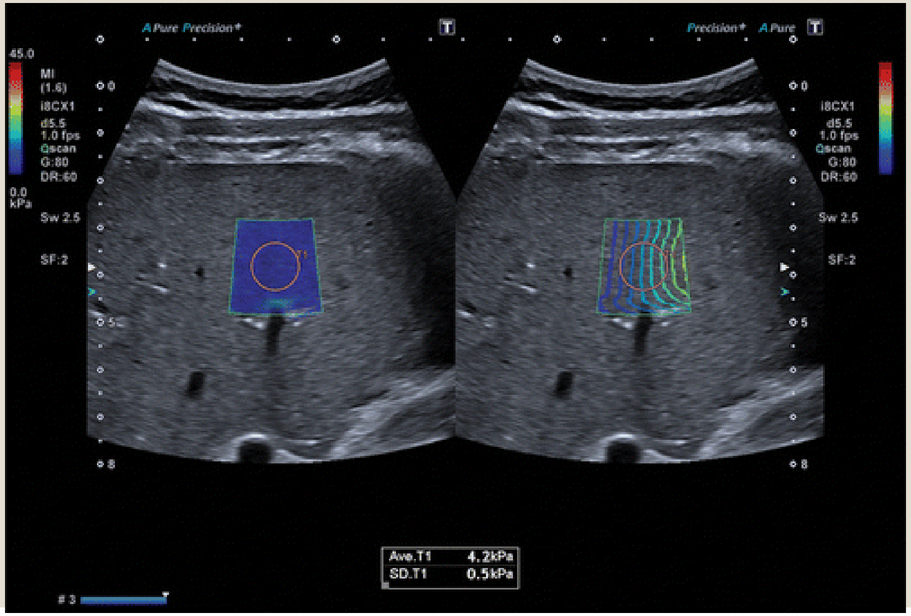
shear wave speed MEASUREMENT	shear wave elastography (SWE)	transient elasto-graphy (TE)[4]	dynamic	mechanically induced – impulse ("thump") at tissue surface	shear wave speed[5]	quantitative	single meas-urement, beam-line average	Echosens	
		point shear wave elastography (pSWE), also known as ARFI quantification[4]		ultrasound induced – focused radiation force impulse at depth	shear wave speed[5]	quantitative	single meas-urement, ROI average	Siemens Philips Hitachi-Aloka Esaote	
shear wave speed IMAGING		two dimensional and three dimensional shear wave elastography (2D-SWE and 3D-SWE)[4]		ultrasound induced – radiation force impulses focused at various depths	shear wave speed[5]	quantitative	single image within a colour box / image within a colour box, running refresh	Siemens / Toshiba Philips Mindray Zonare	
				ultrasound induced – radiation force down multiple simultaneous lines in a "comb push" combined with directional filtering	shear wave speed[5]	quantitative	single image within a colour box	GE	
				ultrasound induced – radiation force focus swept over depth faster than shear wave speed to create a Mach cone	shear wave speed[5]	quantitative	image within a colour box, refreshed at up to several per second[3]	SuperSonic Imagine	

Estimation of liver elasticity through SWE

- **Liver in important target organ** for the use of elastography, liver stiffness is measured
- **Stiffness correlates** with the **degree of fibrosis** and **indirectly with portal hypertension**
- Fasting for minimum 2 hours and rest for a minimum 10 minutes before measurement with SWE

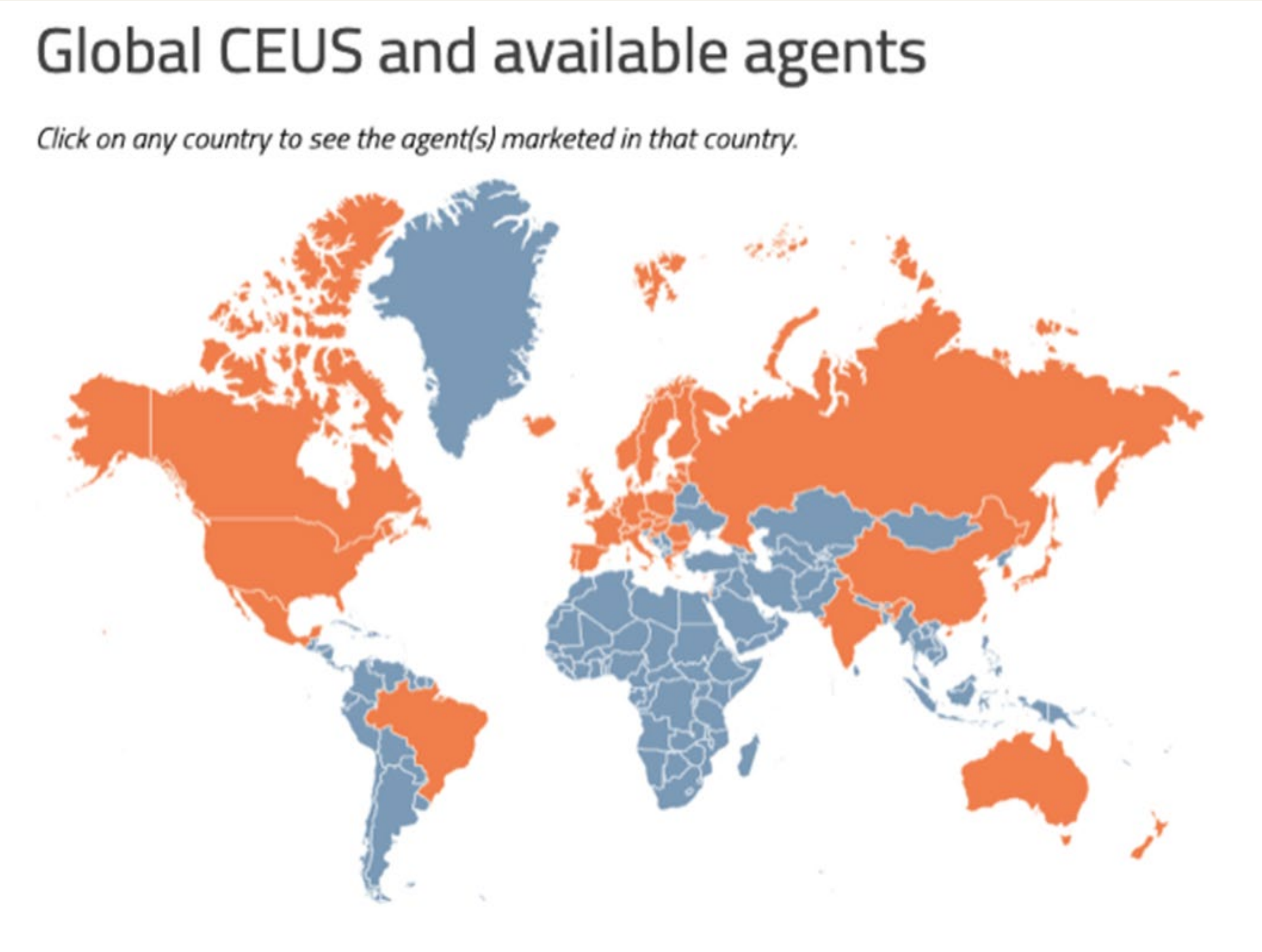
- Liver stiffness does **not solely reflect liver fibrosis**
- Can reflect **many other conditions** (physiological or pathological)
- Hepatic inflammation, obstructive cholestasis, liver congestion, acute hepatitis and infiltrative liver diseases (amyloidosis, lymphomas, extramedullary hemopoesis), acute toxic hepatitis
 (CONGESTION, INFLAMATION, INFILTRATION)





