Shear Wave Elastography

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For the Assessment of Diffuse Liver Disease: Protocol and Case Studies

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Real Time Liver Shear Wave Imaging

Overview

This paper provides an easy-to-follow guideline on the use of Shear Wave Elastography for the assessment of diffuse liver disease.

Shear Wave Elastography is a non-invasive method to assess the staging and the progression of liver fibrosis with good sensitivity and reproducibility in conjunctions with blood tests. It may also be used as a prognostic tool to follow up patients with liver cirrhosis.

As recommended by EFSUMB and WFUMB guidelines on liver Shear Wave Elastography [1,2], proper training in the acquisition of real time 2D with simultaneous Shear Wave Elastography is required in order to obtain a better accuracy and intra-observer and inter-observer reproducibility of liver stiffness measurement.

The illustrated clinical cases in this paper were performed on the Mindray Resona 7 system by the team of experts at Ultrasound Unit of the "Fondazione IRCCS Policlinico San Matteo", Medical School University of Pavia, Italy. These cases were collected to illustrate the advantages of using Shear Wave Elastography in the clinical practice.

Fig. Resona 7 Liver Shear Wave Elastography with kPa measurements

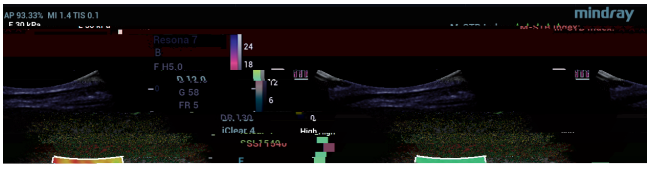
Practical Steps and Protocol

- The patient should be fast at least for 2 hours prior to the Shear Wave Elastography study.
- Following the recommendations of WFUMB and EFSUMB guidelines [1,2], use the intercostal approach with the patient in the supine position and with the right arm raised above the head to increase the width of the intercostal space to survey the liver in B-mode.
- Optimize the B-mode image: a Shear Wave Elastography study of good quality depends on the quality of the B-mode image.
- An important pre-requisite for a reliable liver stiffness measurement is the quality of the ultrasound image, which should show the liver capsule as a white line without rib's or lung's shadowing in the liver parenchyma.
- Position the probe searching for the best acoustic window with the transducer held at 90° perpendicular to the liver capsule; segment VII, VIII or V can be chosen.

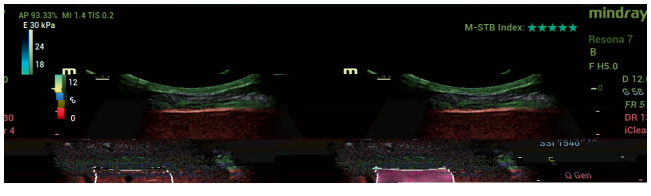
- To avoid reverberation artifacts always position the upper edge of the sampling box (region of interest, ROI) at least one centimeter below the liver capsule and avoid to include any large vessels, and small vessels as well whenever it is possible.
- Even if the size of the ROI could be very large, it is recommended to choose a size that reduces the possibility of including artifacts, which may degrade the quality of the sampling. An ROI 2 – 3 cm in size is a good compromise to qualitatively assess the stiffness of the targeted liver parenchyma area possibly without artifacts.
- Place the Sound Touch Elastography (STE) ROI box in the middle center of the B-mode image in a homogeneous area of the liver parenchyma, avoiding ligaments, vessels or bile ducts.
- Holding the probe steady in place, ask the patient to hold the breath for a few seconds at mid expiration while placing the targeted segment at the center of the image.
- When the patient stops breathing, activate STE on the touch screen, and observe both B-mode and Shear Wave Elastography display, coded with colors, side by side.
- Wait for the system to generate consecutive frames for 3 - 5 seconds and capture sequential STE images in a cine loop.
- Best possible frame of STE image is indicated with both the 5 Green Stars Motion Stability Index **(F 1a & F 2a)**

F 1a – Assessment of liver stiffness with STE: the Motion Stability (M-STB) Index.
From the frames captured in the cine loop, an image with 5 green stars, which indicates a high stability of consecutive frame without artifacts due to movement, should be chosen.

