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Elastografie – principy, indikace, postavení v diagnostice

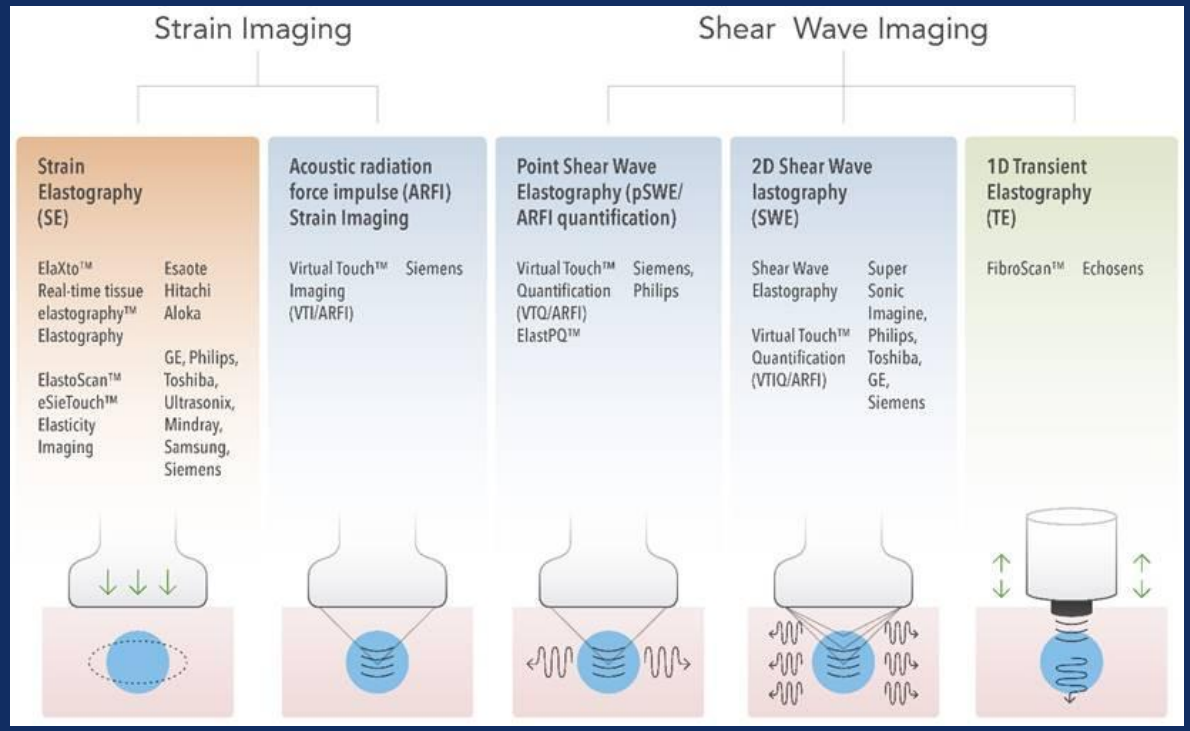
Vlastimil Válek

Klinika radiologie a nukleární medicíny LF MU a FN Brno

Elastografie

- měření tuhosti tkáně → hodnocení jaterní fibrózy

- signál vzniká aktivně pohybem sondy/pasivně od vnitřních struktur (pulzace cév, srdce, dýchání...)
- kvalitativní/semikvantitativní hodnocení



- Transient elastography (TE)
- point shear-wave elastography (pSWE)
- 2D shear-wave elastography (2D SWE)

Lu Y, Giacinto BD, Lu Y, Giacinto BD. Physical Principles and Imaging Techniques of Ultrasound Elastography. In: *Elastography - Current Insights and Applications*. IntechOpen; 2025. doi:10.5772/intechopen.1008254

Paparo F, Corradi F, Cevasco L, et al. Real-Time Elastography in the Assessment of Liver Fibrosis: A Review of Qualitative and Semi-quantitative Methods for Elastogram

Transient elastography

- kromě tuhosti jater můžeme měřit i útlum ultrazvukového vlnění (CAP=controlled atenuation parameter) - odpovídá množství tuku v játrech
- nevýhodou je absence klasického B-módu

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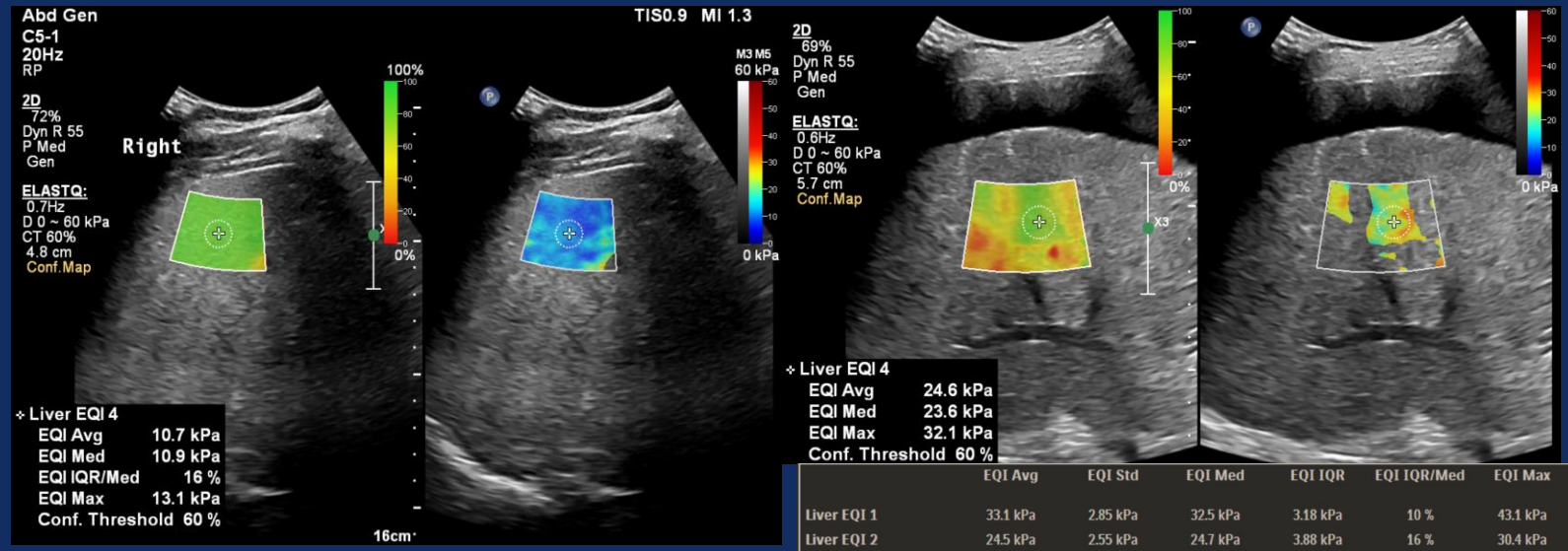
Cui XW, Li KN, Yi AJ, et al. Ultrasound elastography. *Endosc Ultrasound*. 2022;11(4):252-274. doi:10.4103/EUS-D-21-00151

Shear-wave elastography

- 2D SWE
  - získáme barevnou mapu, ve které je každý pixel kódován do odstínu barvy podle tuhosti odpovídajícího bodu tkáně
  - Confidence map (Philips Epiq) – ověření kvality měření