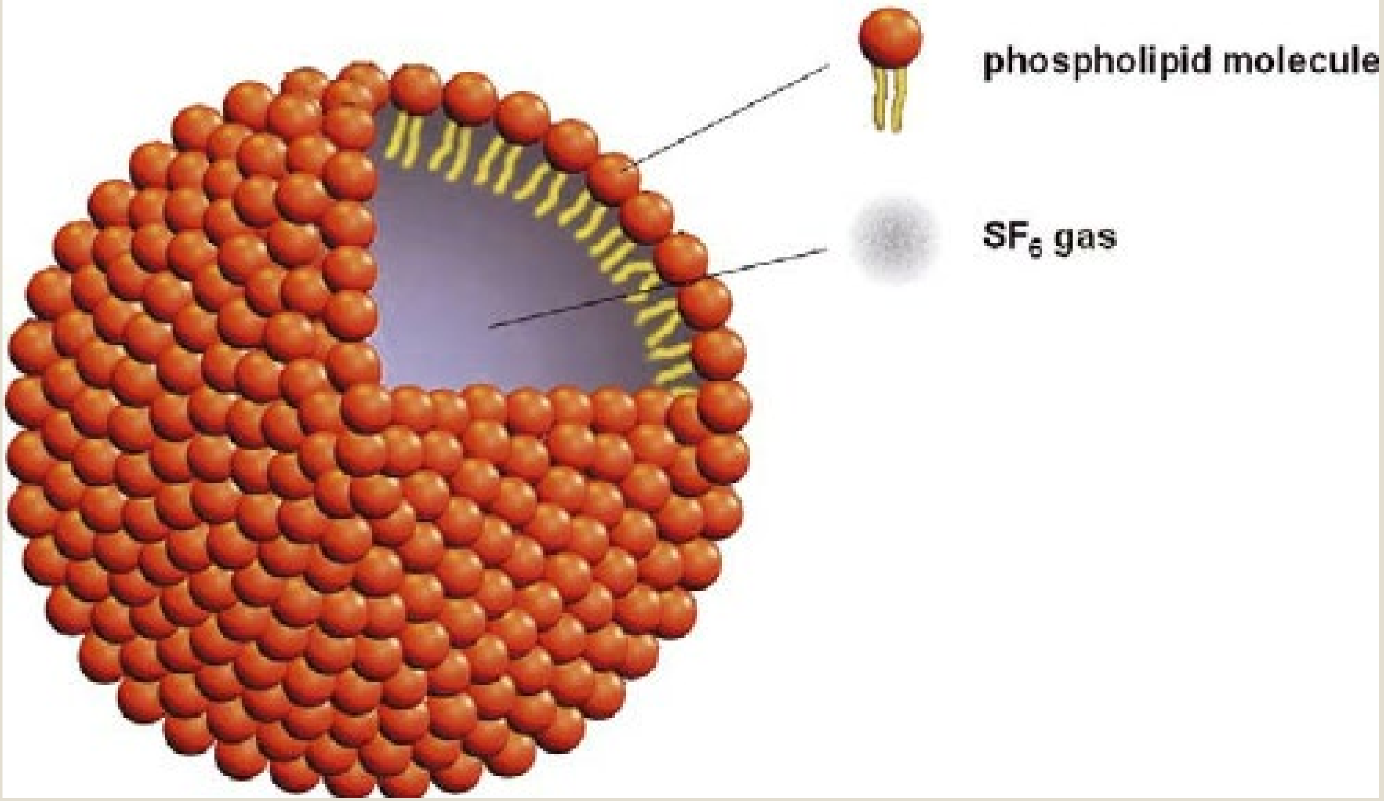
ULTRASOUND contrast agent (UCA)

https://icus-society.org/getting-started/finding-an-agent/



- Availability of UCAs for clinical use:
- is based on the approval by regulatory agencies specific to the territory of intended use.
- Currently, four agents are available internationally for use in the liver:
- Definity/Luminity (Lantheus Medical Imaging, Inc.,
- North Billerica, MA, USA)
- SonoVue/Lumason (Bracco Suisse SA, Geneva, Switzerland)
- Optison (GE Healthcare AS, Oslo, Norway)
- Sonazoid (GE Healthcare AS, Oslo, Norway)

Ultrasound Contrast agent (UCA) - microbubbles



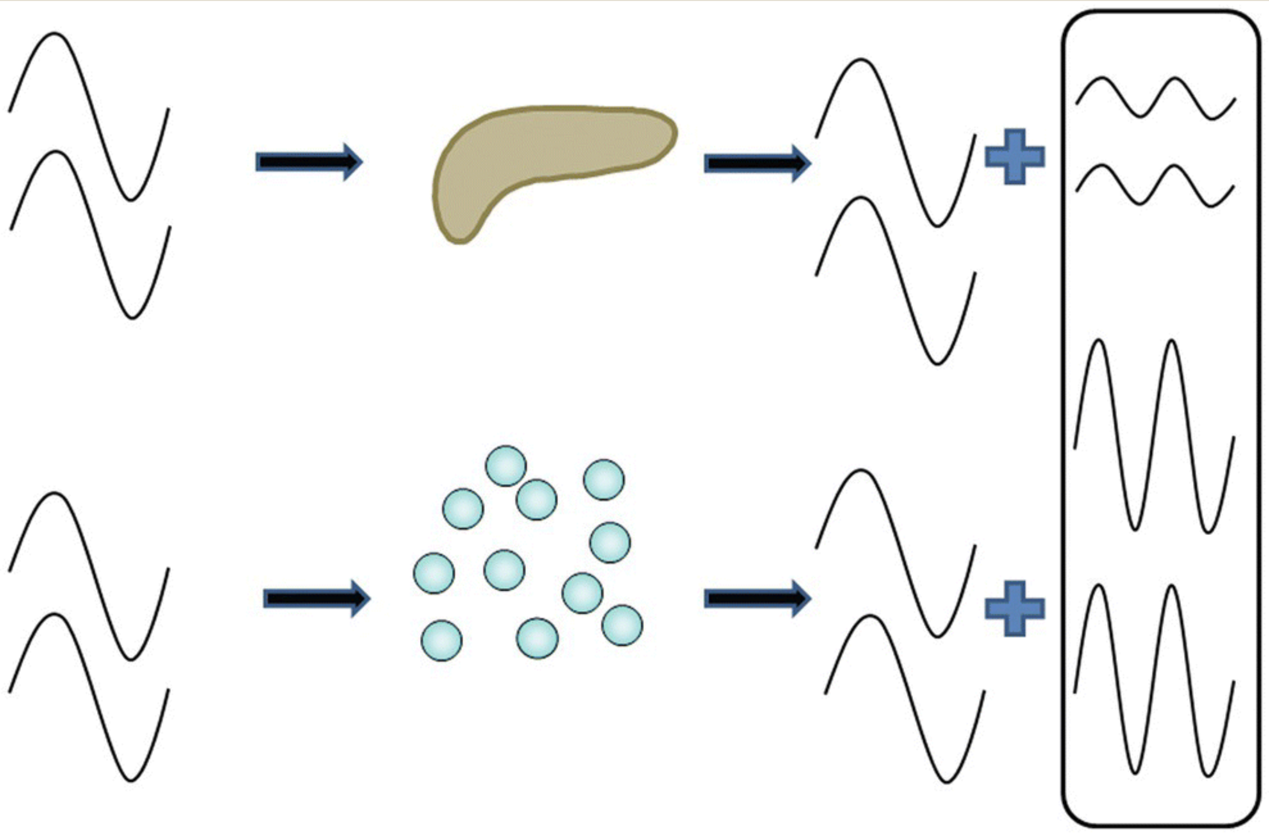
COMPOSITION OF AN UCA'S - microbubbles consisting of **a high-molecular-weight gas core** surrounded by **a lipid or protein shell** are the typical workhorse agents for CEUS

Development of microbubble contrast agent **enabled the display of the liver parenchymal microvasculature**

UCA's **different pharmacokinetics** than CT CA and MR CA

UCA's are **confined to the vascular space** and are not cleared from the blood pool to extravascular space

