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CAR MASLD Working Group Recommendations

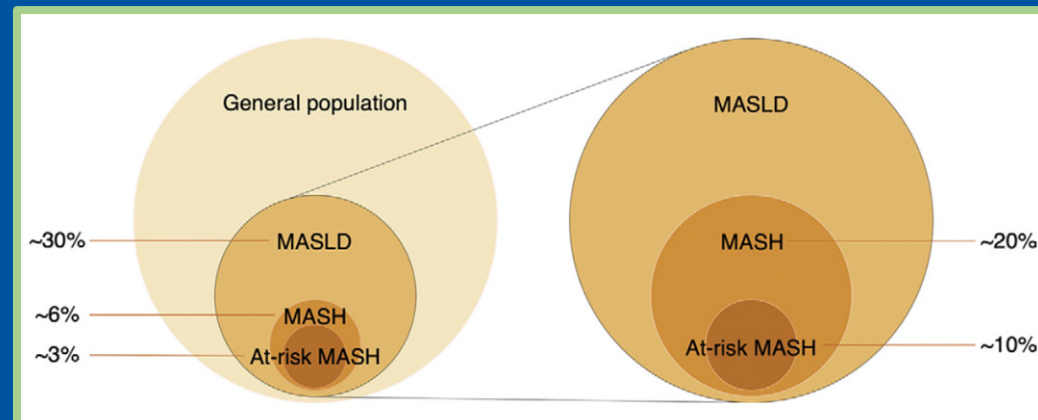
Part 3, Appendix A. Introduction to shear wave elastography presentation for technologists and radiologists.

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On behalf of the CAR MASLD Working Group