	EQI Avg	EQI Std	EQI Med	EQI IQR	EQI IQR/Med	EQI Max	Conf. Threshold
Liver EQI 1	33.1 kPa	2.85 kPa	32.5 kPa	3.18 kPa	10 %	43.1 kPa	60 %
Liver EQI 2	24.5 kPa	2.55 kPa	24.7 kPa	3.88 kPa	16 %	30.4 kPa	60 %
Liver EQI 3	24.6 kPa	3.52 kPa	24.0 kPa	5.29 kPa	22 %	31.1 kPa	60 %
Liver EQI 4	24.6 kPa	3.28 kPa	23.6 kPa	4.59 kPa	19 %	32.1 kPa	60 %
Liver EQI 5	21.9 kPa	2.49 kPa	21.9 kPa	3.18 kPa	15 %	29.6 kPa	60 %

EQI Liver Stiffness Measurements Velocity

	EQI Avg Vel	EQI Std Vel	EQI Med Vel	EQI IQR Vel	EQI IQR/Med Vel	EQI Max Vel	Conf. Threshold
Liver EQI 1	3.32 m/s	0.139 m/s	3.29 m/s	0.161 m/s	5 %	3.79 m/s	60 %
Liver EQI 2	2.86 m/s	0.148 m/s	2.87 m/s	0.228 m/s	8 %	3.18 m/s	60 %
Liver EQI 3	2.86 m/s	0.208 m/s	2.83 m/s	0.307 m/s	11 %	3.22 m/s	60 %
Liver EQI 4	2.86 m/s	0.189 m/s	2.81 m/s	0.268 m/s	10 %	3.27 m/s	60 %
Liver EQI 5	2.70 m/s	0.153 m/s	2.70 m/s	0.197 m/s	7 %	3.14 m/s	60 %

Liver EQI Avg	25.74 kPa
Liver EQI Med	24.60 kPa
Liver EQI IQR/Med	23 %
Liver EQI IQR	5.65 kPa
Liver EQI Std	3.82 kPa
Liver EQI Avg Vel	2.92 m/s
Liver EQI Med Vel	2.86 m/s
Liver EQI IQR/Med Vel	11 %
Liver EQI IQR Vel	0.31 m/s
Liver EQI Std Vel	0.21 m/s

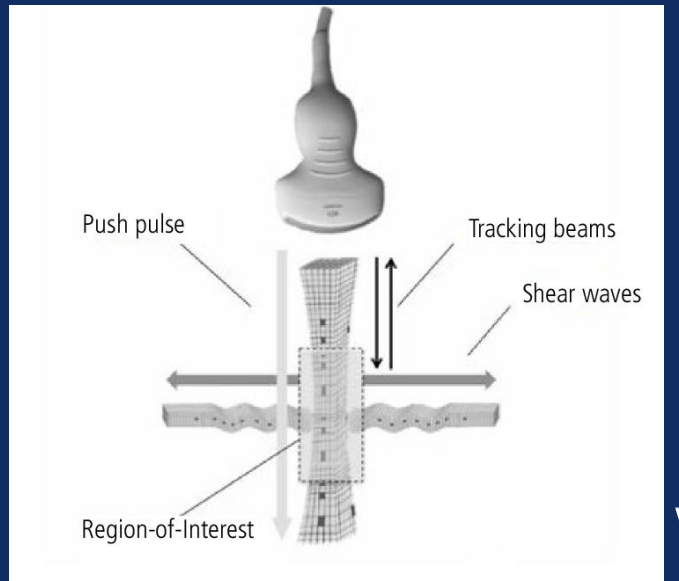
RECOMMENDATION 13

For 2D-SWE a minimum of three measurements should be obtained; the final result should be expressed as the median together with the interquartile range (LoE 2b, GoR B) [27, 117]. Strong consensus (18/0/0, 100 %)

Shear-wave elastography

- Signál vzniká pasivně působením pulzů akustického tlaku (Acoustic Radiation Force)
- Ty způsobují vibrace tkání, které generují **příčné** UZ vlny
  - Pomalejší oproti "diagnostickým" podélným
- Výsledkem vyšetření je rychlost (m/s) šíření příčné vlny - rozdíl v časech, kdy došlo k posunu tkáně v různých místech
  - Přepočtem lze převést na tuhost (Pa)

$$E = 3\rho c^2$$



Hollerieth K, Gaßmann B, Wagenpfeil S, Kemmner S, Heemann U, Stock KF. Does standoff material affect acoustic radiation force impulse elastography? A preclinical study of a modified elastography phantom. *Ultrasonography*. 2017;37(2):140-148. doi:10.14366/usg.17002

Využití – játra (EFSUMB)

- hodnocení fibrózy a cirhózy jaterního parenchymu
  - zlatý standard -> biopsie

RECOMMENDATION 16

TE can be used as the 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) [25, 150, 152]. Broad consensus (17/0/1, 94%)

RECOMMENDATION 17

pSWE as demonstrated with VTQ® can be used as the 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 2a, GoR B) [155]. Broad consensus (17/0/1, 94%)

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 1. SWE can be used to rule out (< 8 kPa) and rule in (>12–15 kPa) advanced liver fibrosis in patients with MASLD (LoE 1a, GoR A). Broad consensus (11/0/1, 92%).

Recommendation 6. pSWE and 2D-SWE may be used for diagnostic purposes in patients with ALD, as their accuracy is comparable to that of VCTE. In the absence of validated cutoffs, the "rule of 4" may be considered (LoE 2b, GoR D). Strong consensus (11/0/0, 100%).

WFUMB
WORLD FEDERATION FOR ULTRASOUND IN MEDICINE AND BIOLOGY

Ferraioli G, Barr RG, Berzigotti A, et al. WFUMB Guideline/Guidance on Liver Multiparametric Ultrasound: Part 1. Update to 2018 Guidelines on Liver Ultrasound Elastography. *Ultrasound Med Biol.* 2024;50(8):1071-1087. doi:10.1016/j.ultrasmedbio.2024.03.013
European Association for the Study of the Liver. EASL Clinical Practice Guidelines on non-invasive tests for evaluation of liver disease severity and prognosis - 2021 update. *J Hepatol.* 2021;75(3):659-689. doi:10.1016/j.jhep.2021.05.025

Hodnocení

STARÁ KLASIFIKACE (METAVIR F0-F4)		
METAVIR	**Tuhost jater**	**Stupeň fibrózy**
F0	≤5 kPa (≤1.3 m/s)	**Bez fibrózy**
F1	5–7 kPa (1.3–1.4 m/s)	Fibróza portálního traktu bez sept
F2	7–9 kPa (1.4–1.6 m/s)	Fibróza portálního traktu s občasným septem
F3	9–12 kPa (1.6–2.0 m/s)	Četná septa (pokročilá fibróza)
F4	>12 kPa (>2.0 m/s)	**Cirhóza**

⚠ **Problém:** Velké překrytí mezi jednotlivými stupni → nízká klinická relevance