Contrast harmonic imaging

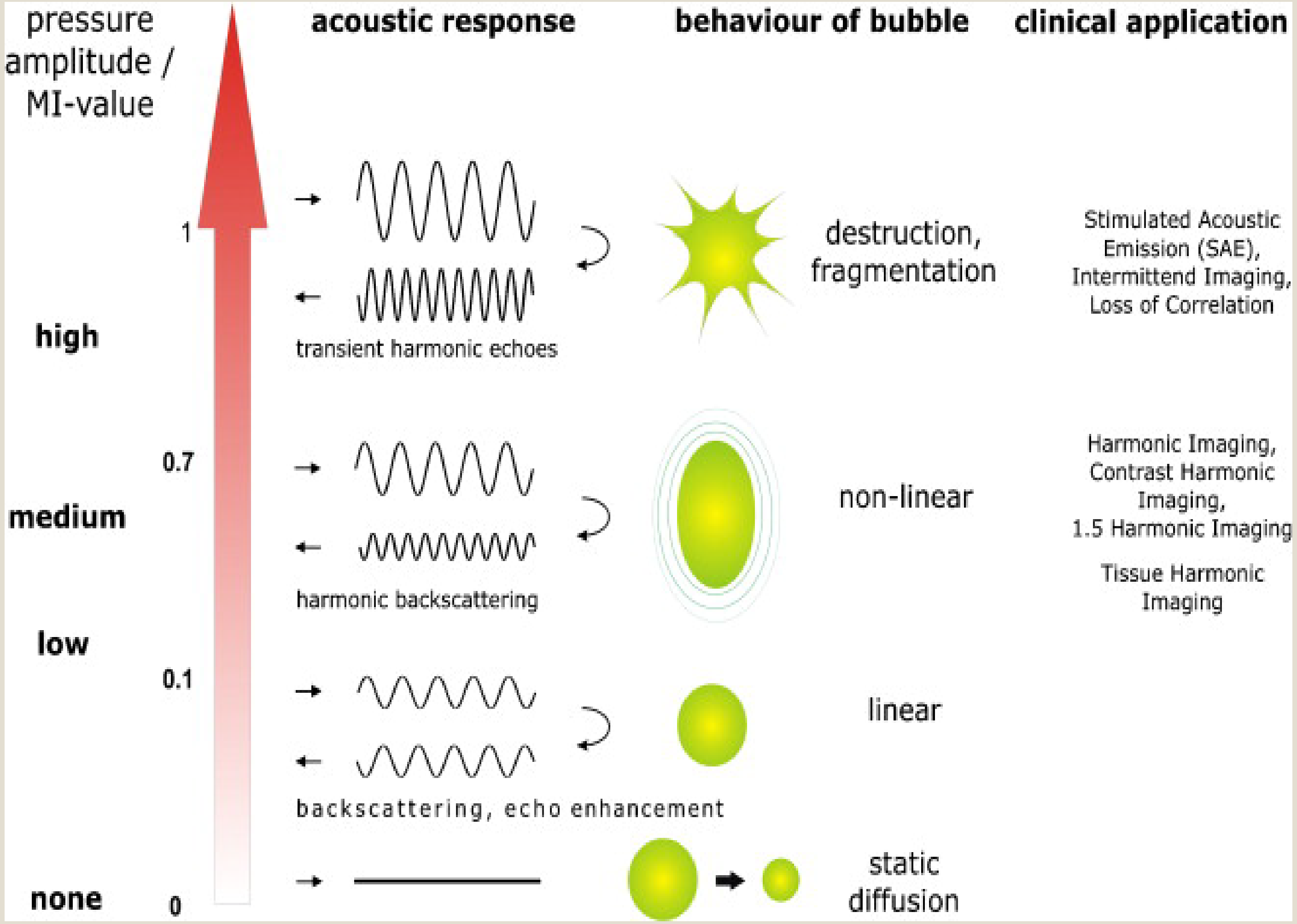


- CONTRAST HARMONIC IMAGING

1. Upon exposure to ultrasound beam, microbubbles in the contrast agent either resonate or disrupt and subsequently release several harmonic signls
2. Exposure leads to the production of harmonic components in tissues and microbubbles that are integer multiples of the fundamental frequency
3. Microbubbles generate higher harmonic content than tissues
4. Selective depicting the second harmonic component facilitates a better visualization of signals from microbubbles

https://radiologykey.com/how-to-do-contrast-enhanced-eus/

Basic principles and physics of low mechanical index CEUS

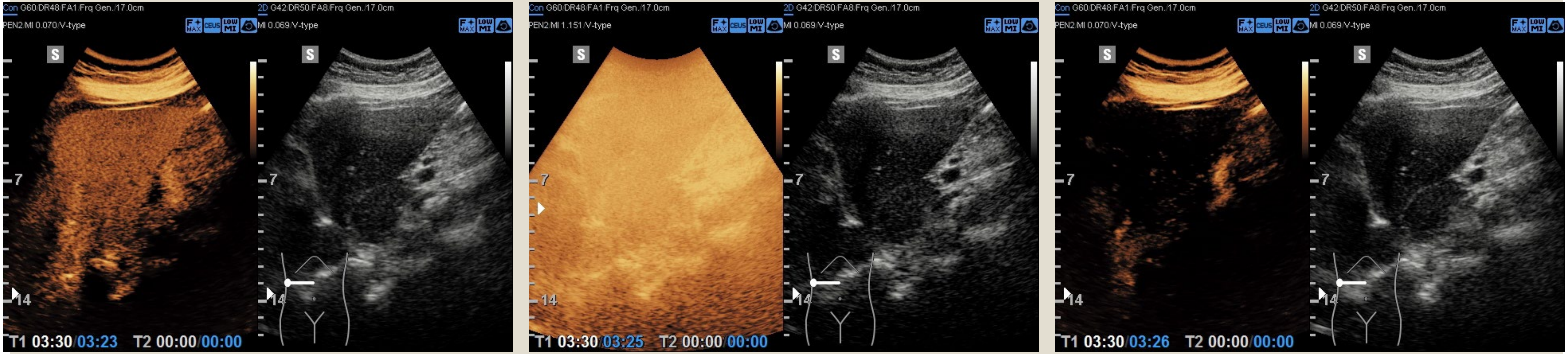


- MI is attampt to measure part of an ultrasound beam's bioeffects
- MI is an indicator of US beam's ability to cause cavitation related bioeffects
- Is proportional to beam's peak negative pressure (or peak rarefaction pressure)
- Higher frequencies have lower MI
- **For CEUS mechanical index (MI) has to be kept at the lowest possible level** which provides reliable contrast, generally much lower than during routine B-mode US

Flash mode

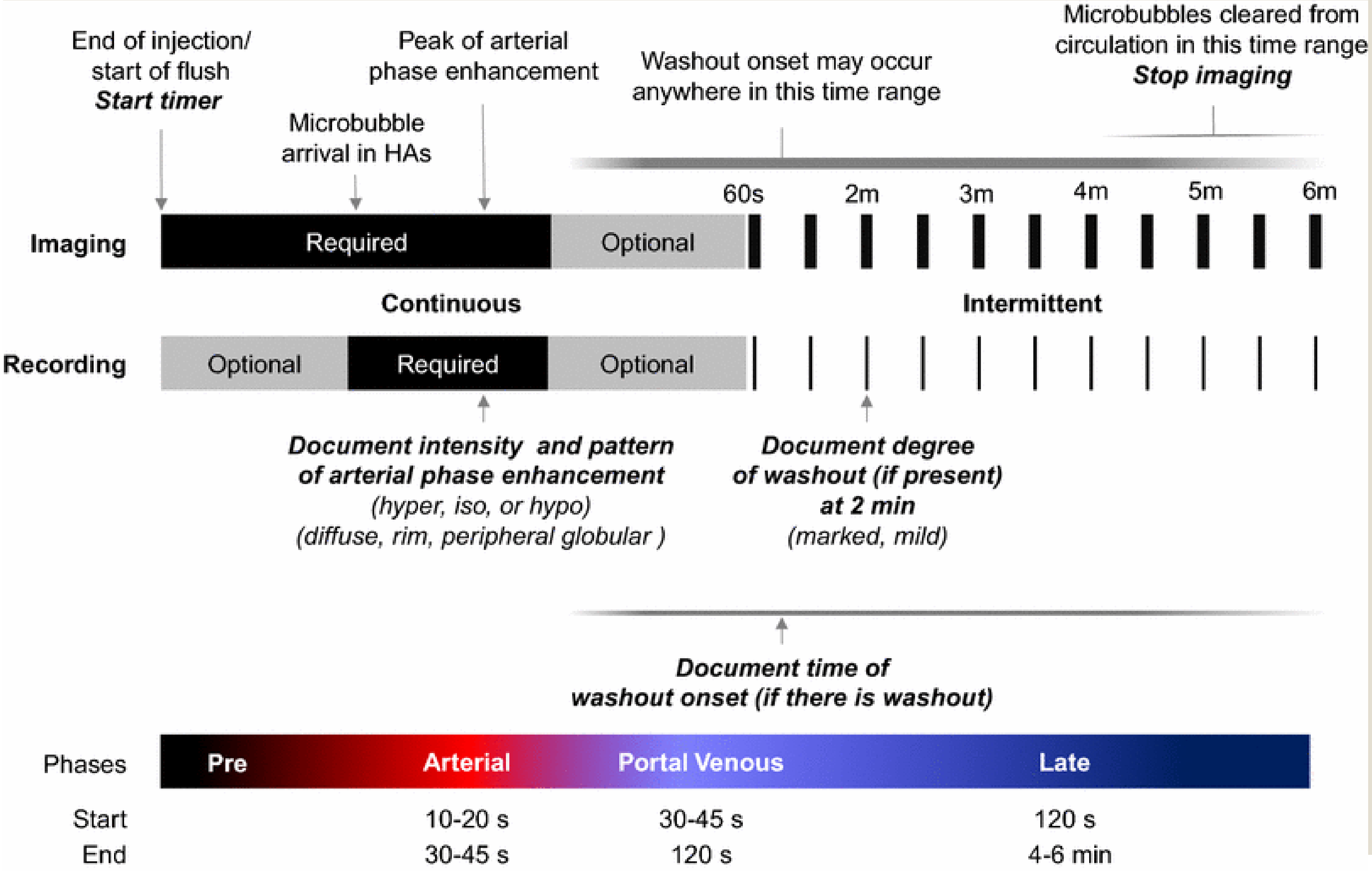
(technique specific for CEUS capable US devices)