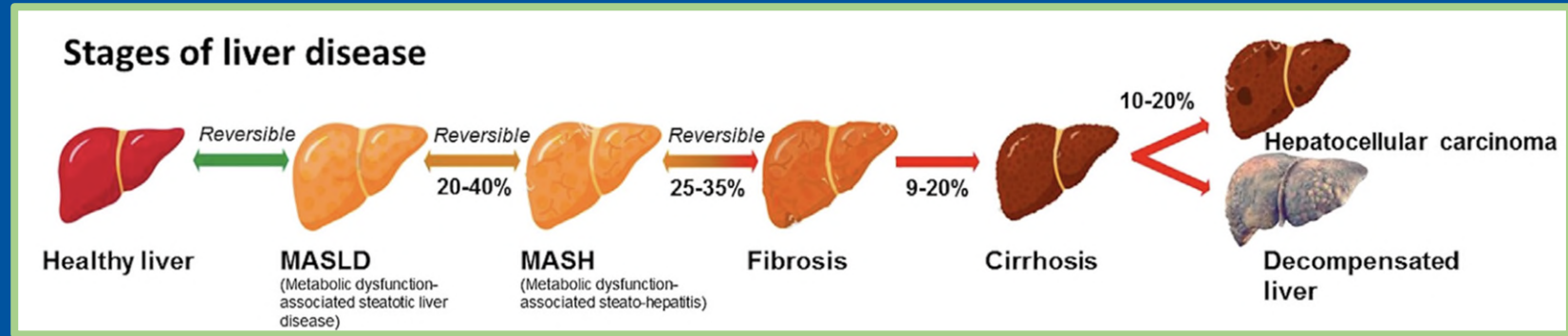


Background

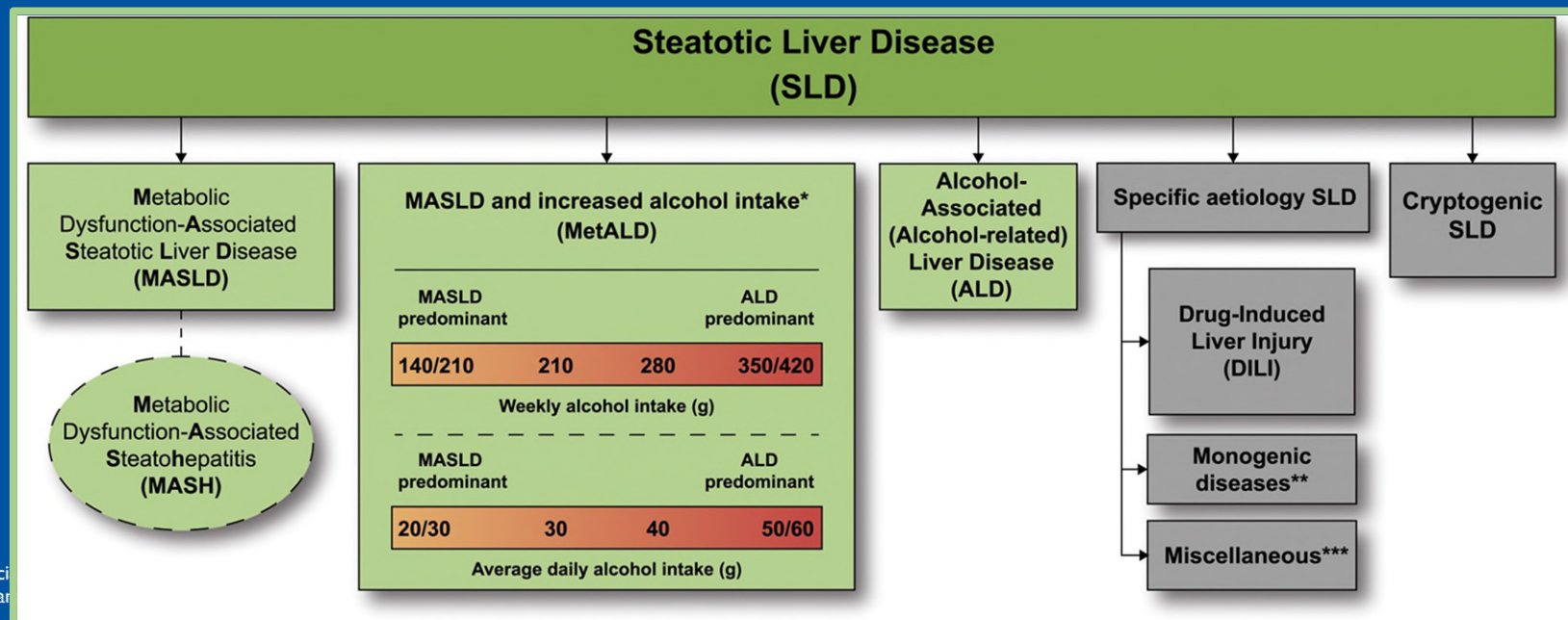
- Chronic liver disease is common and includes several causes:
 - MASLD (Metabolic dysfunction-associated steatotic liver disease)
 - Formerly non-alcoholic fatty liver disease (NAFLD)
 - Alcoholic liver disease
 - Viral hepatitis
 - Others
- Incidence is rising largely driven by prevalence of MASLD
 - Most common cause of chronic liver disease in North America
 - Present in approximately 30% adult patients
 - Approximately 3% at risk for liver related complications