NOVÁ KLASIFIKACE (2020 RSNA – "Rule of Four")	
Tuhost jater (ARFI)	**Klinická interpretace**
≤5 kPa (≤1.3 m/s)	✓ **Normální** – Vyloučí významnou fibrózu
5–9 kPa (1.3–1.7 m/s)	✓ **Vyloučí cACLD** – Bezpečné, bez pokročilého onemocnění
9–13 kPa (1.7–2.1 m/s)	⚠ **NEJISTÝ** – Podezření na cACLD, potřeba potvrzení
≥13 kPa (≥2.1 m/s)	✓ **Vysoce podezřelé** na cACLD (pokročilá fibróza/cirhóza)
≥17 kPa (≥2.4 m/s)	✓ **Vysoká pravděpodobnost CSPH** (portální hypertenze)

Barr RG, Wilson SR, Rubens D, Garcia-Tsao G, Ferraioli G. Update to the Society of Radiologists in Ultrasound Liver Elastography Consensus Statement. *Radiology*. 2020;296(2):263-274. doi:10.1148/radiol.2020192437

Hodnocení

Performance and cutoffs for liver fibrosis staging of a two-dimensional shear wave elastography technique

Ferraioli, Giovanna[a,b]; Maiocchi, Laura[b]; Dellafiore, Carolina[a,b]; Tinelli, Carmine[c]; Above, Elisabetta[b]; Filice, Carlo[a,b]

Author Information

European Journal of Gastroenterology & Hepatology 33(1):p 89-95, January 2021. | **DOI:** 10.1097/MEG.0000000000001702

Three hundred sixty-seven patients (198 males and 169 females) were studied. respectively, were 0.97 (95% confidence interval, 0.91–0.98) and 0.97 (95% confidence interval, 0.95–0.99). The best cutoffs for significant fibrosis and severe fibrosis, respectively, were > 7 and > 9 kPa. Shear-wave-speed dispersion showed a high correlation with fibrosis (r = 0.85, P < 0.0001), whereas there was a very weak correlation with steatosis.

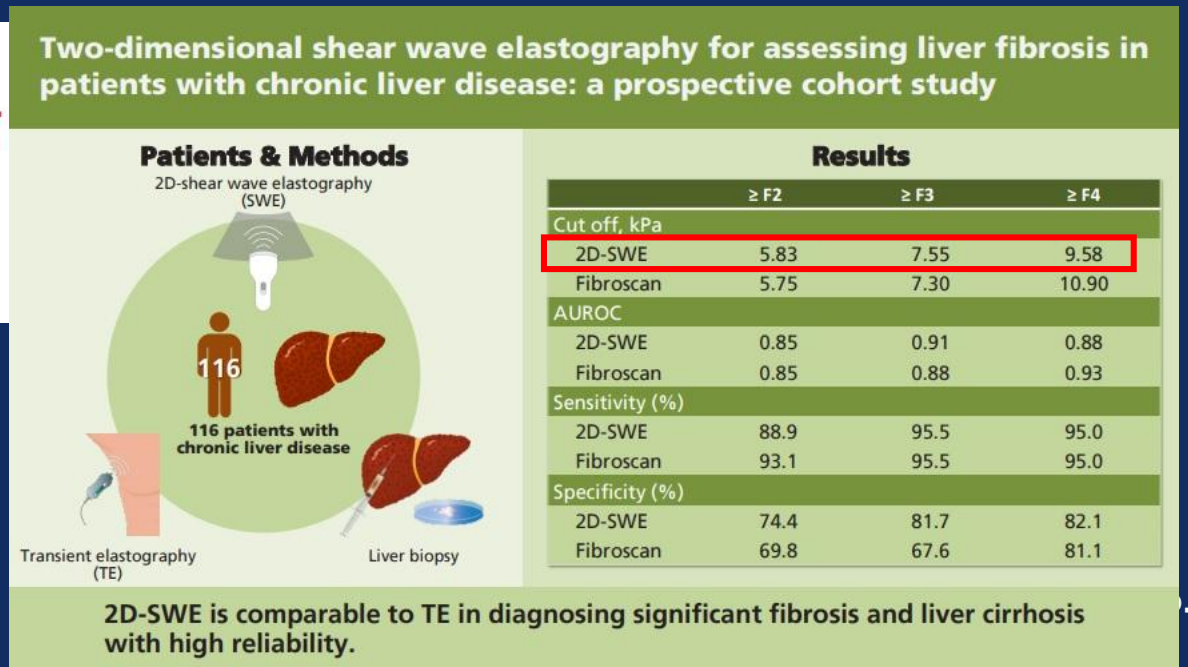
Which are the cut-off values of 2D-Shear Wave Elastography (2D-SWE) liver stiffness measurements predicting different stages of liver fibrosis, considering Transient Elastography (TE) as the reference method?

Ioan Sporea, Simona Bota [1], Oana Gradinaru-Taşcău [2], Roxana Şirli [2], Alina Popescu [2], Ana Jurchiş [2]

Our prospective study included 383 consecutive subjects, with or without hepatopathies, in which LS was evaluated by means of TE and 2D-SWE. To discriminate between various found between TE and 2D-SWE measurements (r=0.68). The best LS cut-off values assessed by 2D-SWE for predicting different stages of liver fibrosis were: $F \geq 1$: >7.1 kPa (AUROC=0.825); $F \geq 2$: >7.8 kPa (AUROC=0.859); $F \geq 3$: >8 kPa (AUROC=0.897) and for F=4: >11.5 kPa (AUROC=0.914).

Two-dimensional shear wave elastography for assessing liver fibrosis in patients with chronic liver disease: a prospective cohort study

Hae Won Yoo[1], Sang Gyune Kim[1], Jae Young Jang[2], Jeong-Ju Yoo[1], Soung Won Jeong[2], Young Seok Kim[1], and Boo Sung Kim[1,2]



Barr RG, Wilson SR, Rubens D, Garcia-Tsao G, Ferraioli G. Update to the Society of Radiologists in Ultrasound Liver Elastography Consensus Statement. *Radiology*. 2020;296(2):263-274. doi:10.1148/radiol.2020192437

Ferraioli G, Maiocchi L, Dellafiore C, Tinelli C, Above E, Filice C. Performance and cutoffs for liver fibrosis staging of a two-dimensional shear wave elastography technique. *European Journal of Gastroenterology & Hepatology*. 2021;33(1):89. doi:10.1097/MEG.0000000000001702

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Hodnocení jaterního parenchymu - elastografie

- 80 % pacientů HCC vzniká v terénu cirhózy → jeden z prediktorů vyšší pooperační morbidity

RECOMMENDATION 9: SWE has high diagnostic accuracy for detecting cirrhosis, better at ruling out (high negative predictive value >90%) than ruling in. (LoE 1a, GoR A) (10,0,0)

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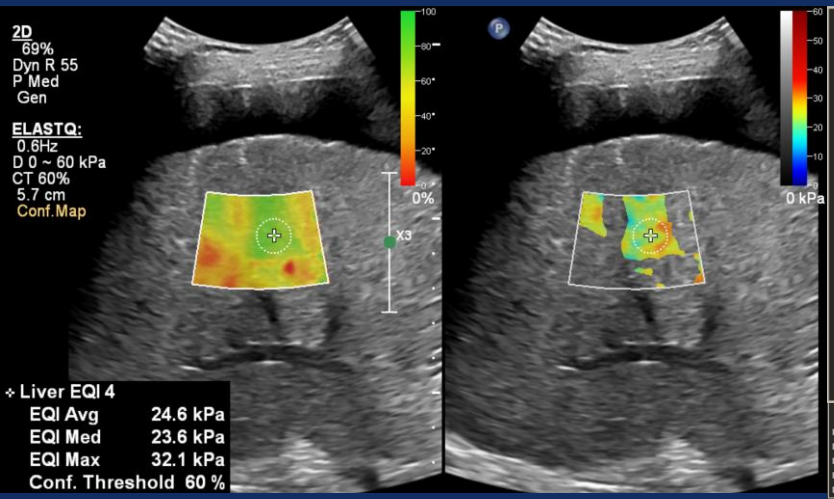