= brief is a short ultrasound pulse with a very high mechanical index (MI), resulting in almost complete destruction of microbubbles in the imaging plane



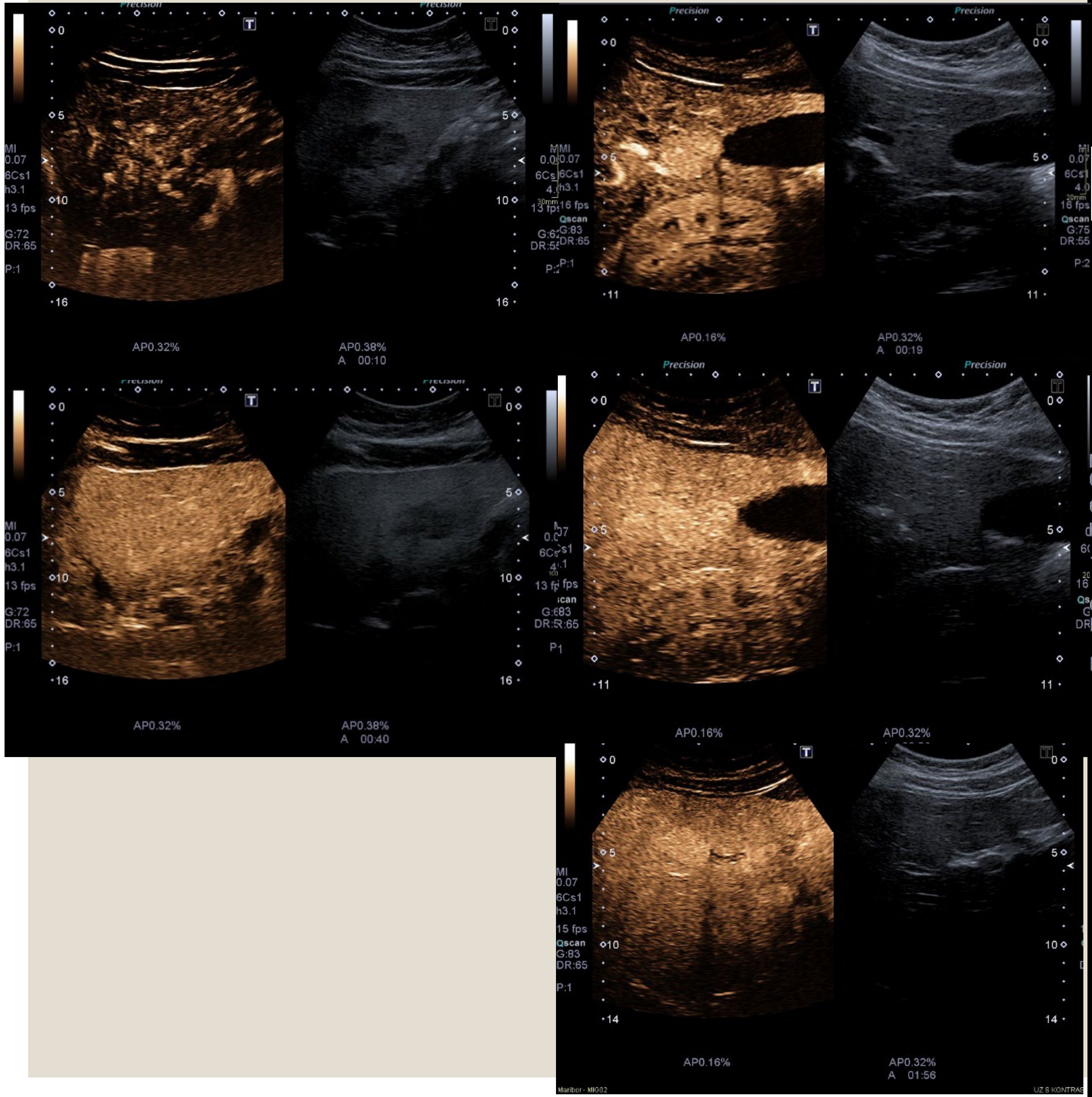
Case courtesy of Bálint Botz, Radiopaedia.org, rID: 72238

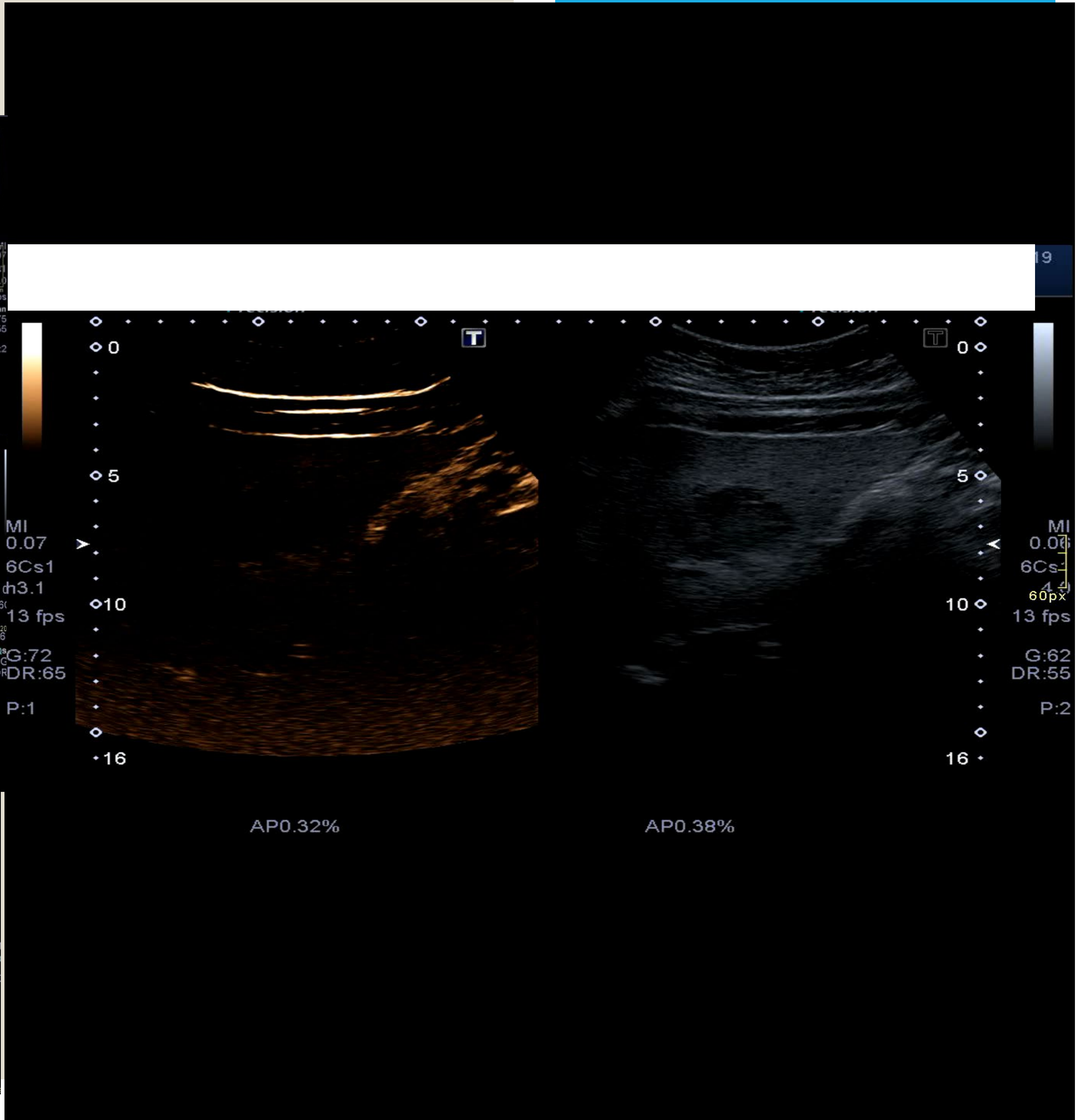
CEUS LIVER Imaging protocol
in different vascular phases



- Lyshchik, A., Kono, Y., Dietrich, C.F. *et al.* Contrast-enhanced ultrasound of the liver: technical and lexicon recommendations from the ACR CEUS LI-RADS working group. *Abdom Radiol* **43**, 861–879 (2018). https://doi.org/10.1007/s00261-017-1392-0

Different vascular phases





Postvascular phase

- Sonovue
- Sonazoid

Figure 2. SonoVue imaging in a 65-year-old woman with 3.5 × 3.1 cm hepatocellular carcinoma. **A,** High signal of the tumor is shown in arterial phase of CE-MRI (arrows). **B,** Attenuation with ringlike enhancement is shown during the portal venous phase of CE-MRI (thin arrows). **C,** Earlier washout of contrast agent than the liver parchenyma is suggested in the early vascular phase (thick arrows). **D,** Washout of contrast agent is revealed in the late vascular phase (arrows), and the whole liver also shows hypoenhancement (white star).