F 1b – The reliability map (RLB) is activated: as shown by the colors of the RLB map, the area on the ROI where there are two vessels is not a good one for the assessment of liver stiffness (Fig. 1a). The measurement is performed in the area with green color, which indicates a high reliability. The mean value in kPa, together with the maximum and minimum values and standard deviation (SD), is displayed on the image. Depth of the measurement and size of the measurement box are shown as well. RLB in the measurement box is 100%.

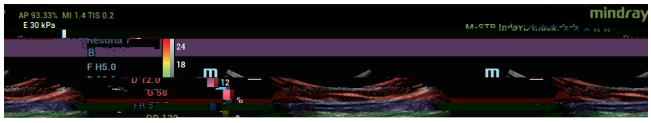


F 2a – Assessment of liver stiffness with STE: the image has 5 green stars.



F 2b – The RLB map shows that there is green color in almost 100% of the ROI. In cases like this one, the measurement box is positioned in the middle of the ROI.

F 3 – Measurement of liver stiffness should never be performed on images like this one, with a low M-STB Index (red stars) or a low reliability, indicated by purple or yellow color.

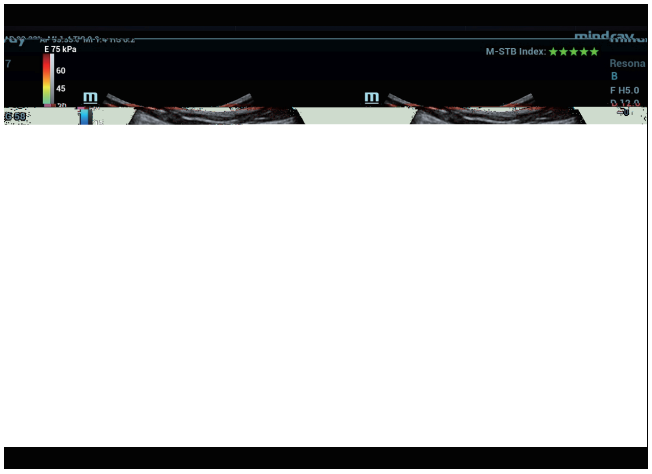


- Use the measurement key to place the " circle " 15mm diameter size within the ROI box in a homogenous color area (**F 1** & **F 2**). For better accuracy, it is recommended to perform only one measurement for each acquisition either in m/s (speed of the shear waves) or kPa (stiffness value derived from the speed of the shear wave by using the Young module). The size of the "circle" can be reduced to 10mm in case of artifacts within the ROI.
- It is important to note that the colors captured in the ROI are related to the E scale, which goes from dark blue to dark red (**F 4**). As a rule, for routine assessment it is better to use always the same scale. With the default scale, i.e. up to 30 kPa**(F 4a)**, it is easier to differentiate the quality of the elastogram and the shades of colors for the different ranges of liver stiffness.
- Guidelines have recommended to obtain a minimum of 3 acquisitions and to use the median value of them as representative of the stiffness [1]. We suggest to obtain up to 5 acquisitions for better judging the variability between measurements by means of the interquartile range/median (IQR/M) ratio.
- It is recommended to use the IQR/M as a quality factor [3]: it should be ≤ 30% when the median value is given in kPa and ≤ 15% when the median value is given in m/s.
- Activate the report box on the touch screen to auto transfer the measurement data to the table report page **(F 5)**.

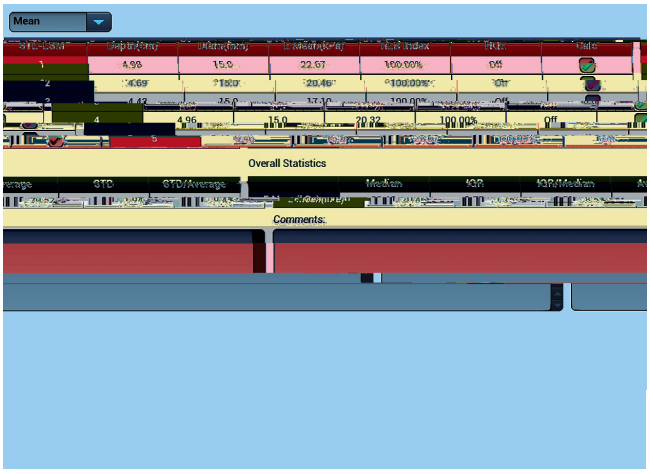
F 4a Elastogram obtained using default E scale 30 kPa

F 4 Elastogram obtained using E scale 15 kPa

F 4 Elastogram obtained using E scale 75 kPa



F 5 Report of the STE-LSM (Liver Stiffness Measurement) in kPa. The five acquisitions, their median value together with the interquartile range (IQR) and the IQR/Median, the average, the standard deviation (STD), and the STD/Average are shown. The median value should be used. A measurement (in kPa) of good quality should have an IQR/Median 30%.