Background

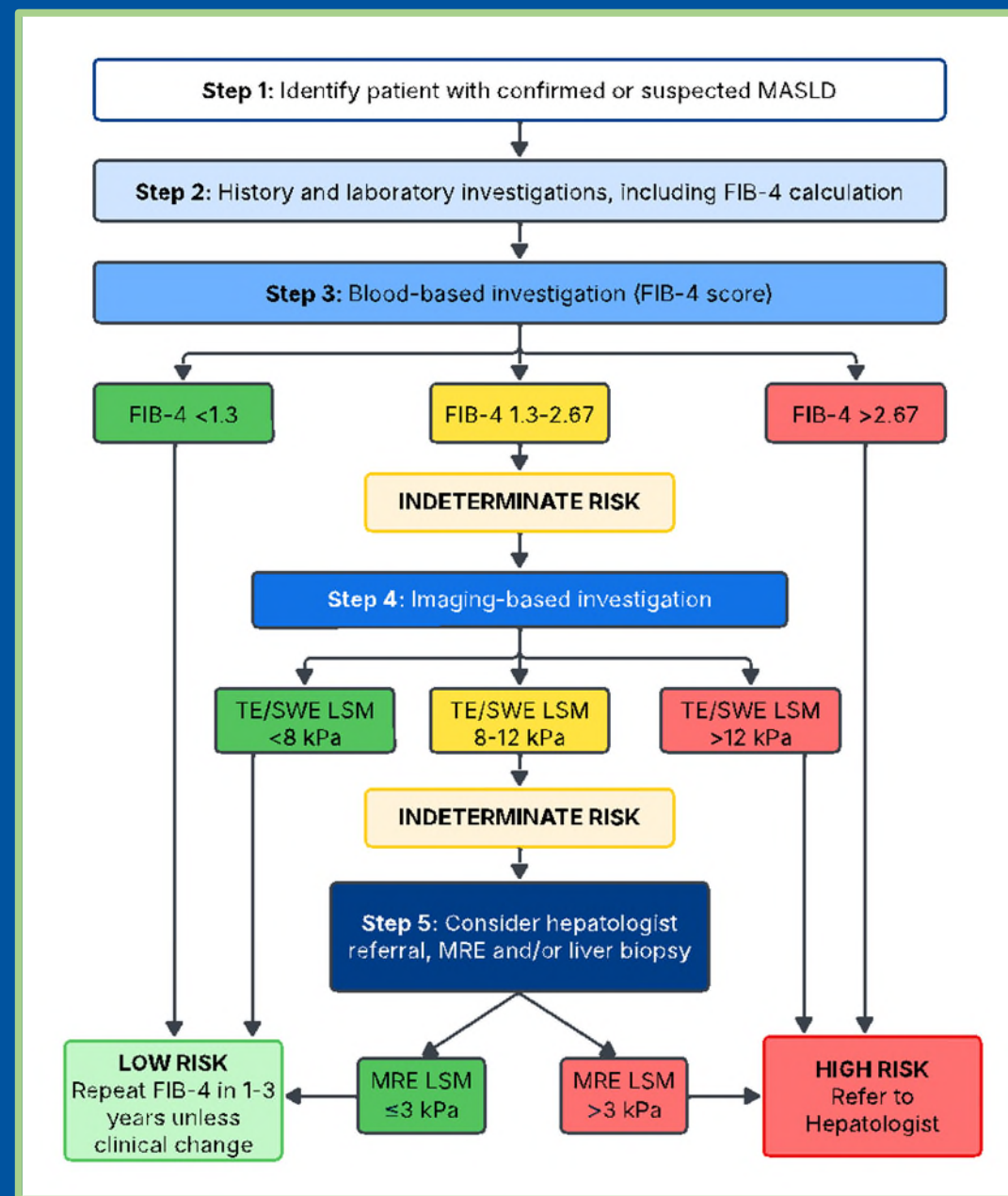


- MASLD represents a spectrum of disease from normal to cirrhosis
- Non-invasive population level risk stratification of these patients is a cost-effective means to prevent and even reverse liver disease severity with the goal of improving clinical outcomes



Background

- Blood-based investigations serve as the initial method for population level risk stratification of adult MASLD patients.
 - The CAR MASLD WG endorses FIB-4 as the initial screening tool.
- Image-based investigations are recommended for patients with indeterminate risk following blood-based investigation.



Background

Approved image-based tools for investigation include:

- Vibration controlled transient elastography (TE)
 - Uses a mechanical plunger to generate shear waves across the liver
 - Does not use image guidance and no imaging details are available
 - Typically used in the clinical setting such as by trained hepatologists
 - Not discussed in these presentations
- Shear wave elastography (SWE)
 - Discussed in this presentation
- Magnetic resonance elastography (MRE)
 - Discussed in Appendix 2 presentation



SWE – Background

- Ultrasound-based technique
- Two forms: point SWE (pSWE) and 2-dimensional SWE (2D-SWE)
- Proprietary software offered by most ultrasound vendors
- Benefits compared to TE:
 - Less influenced by obesity
 - Can be performed in patients with ascites
 - **Can acquire additional sonographic information of the liver**