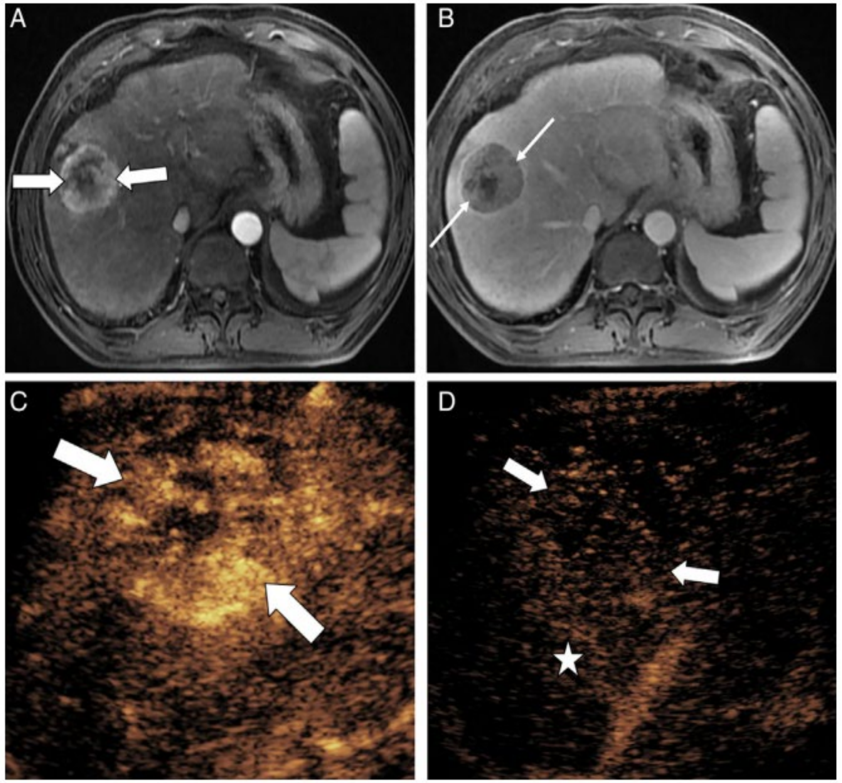
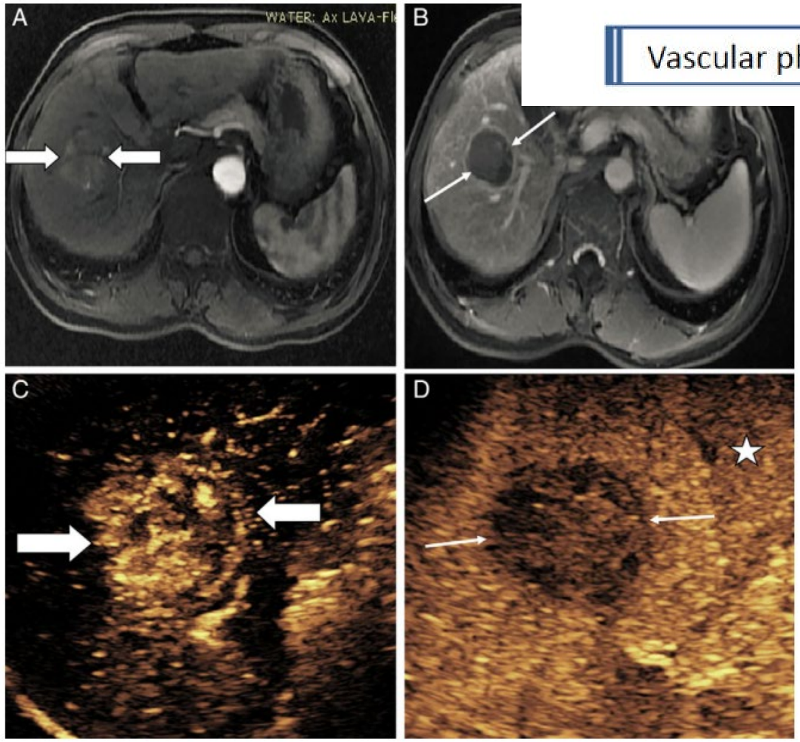
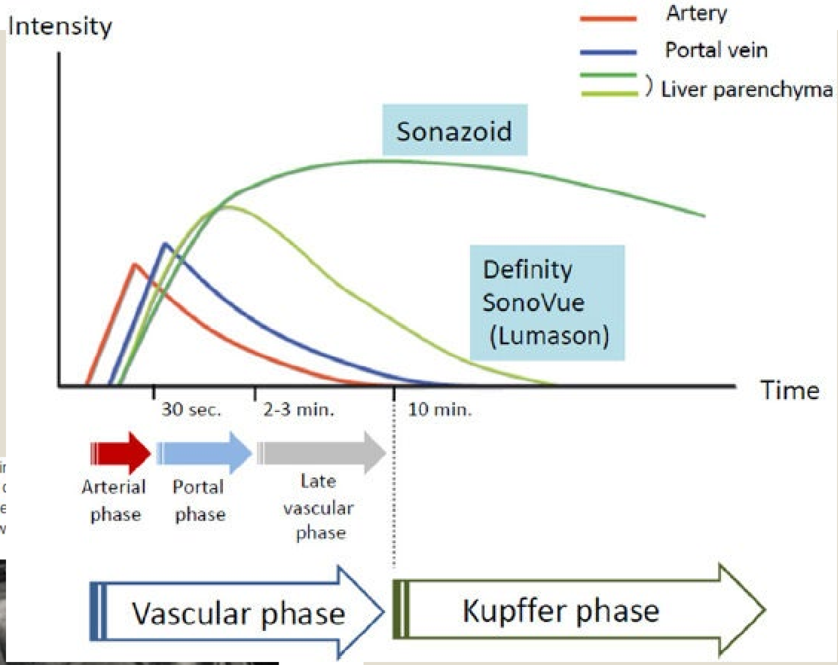


Figure 1. Sonazoid imaging in 48-year-old man with 2.9 × 2.7 cm hepatocellular carci
arterial phase of CE-MRI (arrows). **B,** Attenuation with ringlike enhancement is revealed
C, Disorder tumor vessels are shown in early vascular phase (thick arrows). **D,** A hypoe
tion is indicated during Kupffer phase (thin arrows), while the liver parenchyma still show





Guidelines for CEUS in the liver

- **C.F. Dietrich et al. Guidelines and Good Clinical Practice Recommendations** for Contrast-Enhanced Ultrasound **(CEUS) in the Liver-Update 2020** WFUMB in Cooperation with EFSUMB, AFSUMB, AIUM, and FLAUS. Ultrasound Med Biol. 2020 Oct;46(10):2579-2604. doi: 10.1016/j.ultrasmedbio.2020.04.030. Epub 2020 Jul 24.