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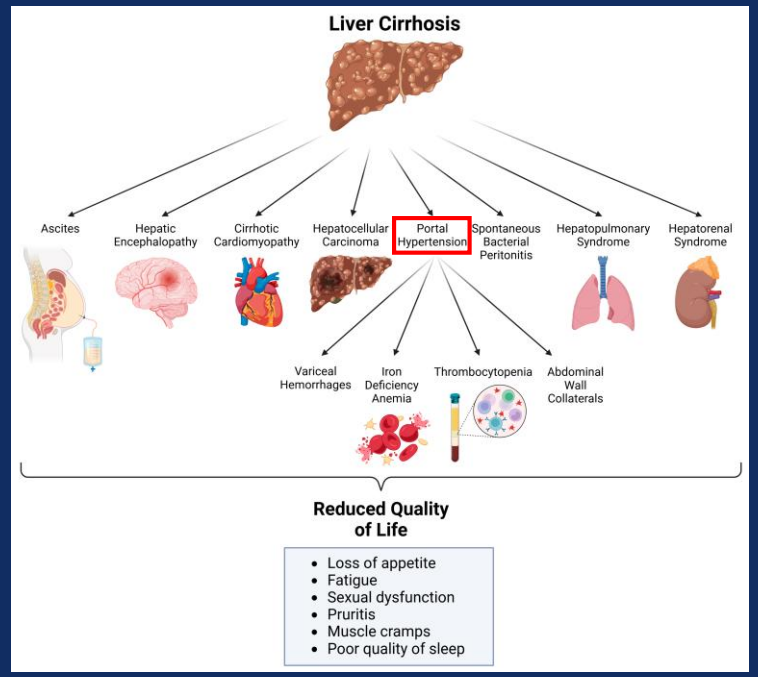


Yang S, Ni H, Zhang A, Zhang J, Zang H, Ming Z. Impact of postoperative morbidity on the prognosis of patients with hepatocellular carcinoma after laparoscopic liver resection: a multicenter observational study. *Sci Rep*. 2025;15:1724. doi:10.1038/s41598-024-85020-9
Premkumar M, Anand AC. Overview of Complications in Cirrhosis. *J Clin Exp Hepatol*. 2022;12(4):1150-1174. doi:10.1016/j.jceh.2022.04.021

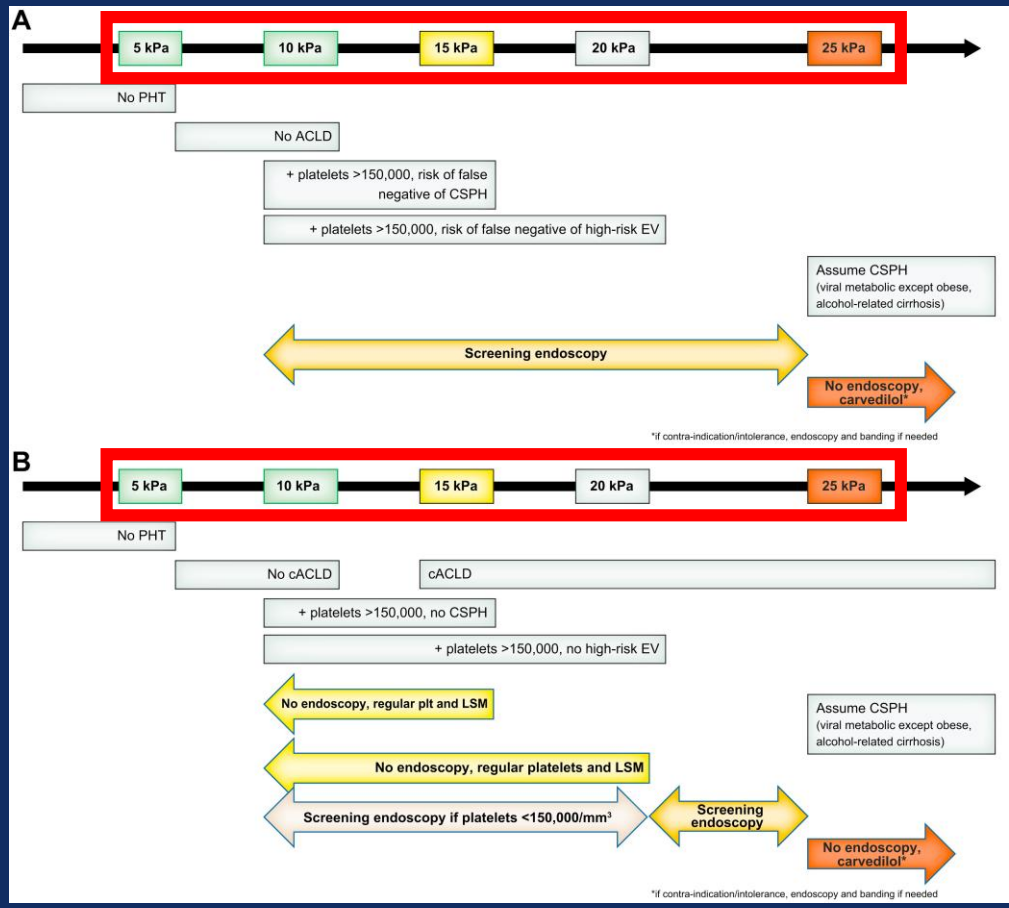
Hodnocení cévního zásobení jater – portální hypertenze

- portosystémový gradient >5 mmHg (měříme HVPG *(hepatic venous pressure gradient))*
- klinicky signifikantní portální hypertenze (CSPH) >10mmHg -> u 32 % pacientů s HCC
- pacienti s HCC a CSPH mají horší přežití oproti pacientům bez CSPH (+další rizika – varixy…)

Review > J Hepatol. 2023 Mar;78(3):658-662. doi: 10.1016/j.jhep.2022.11.019. Epub 2022 Nov 30.