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1. Dietrich CF, Bamber J, Berzigotti A, Bota S, Cantisani V, Castera L, Cosgrove D, Ferraioli G, Friedrich-Rust M, Gilja OH, Goertz RS, Karlas T, de Knegt R, de Ledinghen V, Piscaglia F, Procopet B, Saftoiu A, Sidhu PS, Sporea I, Thiele M. EFSUMB Guidelines and Recommendations on the Clinical Use of Liver Ultrasound Elastography, Update 2017 (Long Version). Ultraschall Med 2017;38:e16-e47.

2. Ferraioli G, Wong VW, Castera L, Berzigotti A, Sporea I, Dietrich CF, Choi BI, Wilson SR, Kudo M, Barr RG. Liver Ultrasound Elastography: An Update to the World Federation for Ultrasound in Medicine and Biology Guidelines and Recommendations. Ultrasound Med Biol 2018; doi:10.1016/j.ultrasmedbio.2018.07.008.

3. Barr RG, Ferraioli G, Palmeri ML, Goodman ZD, Garcia-Tsao G, Rubin J, Garra B, Myers RP, Wilson SR, Rubens D, Levine D. Elastography Assessment of Liver Fibrosis: Society of Radiologists in Ultrasound Consensus Conference Statement. Radiology 2015;276(3):845-61.

Study Case 1

Patient with Non Alcoholic Fatty Liver Disease (NAFLD)

A 45-year-old male with abdominal pain in the right upper quadrant.

- Overweight with a BMI of 28 Kg/m^2.
- Week alcohol intake < 10 drinks.
- Uneventful past medical history except for appendectomy at age of 12.
- Blood tests negative for hepatitis B virus and hepatitis C virus.
- Mild increase of the transaminases and gamma-glutamyl transferase values.
- Platelet count and other blood tests within the normal range.

B-mode and Doppler Findings:

- There is a bright liver with smooth margins **(F 6a)**.
- The portal vein is patent and the mean portal blood flow velocity is 28 cm/s.
- The flow in the hepatic veins has a biphasic pattern **(F 6b)**.

F 6a

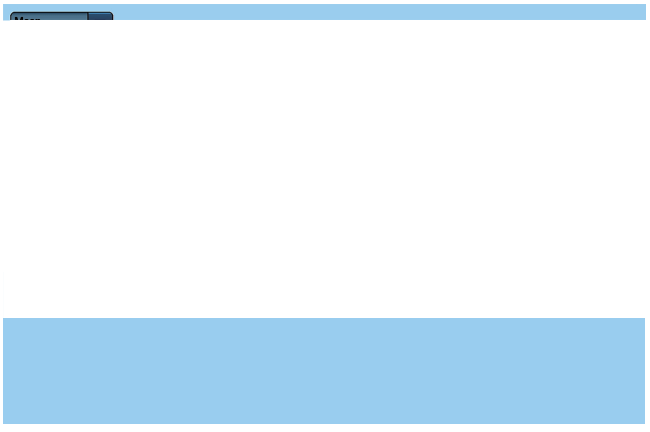
F 6b

Shear Wave Elastography:

- 2D-SWE with the STE technique of the Resona7 Mindray US system shows a median value of 8.83 kPa (IQR/M = 1.8%). The value indicates significant fibrosis and the liver stiffness measurement is reliable **(F 6c & F 6d)**.
- Transient elastography with FibroScan device is performed in the same session soon after the evaluation with the Resona7 Mindray US system and the values obtained with the Fibroscan is 8.5 kPa. Liver biopsy, performed a week later, shows a fibrosis stage 2.

F 6c

F 6d



Nowadays, NAFLD has become the most common liver disease. The term encompasses a large spectrum of disease, from simple steatosis to NASH that may evolve to liver cirrhosis with its related complications. Assessing the stage of liver fibrosis in patients with NAFLD is extremely important, since it has been reported that NAFLD patients with fibrosis, regardless of steatohepatitis or NAFLD activity score, have shorter survival respect to patients without fibrosis [1]. Patients with NAFLD are often asymptomatic and the diagnosis could be made incidentally on imaging requested for unrelated symptoms [2]. Our patient had significant liver steatosis on ultrasound examination. The availability of an ultrasound system, in which shear wave elastography technique is implemented, has allowed us to evaluate the liver stiffness as well. The results were compatible with significant fibrosis (F2), confirmed by liver biopsy.