ELSEVIER

Check for updates

Ultrasound in Med. & Biol., Vol. 46, No. 10, pp. 2579–2604, 2020

0301-5629/$ - see front matter

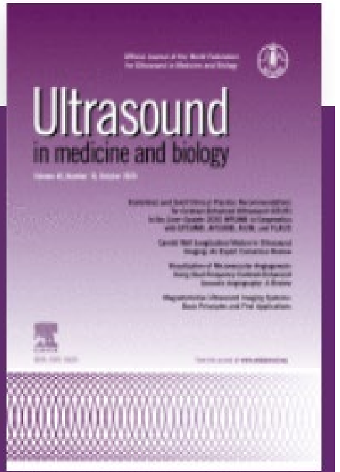
https://doi.org/10.1016/j.ultrasmedbio.2020.04.030

● *Review Article*

GUIDELINES AND GOOD CLINICAL PRACTICE RECOMMENDATIONS FOR CONTRAST-ENHANCED ULTRASOUND (CEUS) IN THE LIVER—UPDATE 2020 WFUMB IN COOPERATION WITH EFSUMB, AFSUMB, AIUM, AND FLAUS

Christoph F. Dietrich,[*,†2] Christian Pállson Nolsøe,[‡,2] Richard G. Barr,[§,¶] Annalisa Berzigotti,[‖] Peter N. Burns,[#] Vito Cantisani,[**] Maria Cristina Chammas,[††] Nitin Chaubal,[‡‡] Byung Ihn Choi,[§§] Dirk-André Clevert,[¶¶] Xinwu Cui,[‖‖] Yi Dong,[##] Mirko D'Onofrio,[***] J. Brian Fowlkes,[†††] Odd Helge Gilja,[‡‡‡] Pintong Huang,[§§§]

ScienceDirect



Publications for use of CEUS in the liver

1. Guidelines for use of UCA's published in 2004 for liver applications only (Albrecht et al. 2004)
2. Second edition guidelines in 2008 reflected changes in the availeble contrast agents and updated applications for the liver, as well as implementing some non-liver applications
3. Third iteration of recommendation for the hepatic use of CEUS (Claudon et al. 2013)


Ultraschall in der Medizin
European Journal of Ultrasound
Thieme
Year (Archive)

Ultraschall Med 2004; 25(4): 249-256
DOI: 10.1055/s-2004-813245

Download PDF

Guidelines

© Georg Thieme Verlag KG Stuttgart · New York

Guidelines for the Use of Contrast Agents in Ultrasound - January 2004

Leitlinien für den Gebrauch von Ultraschallkontrastmitteln - Januar 2004

T. Albrecht[1], M. Blomley[1], L. Bolondi[1], M. Claudon[1], J.-M Correas[1], D. Cosgrove[1], L. Greiner[1], K. Jäger[1], N. de Jong[1], E. Leen[1], R. Lencioni[1], D. Lindsell[1], A. Martegani[1], L. Solbiati[1], L. Thorelius[1], F. Tranquart[1], H. P. Weskott[1], T. Whittingham[1]


Ultraschall in der Medizin
European Journal of Ultrasound
Thieme

Ultraschall Med 2008; 29(1): 28-44
DOI: 10.1055/s-2007-963785

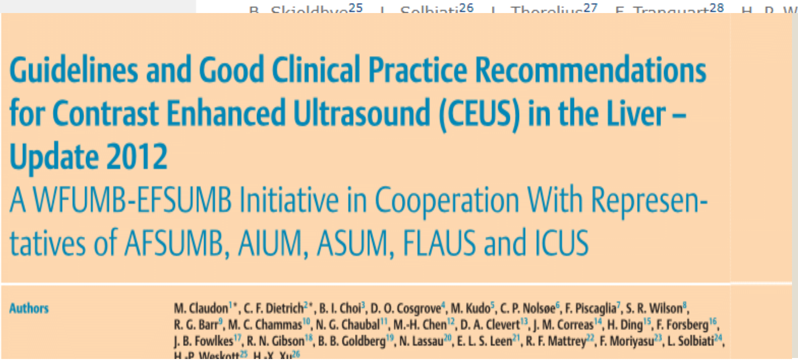
Download PDF

Guidelines

© Georg Thieme Verlag KG Stuttgart · New York

Guidelines and Good Clinical Practice Recommendations for Contrast Enhanced Ultrasound (CEUS) - Update 2008

M. Claudon[1], D. Cosgrove[2], T. Albrecht[3], L. Bolondi[4], M. Bosio[5], F. Calliada[6], J.-M Correas[7], K. Darge[8], C. Dietrich[9], M. D'Onofrio[10], D. H. Evans[11], C. Filice[12], L. Greiner[13], K. Jäger[14], N. de Jong[15], E. Leen[16], R. Lencioni[17], D. Lindsell[18], A. Martegani[19], S. Meairs[20], C. Nolsøe[21], F. Piscaglia[22], P. Ricci[23], G. Seidel[24],


Guidelines and Good Clinical Practice Recommendations for Contrast Enhanced Ultrasound (CEUS) in the Liver – Update 2012

A WFUMB-EFSUMB Initiative in Cooperation With Representatives of AFSUMB, AIUM, ASUM, FLAUS and ICUS

Authors

M. Claudon[1*], C. F. Dietrich[2*], B. I. Choi[3], D. O. Cosgrove[4], M. Kudo[5], C. P. Nolsøe[6], F. Piscaglia[7], S. R. Wilson[8], R. G. Barr[9], M. C. Chammas[10], N. G. Chaubal[11], M.-H. Chen[12], D. A. Clevert[13], J. M. Correas[14], H. Ding[15], F. Forsberg[16], J. B. Fowlkes[17], R. N. Gibson[18], B. B. Goldberg[19], N. Lassau[20], E. L. S. Leen[21], R. F. Mattrey[22], F. Moriyasu[23], L. Solbiati[24],

Recommendations CEUS in the liver. Update 2020.

C.F.Dietrich. Ultrasound Med Biol. 2020 Oct;46(10):2579-2604

- **i.v. use** of UCA's in **adult and pediatric** population **is safe**
- **Intracavitary use** of UCSs **is safe**
- For patients with **inconclusive findings at CT or MR** imaging
- Considered as the first contrast imaging modality **in patients with renal insufficiency**
- Can be used **for liver metastasis detection** as part of a multimodality approach

- Routine use for the **surveilleance** of patients at risk **for HCC is not recommended**
- **For staging of HCC** is **not recommended**

Characterization of focal liver lesions (FLL)

- Before CEUS for FLL characterization a systematic liver examination using B-mode and Doppler
- First line imaging tecnique for the characterization of **incidentaly detected, indeterminate FLLs at US** (non-cirrhotic, without malignant disease)
- As first line for FLLs detected with US in non-cirrhotic but **history or clinical suspicion of malignant disease** (weak)
- Is sugested if **biopsy of FLL was inconclusive**
- If both **CT and MRI are contraindicated**
- CEUS definitively characterized a **benign FLL, further investigatios are not needed**
- In the appropriate setting **hepatic abscess**

Recommendations liver update 2020

- Characterization of FLL in liver cirrhosis
- CEUS can be used for charact. of FLL found in liver cirrhosis to establish CEUS LR-M (malignancy) or CEUS LR-5 (HCC) but **CT and MR imaging is required to accurate staging**
- when CT and MR is inconclusive
- for the selection of FLL in cirrhotic liver to be biopsied (when multiple lesions and different contrast patterns
- To monitor changes in enhancement pattern in FLLs requiring follow-up

- Characterization of portal vein thrombosis
- CEUS is recommended for differentiation between benign and malignant portal vein thrombosis

- Contrast enhanced intraoperative US (CE-IOUS)
- Can be used to detect and characterize FLLs not detected at pre-operative imaging
- Assessment of region of resection for preciously treated and regressed colorectal metastases

Recommendations liver update 2020

- CEUS for guiding biopsy
- Guidance should be attempted to biopsy FLLs that are invisible or inconspiuous at B-mode
- Considered for FLLs with potential necrotic areas or if previous biopsy resulted in necrotic material

- Intracavitary use (ICCEUS)
- ICCEUS for delineation of the liver abscess cavity and identification of correct drain position and of communication with other structures
- To guide transhepatic biliary interventions

- CEUS for interventional tumor ablations
- CEUS before US-guided ablation procedure is recommended as a complement to US, CT and MRI for treatment planning
- CEUS guidence for tumors that are invisible or inconspicuous on US

- Monitoring medical tumor treatment response
- Dynamic CEUS (DCEUS) can be used in the quantitative assessment of response to targeted therapies in patients with malignant tumors of the liver

Radiologe 2021 · 61 (Suppl 1):S19–S28
https://doi.org/10.1007/s00117-021-00891-7
Accepted: 29 June 2021
Published online: 10 August 2021

Contrast-enhanced ultrasound perfusion imaging of organs

Ernst-Michael Jung[1,4] · Marc-André Weber[2] · Isabel Wiesinger[3]

[1] Institute of Radiology, Interdisciplinary Department for Ultrasound, University Medical Center, Regensburg, Germany
[2] Institute of Diagnostic and Interventional Radiology, Pediatric Radiology and Neuroradiology, University Medical Center Rostock, Rostock, Germany
[3] Institute of Neuroradiology, Bezirksklinikum Regensburg, Regensburg, Germany
[4] Institut für Röntgendiagnostik/Interdisziplinäres Ultraschallzentrum, Universitätsklinikum Regensburg, Regensburg, Germany