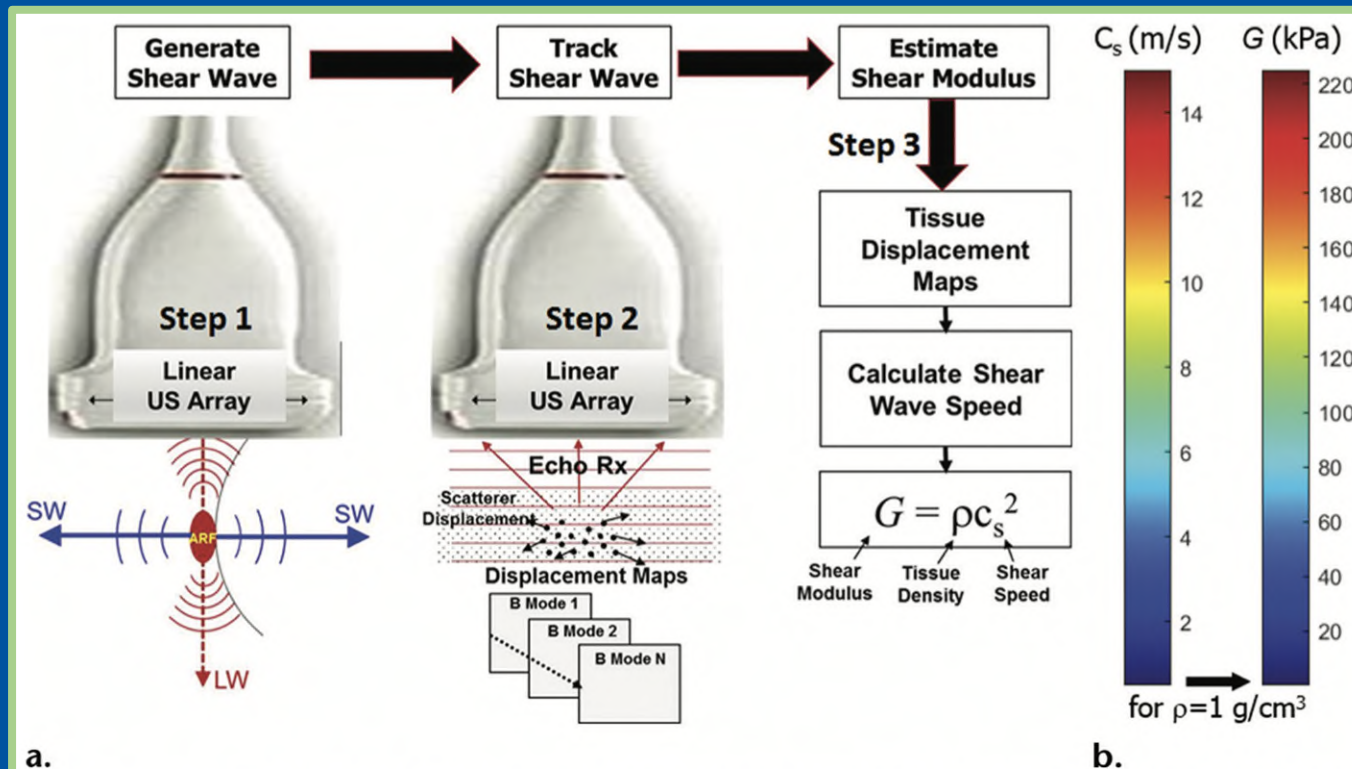
SWE– Basic Physics

- An acoustic radiation force impulse (ARFI) is generated perpendicular to the ultrasound probe
 - This is a short duration acoustic radiation force (<1 ms).
 - This high-powered focused impulse imparts a mechanical movement of liver tissue perpendicular to the probe.
 - The impulse does not require external compression (unlike TE and MRE techniques).
- A subsequent lateral wave propagation (perpendicular to the ARFI, transverse across liver tissue) is known as a shear wave.
- Increased tissue stiffness is correlated with faster shear wave velocities.
- The shear wave is measured by the probe as a shear wave speed (m/s) and elasticity using Young's Modulus (kPa).

*Further details on the mathematical modeling can be found in technical papers on SWE.



SWE– Basic Physics



a.

b.

Figure 1. (a) Basic physics of SWE. In step 1, shear waves are generated using acoustic radiation force; they propagate perpendicularly to the primary US wave at a lower velocity. In step 2, fast plane wave excitation is used to track displacement and velocity as shear waves propagate, and tissue displacement is calculated using a speckle tracking algorithm. In step 3, tissue displacements are used to calculate shear-wave velocity (c_s) and shear modulus (G). (b) Relationship between shear velocity and shear modulus expressed as a color bar, which assumes, in this case, a density equal to that of water (1 g/cm^3). Actual density estimates will vary for different types of soft tissue and can also be found using values published in the literature.