Treatment of portal hypertension in patients with HCC in the era of Baveno VII

Dominique Thabut [1], Masatoshi Kudo [2]



Thabut D, Kudo M. Treatment of portal hypertension in patients with HCC in the era of Baveno VII. *Journal of Hepatology.* 2023;78(3):658-662. doi:10.1016/j.jhep.2022.11.019

Hodnocení cévního zásobení jater – portální hypertenze

EASL Clinical Practice Guidelines on the management of hepatocellular carcinoma

European Association for the Study of the Liver

Clinically significant portal hypertension and Child-Pugh class B cirrhosis should be regarded as an absolute contraindication to major resections (*i.e.*, >2 segments) **(LoE 3, strong recommendation, strong consensus).**

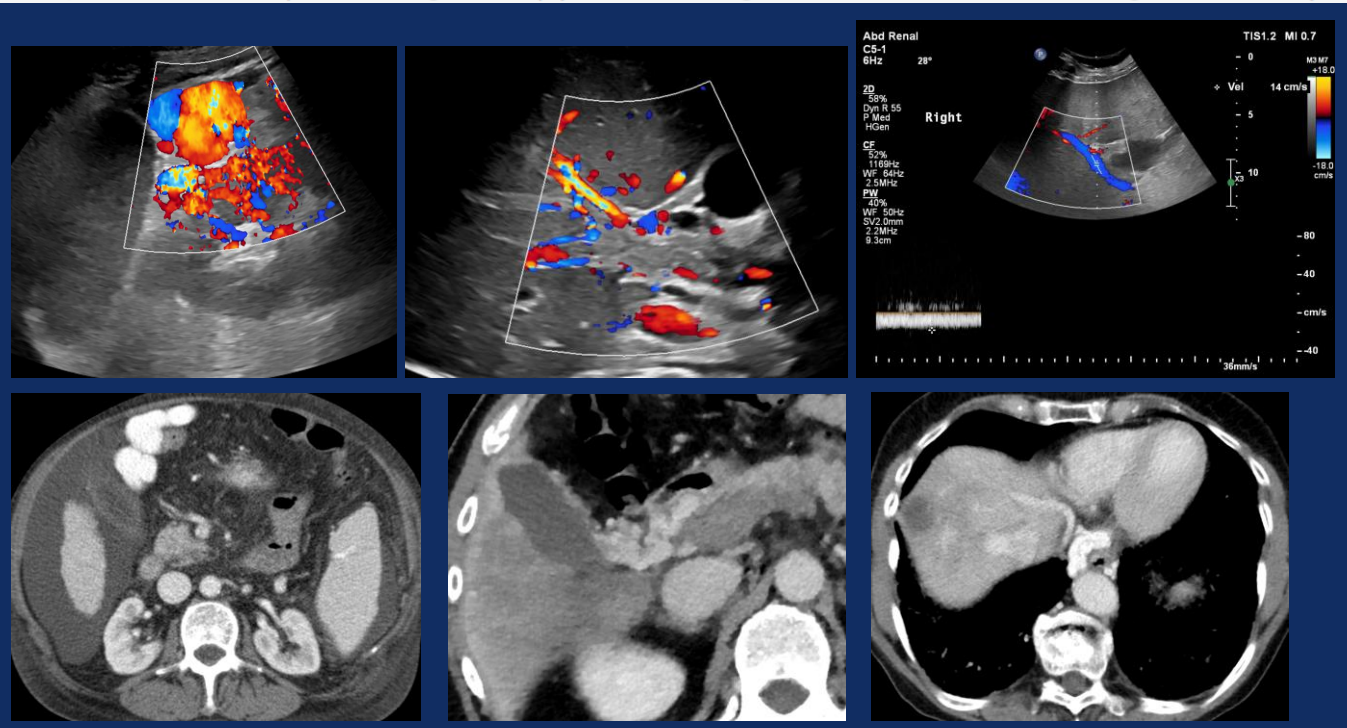
=> screening CSPH před plánovanou resekcí HCC

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

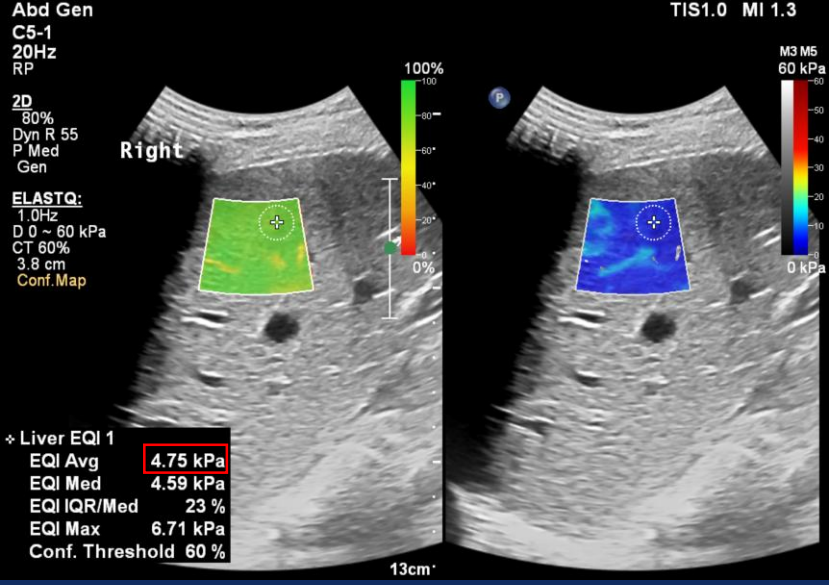
Liver Stiffness Value	Recommendation
≤5 kPa (1.3 m/sec)	High probability of being normal
<9 kPa (1.7 m/sec)	In the absence of other known clinical signs, rules out cACLD. If there are known clinical signs, may need further test for confirmation
9–13 kPa (1.7–2.1 m/sec)	Suggestive of cACLD but need further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