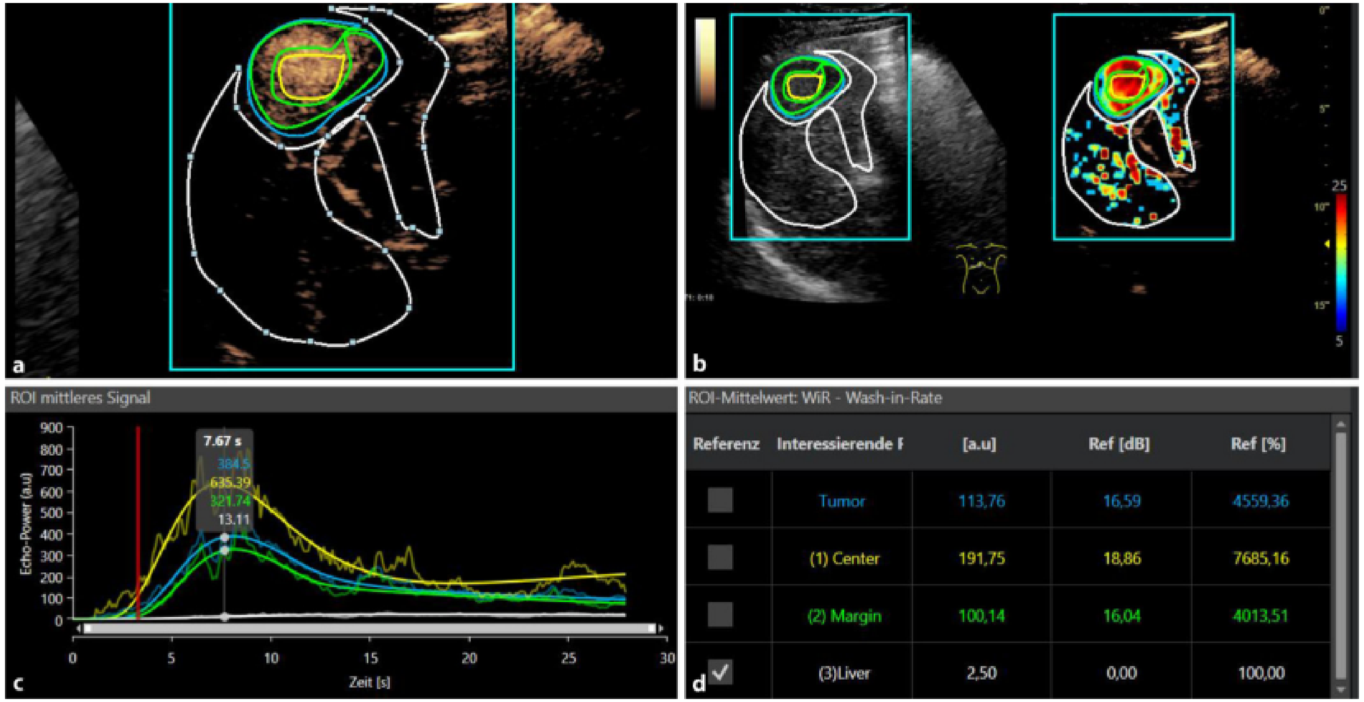
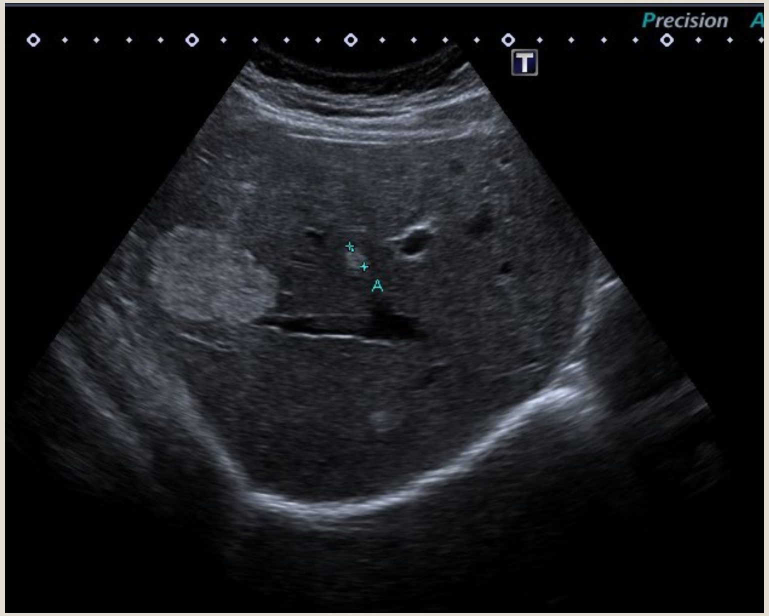
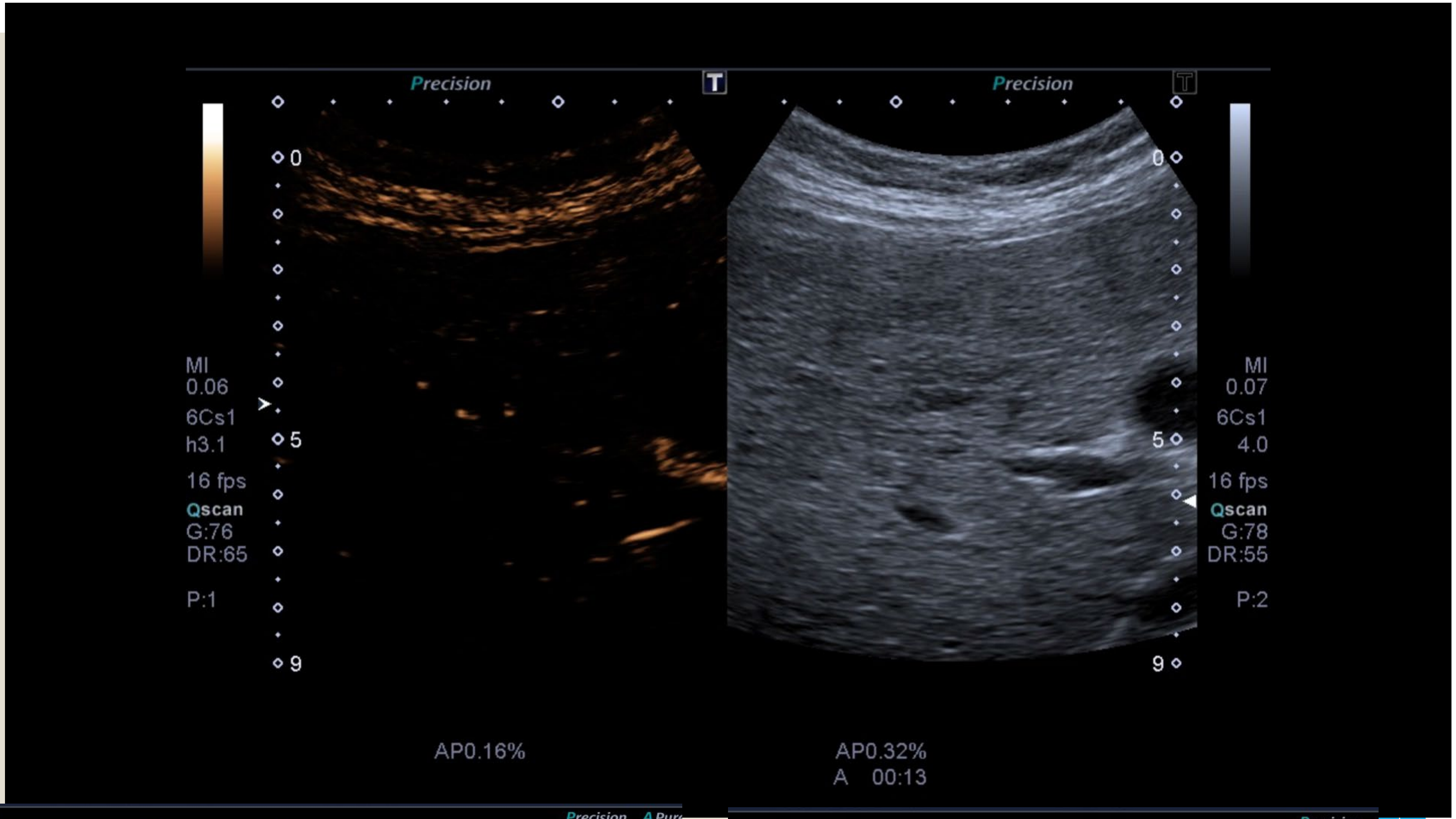