SWE– Basic Physics

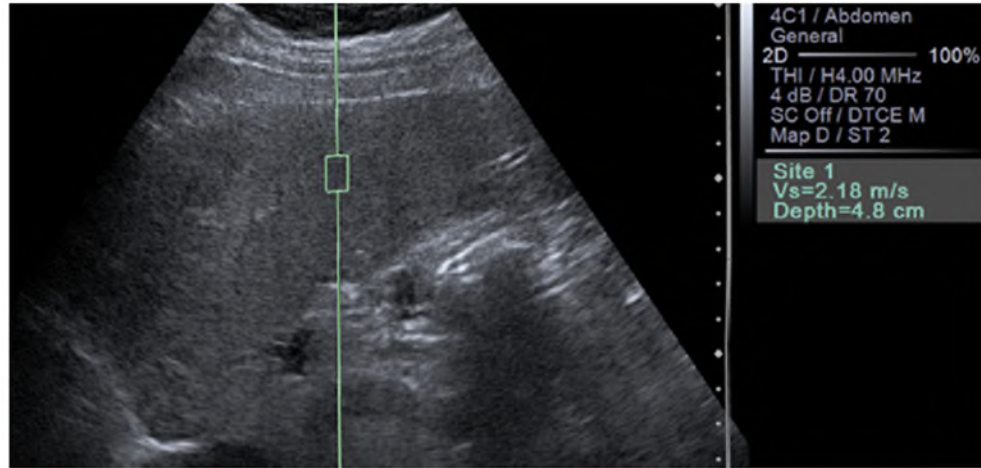


Fig. 2. Image from a point shear wave elastogram (p-SWE). The square ROI is placed 1.5–2.0 cm below the liver capsule with the ARFI pulse placed perpendicular to the liver capsule. After initiating the pulse, the measurement is displayed either in kPa or m/s, in this case 2.18 m/s.

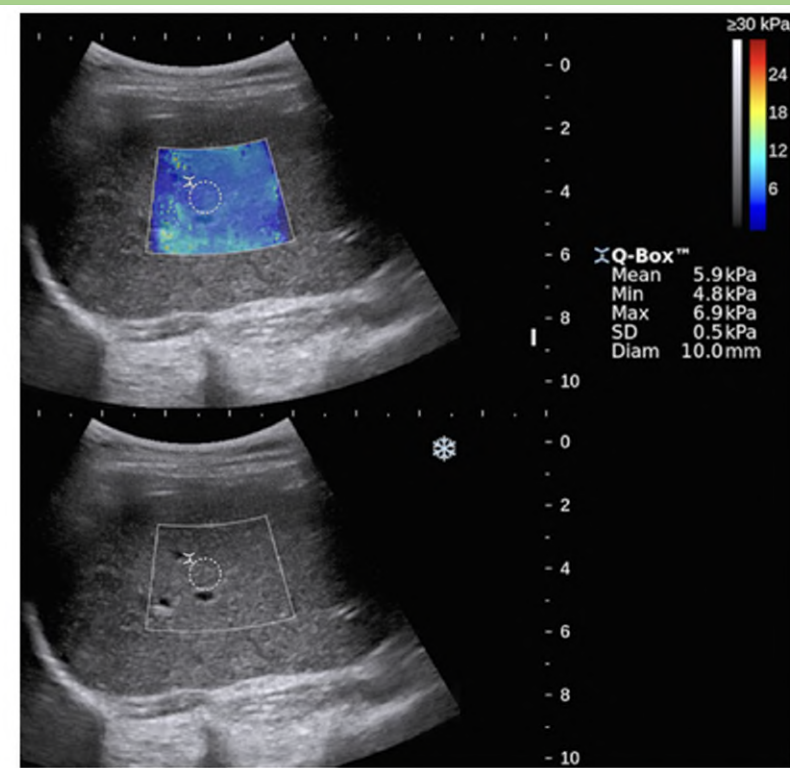


Fig. 3. Image from a 2D shear wave elastogram (2D-SWE). Some systems perform using a single shot (one still image) and other in real time. The large FOV is placed with the top of the box 1.5–2.0 cm below the liver capsule. A smaller ROI can then be placed in the FOV and measurements of stiffness obtained. Most systems provide the mean, minimum, maximum, and a standard deviation of the pixel values in the ROI.

- In pSWE (left), a small (approximately 1 cc) ROI is placed at the site where the measurement is taken and the ARFI is applied. Masses and large vessels can be identified and avoided. CAR MASLD WG recommendations are that pSWE measurements be reported in kPa for uniformity across modalities.
- In 2D-SWE (right), multiple ARFIs are used to generate shear waves in a larger field of view, allowing for averaging over a larger area.