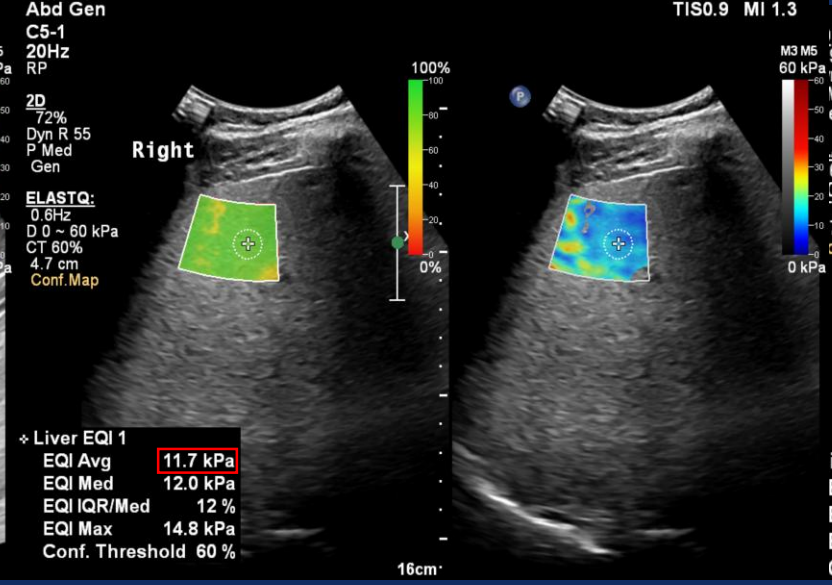
2D shear wave elastografie



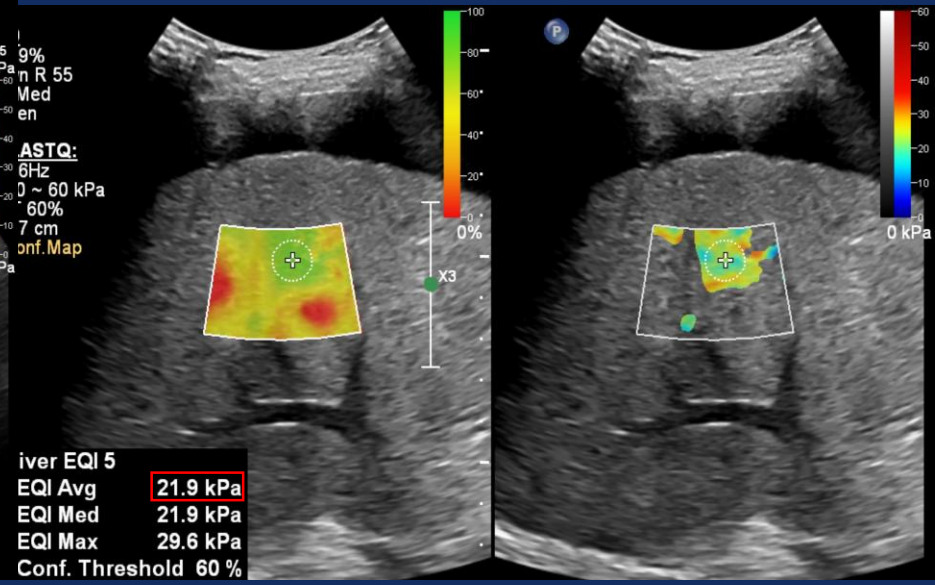
Zhao S, Zhu J, Zhu Y, et al. Identifying the Optimal Treatment for Patients with Hepatocellular Carcinoma and Clinically Significant Portal Hypertension: A Multicenter Propensity Score-Weighted Analysis. *Ann Surg Oncol.* Published online November 15, 2025. doi:10.1245/s10434-025-18744-1



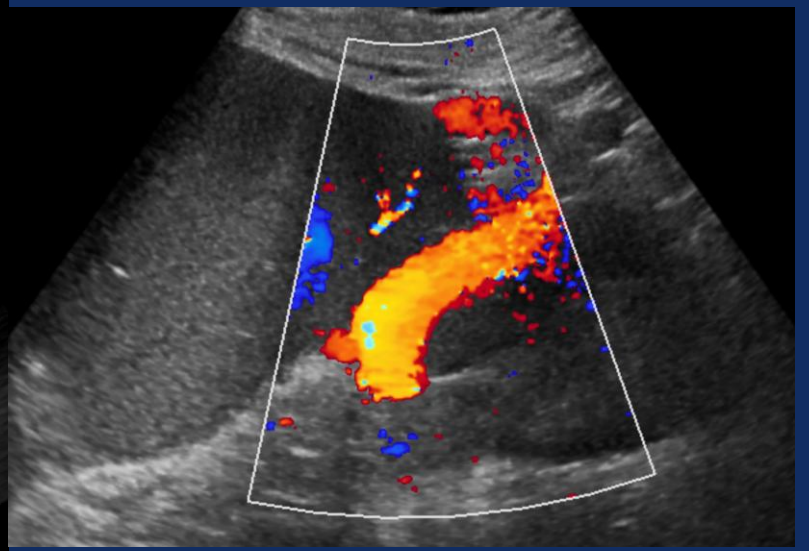
normální nález



podezření na pokročilé chronické jaterní onemocnění



cirhóza (podezření na klinicky signifikantní portální hypertenzi)



Limitace (EFSUMB)

- Zánět
- Obstrukční cholestáza
- Stav po jídle
- Cvičení
- Žilní kongesce

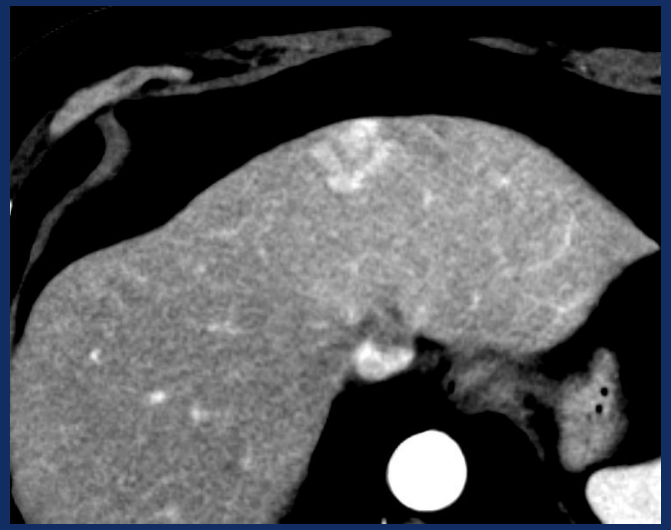
RECOMMENDATION 7

The major potential confounding factors (liver inflammation indicated by AST and/or ALT elevation > 5 times the normal limits, obstructive cholestasis, liver congestion, acute hepatitis and infiltrative liver diseases) should be excluded before performing LSM with SWE, in order to avoid overestimation of liver fibrosis (LoE 2b, GoR B), and/or should be considered when interpreting the SWE results (LoE 1b, GoR B) [41 – 46, 49 – 51, 56 – 59]. Broad consensus (15/0/1, 94 %)

European Association for the Study of the Liver. EASL Clinical Practice Guidelines on non-invasive tests for evaluation of liver disease severity and prognosis - 2021 update. *J Hepatol.* 2021;75(3):659-689. doi:10.1016/j.jhep.2021.05.025

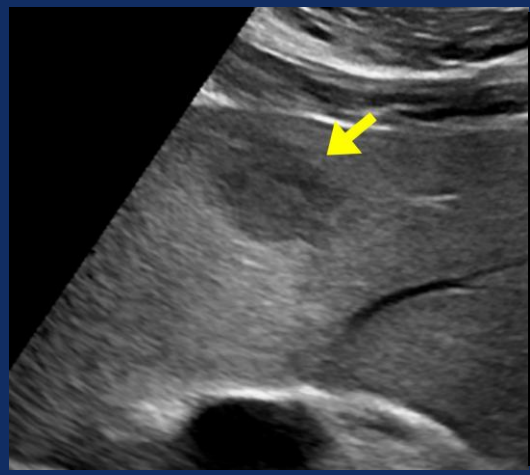
Závěr

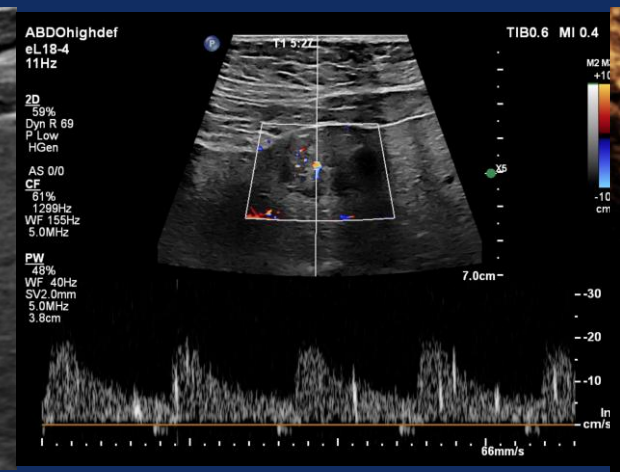
žena, 60*, elevace ANA a jaterních testů => CT