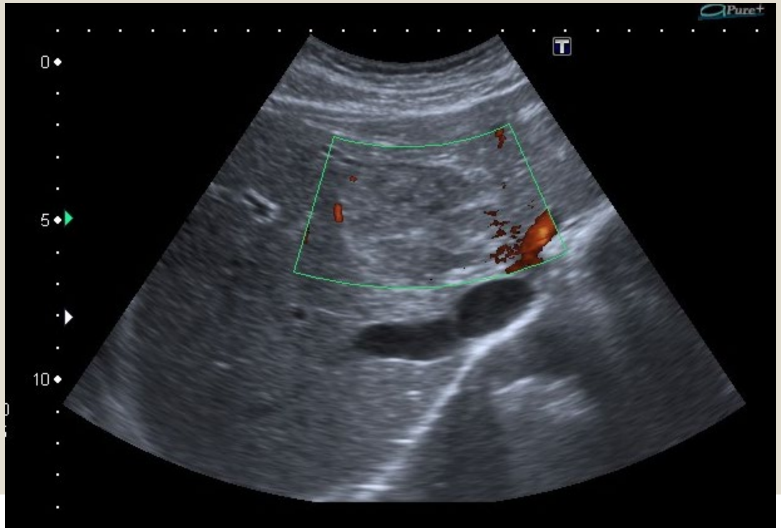
Fig. 1 ▲ Contrast-enhanced ultrasound perfusion imaging with VueBox® (Bracco, Italy) of a small histopathologically proven hepatocellular carcinoma. **a** Irregular arterial hypervascularization in the tumor center and at the tumor margin with wash-out beginning in the portal venous phase. **b** False colors for parametric imaging: *red and yellow* for the tumor hyperenhancement. **c** Evaluation of the wash-in rate. **d** Numeric values of the TIC analysis (**c**), VueBox® Screenshot with permission of Bracco Imaging, Italy

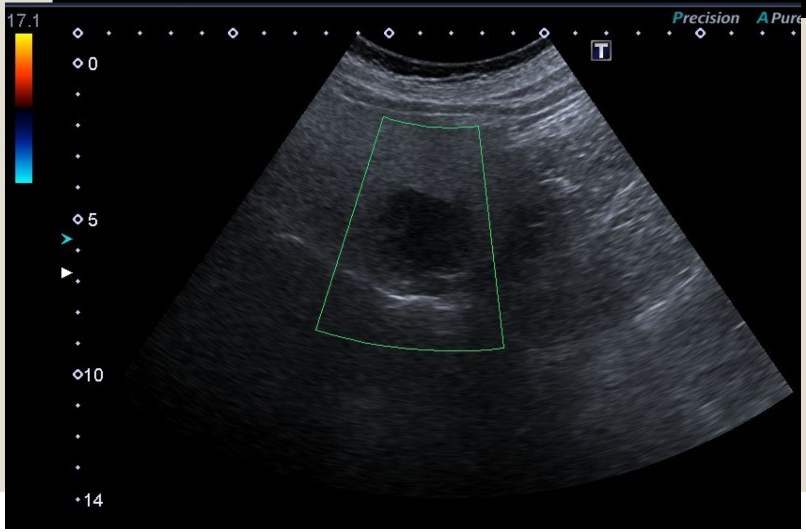
DCEUS

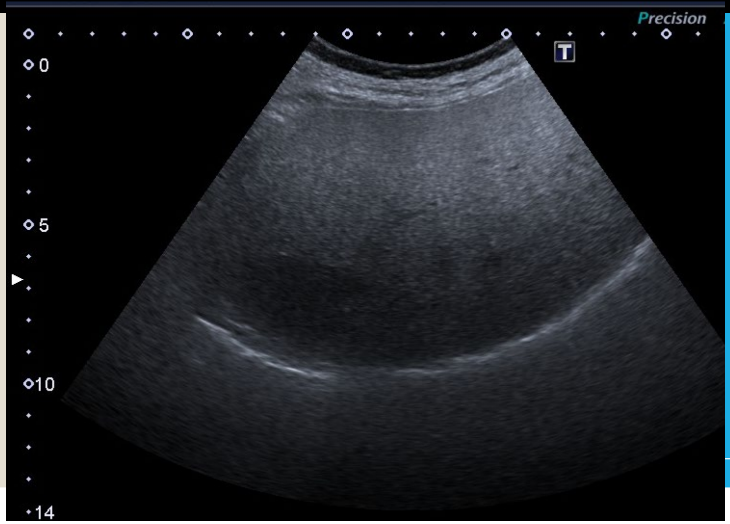
HAEMANGIOMA











CEUS in characterizing pediatric liver lesions and solid organ injury

- Advantages of CEUS

- CEUS **assessement of FLLs in children is consistent with findings in the adult** patients, and **it should be used to characterize these lesions**

- CEUS **follow-up of traumatic liver injuries in children** should be utilized for the assessement of complications , reducing ionizing radiation exposure

- Waiting for new recommendation: CEUS in pregnancy is safe!

Sidhu PS, Huang DY, Fang C. Contrast enhanced ultrasound (CEUS) in Pregnancy: Is this the last frontier for microbubbles? Ultraschall Med. 2020 Feb;41(1):8-11. English. doi: 10.1055/a-0964-9827. Epub 2020 Feb 5. PMID: 32023627.

Potential pitfalls of ceus

- Operator dependancy
- Long learning curve (correct diagnosis with CEUS is dependent on operator skills and requires an extensive training)
- CEUS is subject to specific artifacts, their knowledge is of utter importance by operators

- The quality of the baseline US detemines the quality of CEUS
- Extreme meteorism, obesity
- Fatty liver (reduced sensitivity and specificity for CEUS)
- Deeply located and subdiaphragmatic lesions my not be accesible
- Awkward position of the lesion that renders the CEUS image suboptimal (cross sectional imaging is mandatory)

The use of high mechanical index should be avoided (unless when we want destruction in a scaned plane – flash mode)

Continuos insonation must be avoided

CEUS is limited in the evaluation of the whole liver in the arterial phase

Limitations in case of multiple lesions (only one FLL can be evaluated at a time) – CEUS does not allow multiple FLLs to be evaluated st the same time

Very small lesions may be overlooked

Cost analysis of the three imaging techniques: CEUS, multiphasic CT and dynamic MRI

- **CEUS is the most advantageous in economic terms** (lower cost of the eqipment, smaller number of professionals involved and lower impact of variable cost)
- CEUS is the **most economical second-level technique** for the diagnosis of benign FLLs, allowing cost savings in the management of internal resources
- Use of CEUS for FLLs characterization **leads to significant cost savings while providing a diagnostic accuracy comparable to CT and MRI**
- CEUS performed immediately after detection of the finding (given that the majority of incidental FLLs are benign) – **could avoid extensions of diagnostic workup**

Table 2 Cost analysis of the three imaging techniques: CEUS, multiphasic CT and dynamic MRI

	CEUS	CT	MR imaging
Full costs (€)			
Equipment	1.88	20.74	36.40
Variable costs	40.26	79.82	67.77
Medical doctors	31.20	24.89	37.86
Residents	6.80	1.96	4.56
Radiographers	0	10.39	20.79
Nurses	0	9.63	0
Common costs (€)	5.3	5.3	5.3
External costs (€)	0	2.3	1.9
Total costs (€)	€85.44	€ 155.03	€ 174.58

Lorusso A, Quaia E. Activity-based cost analysis… Insights Imaging (2015) 6:499–508

Diagnostic specificity of combination of CEUS (Sonazoid), CT and mri

Table 4. Diagnostic specificity of combinations of CEUS, MRI, and CT for the diagnosis of liver tumors smaller than 3 cm.

Combination *	HCC	Liver Metastasis	All Malignancy
	Specificity	Specificity	Specificity
CEUS + CT	96	100	100
CEUS + MRI	92	100	100
MRI + CT	92	98	90

* Combination indicates that the diagnosis was based on double positive results from the two imaging exams. CEUS, contrast-enhanced ultrasound; CT, computed tomography; HCC, hepatocellular carcinoma; MRI, magnetic resonance imaging.

J. Clin. Med. 2019, 8, 1353; doi:10.3390/jcm8091353

Anja Brodnjak, MD
radiology consultant
anja.brodnjak@gmail.com