SWE– Technique

- The CAR MASLD WG supports SRU recommendations for operator technique:

- | |
|--|
| a. Patient should be fasting for a minimum of 4 hours prior to the examination. |
| b. Measurements should be taken in an intercostal space with the patient in supine or slight lateral decubitus (30 degrees) position with right arm in extension. |
| c. Measurement should be taken during breath hold at neutral breathing. |
| d. The 2D SWE region of interest can be positioned closer to the liver capsule, if reverberation artifacts are avoided; however, the measurement box should be positioned at least 15–20 mm below the liver capsule. |
| e. The CAR MASLD WG recommends reporting in kilopascals regardless of modality or vendor. |
| f. In most systems, the maximum ARFI push pulse is at 4–4.5 cm from the transducer, which is the optimal location for obtaining measurements. |
| g. In most systems, the ARFI push pulse is attenuated by 6–7 cm, limiting adequate shear wave generation. |



SWE– Technique

- The CAR MASLD WG supports SRU recommendations for operator technique:

h. Major potential confounding factors include liver severe inflammation indicated by AST and/or ALT elevation greater than five times upper normal limits, obstructive cholestasis, liver congestion, acute hepatitis, and infiltrative liver disease (these all lead to overestimation of the stage of fibrosis).

i. Ten measurements should be obtained with pSWE, and the final result should be expressed as the median together with the IQR/M.

j. Fewer than 10 measurements with pSWE can be obtained (at least five); however, the IQR/M should be within the recommended range.

k. For 2D SWE, five measurements should be obtained when the manufacturer's quality criteria are available, and the final result should be expressed as the median together with the IQR/M.

l. The most important reliability criterion is an IQR/M of $\leq 30\%$ of the 10 measurements (pSWE) or five measurements (2D SWE) for kilopascals and $\leq 15\%$ for measurements in velocity (in meters per second).

m. Adequate B-mode liver imaging is a prerequisite for point and 2D SWE as shear waves are tracked with B-mode.



SWE– Technique – Pearls

- Applying too much pressure is a common error for technologists learning this technique and can artificially elevate elasticity values. Care should be taken to only apply soft probe pressure.
- Increased liver stiffness occurs below the level of the capsule and measurements should be taken at least 1.5-2 cm below the capsule.
- Non-diagnostic cases will occur on account of tissue depth. If the liver cannot be measured within 5-6 cm (ideal 4-4.5 cm depth) from the probe and at least 1.5-2 cm below the capsule *with minimal probe pressure on the soft tissues*, a non-diagnostic study may be required for technical reasons.
- For 2D-SWE measurements, acquire an ROI representative of the overall box rather than specifically selecting regions of lower stiffness.



SWE– Technique – Pearls

- A minimum of 10 measurements with pSWE are recommended.
- A minimum of 5 measurements with 2D-SWE are needed with each ROI using a different acquisition (ie: use only one measurement per wave propagation box when only 5 measurements are used).
- IQR/median represents the single most important feature of reliability and can be considered adequate if $\leq 30\%$. Additional information on reliability may also be provided by your manufacturer.



SWE– Reporting

- For MASLD patients with indeterminate FIB-4 score (1.3-2.67), CAR MASLD WG recommended thresholds are as follows:

a. < 8 kPa – Low risk for advanced liver disease. Return to routine surveillance with FIB-4 in 1-3 years recommended.

b. 8-12 kPa – Indeterminate risk for advanced liver disease. MR elastography, liver biopsy and/or liver specialist referral may be appropriate.

c. > 12 kPa – Rules in advanced liver disease. Liver specialist referral is recommended.

SWE– Reporting

- For MASLD patients where FIB-4 is unknown, CAR MASLD WG recommended thresholds are as follows:

a. < 5 kPa – Low risk for advanced liver disease. Return to routine surveillance with FIB-4 in 1-3 years recommended in appropriate patients.

b. 5-13 kPa – Indeterminate risk for advanced liver disease. Further testing with FIB-4 is recommended. MR elastography, liver biopsy and/or liver specialist referral may be appropriate.

c. > 13 kPa – Rules in advanced liver disease. Liver specialist referral is recommended.

SWE– Reporting

- For non-MASLD patients, deferral is made to other guidelines including the American Gastroenterology Association, American Association for the Study of Liver Diseases and/or the Society of Radiologists in Ultrasound (see *Kanwal et al*, *Sterling et al*, and *Barr et al*).
- The SRU guidelines are as follows:

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.