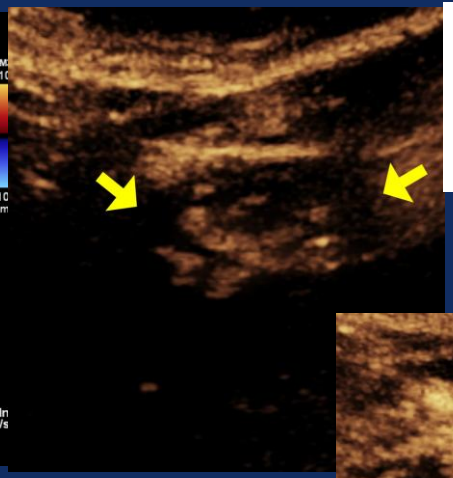


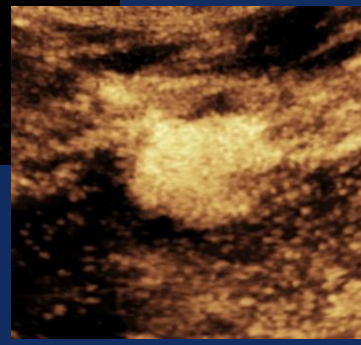
popsáno nejasné ložisko jater

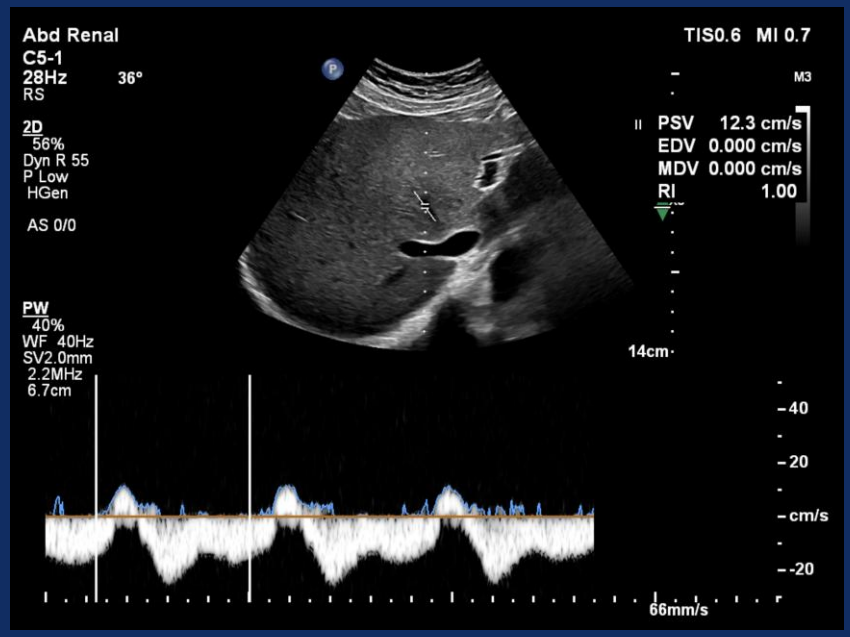
doporučeno UZ

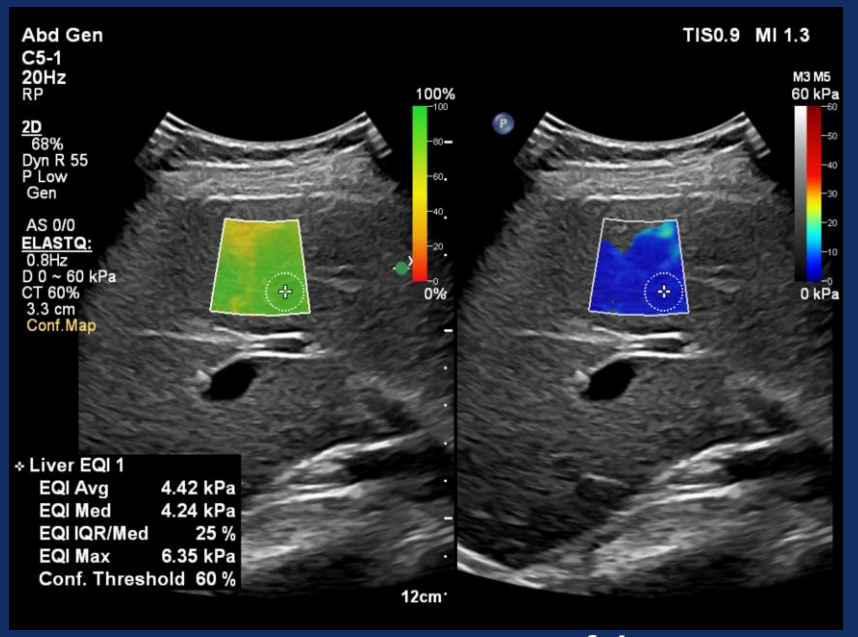












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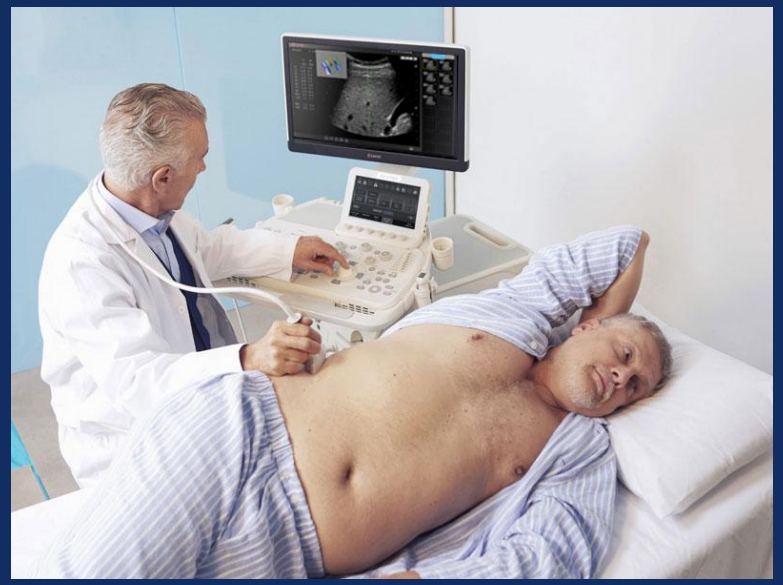
Provedení (EFSUMB)

RECOMMENDATION 3

Measurement of liver stiffness by SWE should be performed through a right intercostal space in supine position, with the right arm in extension, during breath hold, avoiding deep inspiration prior to the breath hold (LoE 2b, GoR B) [1, 32]. Strong consensus (18/0/0, 100 %)

-pravý mezižeberní prostor
-vleže na zádech/nadzvedlý pravý bok/ne levém boku
-pravá ruka za hlavou
-zadržený dech (bez hlubokého nádechu)



RECOMMENDATION 6

Patients should fast for a minimum of 2 hours and rest for a minimum of 10 minutes before undergoing liver stiffness measurement with SWE (LoE 2b, GoR B) [1]. Majority consensus (13/2/3, 72 %)

Patient should fast for 4 h before examination.