References

1. Angulo P, Kleiner DE, Dam-Larsen S, et al. Liver fibrosis, but no other histologic features, is associated with long-term outcomes of patients with nonalcoholic fatty liver disease. Gastroenterology 2015;149:389-97.

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A meta-analysis, that has assessed the diagnostic performance of US for identifying chronic liver disease in a high risk population, has reported that liver echogenicity had poor diagnostic accuracy, whereas the results for portal vein maximum velocity and spleen size were variable, and the results for liver surface had moderate diagnostic accuracy [1]. In a study on 300 patients with chronic viral hepatitis, it has been reported that a quarter of patients with severe fibrosis or cirrhosis were negative for liver surface nodularity and caudate lobe hypertrophy and had normal hepatic venous flow [2].

The widespread use of the US imaging technique is due to its availability, absence of exposure to ionizing radiation, non-invasiveness, repeatability, and low cost compared to other imaging techniques. US is the imaging modality most frequently used in the surveillance for hepatocellular carcinoma among patients with chronic viral hepatitis. B-mode US assesses the acoustic properties of tissue whereas elastography assesses its bio-mechanical properties, and these properties are not related to each other. The availability of shear wave elastography technique in the ultrasound system permits to carry out a thorough, painless and accurate evaluation the liver.

References

1. Allan R, Thoirs K, Phillips M. Accuracy of ultrasound to identify chronic liver disease. World J Gastroenterol 2010; 16: 3510-20.
2. Colli A, Fraquelli M, Andreoletti M, Marino B, Zuccoli E, Conte D. Severe liver fibrosis or cirrhosis: accuracy of US for detection--analysis of 300 cases. Radiology 2003; 227: 89-94.

Study Case 3

Normal case

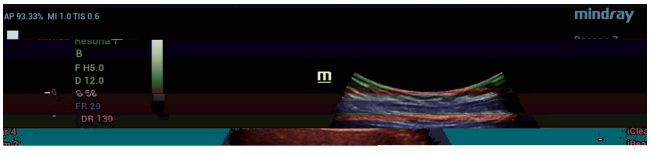
- 48-year-old male, inguinal hernia repair 11 years ago, complain of vague abdominal pain in the RUQ, which started few weeks ago.
- The patient has a BMI within the normal range.
- He's abstemious and negative for hepatitis B virus and hepatitis C virus.
- Lab tests, including transaminases, bilirubin, gamma-glutamyl transferase and alkaline phosphatase, are within normal range.

B-mode and Doppler Findings:

- B-mode ultrasound shows a liver of normal size with smooth and regular margins; the hepatic echotexture is homogeneous **(F 8a)**.
- There are small gallbladder polyps **(F 8b)**.
- The spleen has a normal size.
- The portal vein is patent, has a diameter of 10mm and the blood flow mean velocity is 27.1cm/s **(F 8c)**.

F 8a

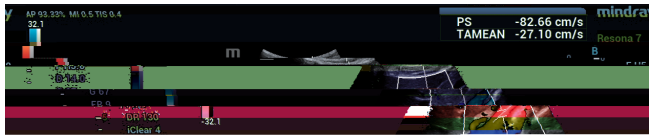
F 8b



Shear Wave Elastography:

- 2D-SWE with the STE technique of the Mindray Resona 7 US system **(F 8d)** shows a median value of 4.63 kPa, which indicates absence of fibrosis; the IQR/M is 4.2%, thus the liver stiffness measurement is reliable.
- TE, performed with the FibroScan device in the same session soon after the evaluation with the Mindray Resona 7 US system, confirms this finding.

F 8c



F 8d

Summary of study cases

The assessment of liver stiffness with shear wave elastography requires a very short time (few minutes) and gives the possibility to perform a thorough evaluation of the liver in the same session using ultrasound. It is a non-invasive technique easy to use after a proper training and without any discomfort to the patient. A value of liver stiffness within the normal range can rule out significant liver fibrosis if in agreement with the clinical and laboratory data.