SWE– Reporting – Follow up surveillance

- In follow up, a change in liver stiffness of $>10\%$ is considered a clinically significant change.
- Serial exams should be performed with the same equipment whenever possible, to reduce to risk of variability.



SWE– Reporting – Limitations and Pitfalls

- Literature for SWE is established for MASLD and viral hepatitis. The utility of SWE for other causes including alcoholic hepatitis, primary biliary cirrhosis, Wilson disease, autoimmune hepatitis, sclerosing cholangitis and drug-induced liver disease should be determined on an individualized basis as less literature is available for these populations.
- Several confounding variables may artificially increase liver stiffness unrelated to liver fibrosis including but not limited to:
postprandial hyperemia, recent intense physical exercise, acute hepatitis/ liver inflammation, obstructive cholestasis, hepatic congestion, and infiltrative liver diseases such as amyloidosis, lymphoma and extramedullary hematopoiesis.

Box 3

Confounding factors for accurate liver stiffness values with elastography

Method of performing examination (MRE, TE, SWE)

Type of equipment (hardware and software)

Patient factors

Obesity

Ascites

Medications

Fasting

Lab Values (AST, ALT)

Co-morbidities

Acute on chronic disease

Vascular congestion (CHF, fluid overload)

Pre-test and post-test probability

Technologist experience



SWE– Reporting – Limitations and Pitfalls

- It is the authors' experience that frankly cirrhotic patients can have abnormally lower liver stiffness measurements, thought to be related to the "eggshell effect" where the hardened liver capsule may preclude adequate penetration of the ARFI (*Taljanovic, Chen*).
 - Special attention to morphologically cirrhotic livers is recommended to guide any further recommendations even when liver stiffness measurements are within normal range.

Recommended Reading

The following are recommended for more detailed reading:

1. Shabanan SH et al. MASLD: What we have learned and where we need to go – A call to action. Radiographics 2024;44(11):e240048.
2. Rinella ME et al. NAFLD nomenclature consensus group. A multisociety Delphi consensus statement on new fatty liver disease nomenclature. Hepatology 2023;78(6):1966-1986.
3. Barr RG. Multiparametric ultrasound for chronic liver disease. Radiol Clin North Am 2025;63(1):13-28.
4. Barr RG et al. Update to the Society of Radiologists in Ultrasound liver elastography consensus statement. Radiology 2020;296(2):263-274.
5. Taljanovic MS et al. Shear-wave elastography: Basic physics and musculoskeletal applications. Radiographics 2017;37:855-870.



References

1. Shabanan SH et al. MASLD: What we have learned and where we need to go – A call to action. Radiographics 2024;44(11):e240048.
2. Rinella ME et al. NAFLD nomenclature consensus group. A multisociety Delphi consensus statement on new fatty liver disease nomenclature. Hepatology 2023;78(6):1966-1986.
3. Barr RG. Multiparametric ultrasound for chronic liver disease. Radiol Clin North Am 2025;63(1):13-28.
4. **Wilson et al. PART 2: CAR MASLD Working Group recommendations for screening and risk stratifying patients with MASLD. CARJ:Epub ahead of print.**
5. Taljanovic MS et al. Shear-wave elastography: Basic physics and musculoskeletal applications. Radiographics 2017;37:855-870.
6. Barr RG. Shear wave elastography. Abdom Radiol (NY) 2018;43(4):800-807.
7. Barr RG et al. Update to the Society of Radiologists in Ultrasound liver elastography consensus statement. Radiology 2020;296(2):263-274
8. Chen CT, Gu GX. Physics-informed deep-learning for elasticity: Forward, inverse, and mixed-problems. Adv Sci (Weinh) 2023;10(18):2300439.
9. Sterling RK et al. AASLD practice guideline on imaging-based noninvasive liver disease assessment of hepatic fibrosis and steatosis. Hepatology 2025;81(2):672-724.
10. EASL, EASD, EASO. EASL-EASD-EASO clinical practice guidelines on the management of metabolic dysfunction-associated steatotic liver disease. J Hepatol 2024;81(3):492-542.
11. Kanwal F et al. Clinical care pathway for the risk stratification and management of patients with nonalcoholic fatty liver disease. Gastroenterology 2021;161(5):1657-1669.