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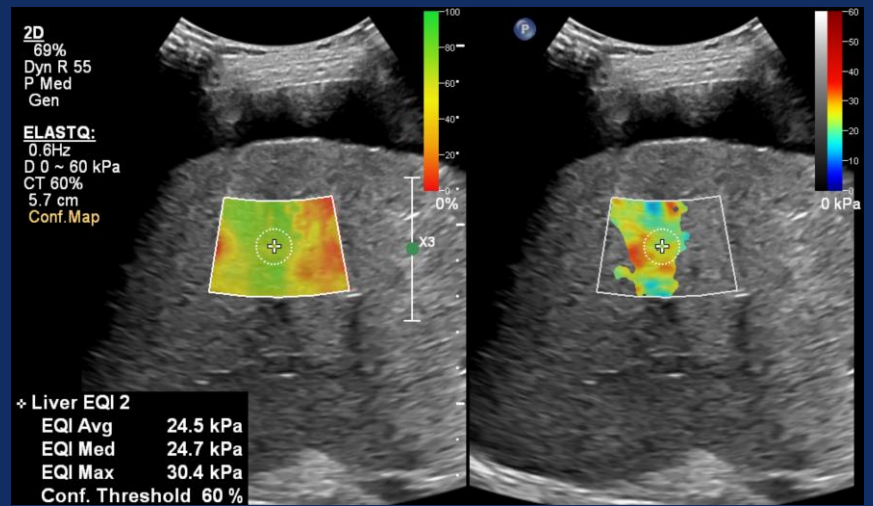
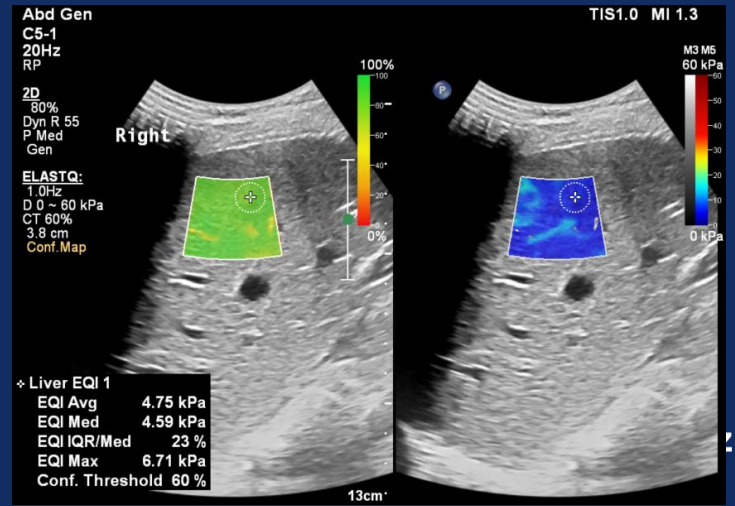
RECOMMENDATION 5

Measurement of liver stiffness by pSWE and 2D-SWE should be performed at least 10 mm below the liver capsule (LoE 1b, GoR A) [24 – 27, 32 – 35]. Strong consensus (18/0/0, 100 %)





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RECOMMENDATION 12

The median value of at least 10 measurements should be used for liver elastography by pSWE (LoE 2b, GoR B) [102] Strong consensus (18/0/0, 100 %)

	EQI Avg	EQI Std	EQI Med	EQI IQR	EQI IQR/Med	EQI Max	Conf. Threshold
Liver EQI 1	33.1 kPa	2.85 kPa	32.5 kPa	3.18 kPa	10 %	43.1 kPa	60 %
Liver EQI 2	24.5 kPa	2.55 kPa	24.7 kPa	3.88 kPa	16 %	30.4 kPa	60 %
Liver EQI 3	24.6 kPa	3.52 kPa	24.0 kPa	5.29 kPa	22 %	31.1 kPa	60 %
Liver EQI 4	24.6 kPa	3.28 kPa	23.6 kPa	4.59 kPa	19 %	32.1 kPa	60 %
Liver EQI 5	21.9 kPa	2.49 kPa	21.9 kPa	3.18 kPa	15 %	29.6 kPa	60 %

EQI Liver Stiffness Measurements Velocity

	EQI Avg Vel	EQI Std Vel	EQI Med Vel	EQI IQR Vel	EQI IQR/Med Vel	EQI Max Vel	Conf. Threshold
Liver EQI 1	3.32 m/s	0.139 m/s	3.29 m/s	0.161 m/s	5 %	3.79 m/s	60 %
Liver EQI 2	2.86 m/s	0.148 m/s	2.87 m/s	0.228 m/s	8 %	3.18 m/s	60 %
Liver EQI 3	2.86 m/s	0.208 m/s	2.83 m/s	0.307 m/s	11 %	3.22 m/s	60 %
Liver EQI 4	2.86 m/s	0.189 m/s	2.81 m/s	0.268 m/s	10 %	3.27 m/s	60 %
Liver EQI 5	2.70 m/s	0.153 m/s	2.70 m/s	0.197 m/s	7 %	3.14 m/s	60 %

Liver EQI Avg	25.74 kPa
Liver EQI Med	24.60 kPa
Liver EQI IQR/Med	23 %
Liver EQI IQR	5.65 kPa
Liver EQI Std	3.82 kPa
Liver EQI Avg Vel	2.92 m/s
Liver EQI Med Vel	2.86 m/s
Liver EQI IQR/Med Vel	11 %
Liver EQI IQR Vel	0.31 m/s
Liver EQI Std Vel	0.21 m/s

RECOMMENDATION 13

For 2D-SWE a minimum of three measurements should be obtained; the final result should be expressed as the median together with the interquartile range (LoE 2b, GoR B) [27, 117]. Strong consensus (18/0/0, 100 %)

	EQI Avg	EQI Std	EQI Med	EQI IQR	EQI IQR/Med	EQI Max	Conf. Threshold
Liver EQI 1	11.7 kPa	1.50 kPa	12.0 kPa	1.41 kPa	12 %	14.8 kPa	60 %
Liver EQI 2	11.1 kPa	1.49 kPa	11.6 kPa	2.47 kPa	21 %	13.8 kPa	60 %
Liver EQI 3	10.4 kPa	1.23 kPa	10.2 kPa	1.76 kPa	17 %	12.7 kPa	60 %
Liver EQI 4	10.7 kPa	1.14 kPa	10.9 kPa	1.76 kPa	16 %	13.1 kPa	60 %
Liver EQI 5	12.3 kPa	1.18 kPa	12.4 kPa	1.76 kPa	14 %	14.8 kPa	60 %

EQI Liver Stiffness Measurements Velocity

	EQI Avg Vel	EQI Std Vel	EQI Med Vel	EQI IQR Vel	EQI IQR/Med Vel	EQI Max Vel	Conf. Threshold
Liver EQI 1	1.97 m/s	0.129 m/s	2.00 m/s	0.119 m/s	6 %	2.22 m/s	60 %
Liver EQI 2	1.92 m/s	0.132 m/s	1.97 m/s	0.214 m/s	11 %	2.14 m/s	60 %
Liver EQI 3	1.86 m/s	0.109 m/s	1.85 m/s	0.158 m/s	9 %	2.06 m/s	60 %
Liver EQI 4	1.88 m/s	0.103 m/s	1.91 m/s	0.155 m/s	8 %	2.09 m/s	60 %
Liver EQI 5	2.02 m/s	0.098 m/s	2.03 m/s	0.144 m/s	7 %	2.22 m/s	60 %

Liver EQI Avg	11.24 kPa
Liver EQI Med	11.10 kPa
Liver EQI IQR/Med	13 %
Liver EQI IQR	1.45 kPa
Liver EQI Std	0.69 kPa
Liver EQI Avg Vel	1.93 m/s
Liver EQI Med Vel	1.92 m/s
Liver EQI IQR/Med Vel	7 %
Liver EQI IQR Vel	0.13 m/s
Liver EQI Std Vel	0.06 m/s

Ten measurements should be obtained from 10 independent images, in the same location, with the median value used for transient elastography and point shear wave elastography techniques. Three or five measurements may be appropriate for 2-D shear wave elastography when a quality assessment parameter is used.