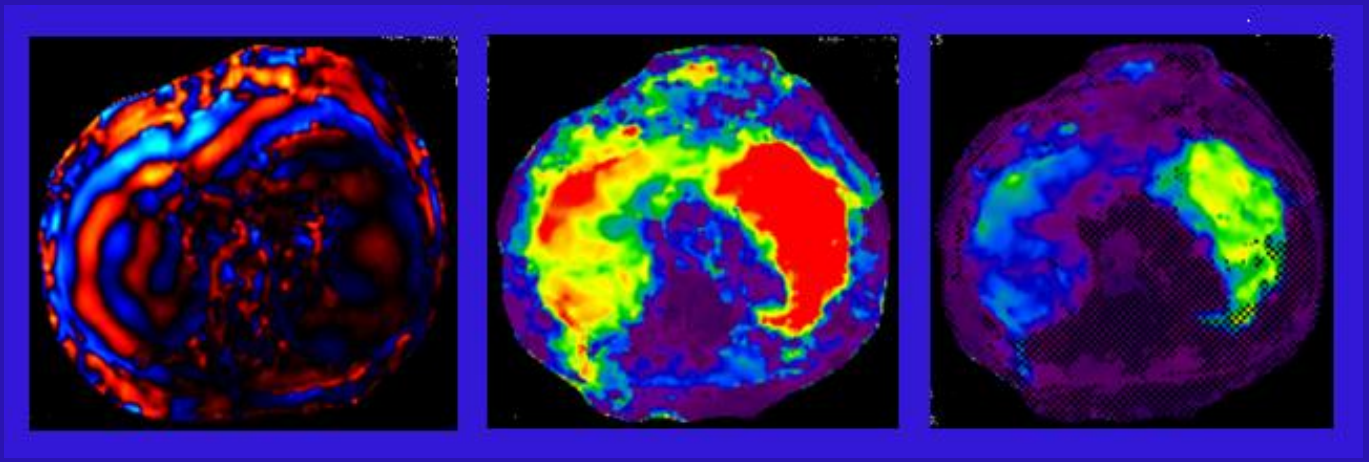
Problems and possible solutions in MR Elastography of the liver



I. Mussetto, J. Matos, L. Bacigalupo, L. Cevasco, S. Perugin Bernardi, M. De Cesari, F. Paparo and G. Rollandi

University of Genoa

E.O. Ospedali Galliera

Learning objectives

- To describe the correct technique of performing an MR Elastography of the liver

- To review the limitations, technical problems and possible solutions presenting cases from our experience.

Background

MR Elastography (MRE) of the liver is a non-invasive technique that allows quantitative evaluation and staging of liver stiffness.

MRE is a safe, fast, and highly accurate technique that evaluates a large area of liver parenchyma, with good reproducibility, when compared with biopsy and other US-based elastography methods.

It allows stiffness calculation even in the case of obese patients with thick subcutaneous tissue and in those with hepatic steatosis.

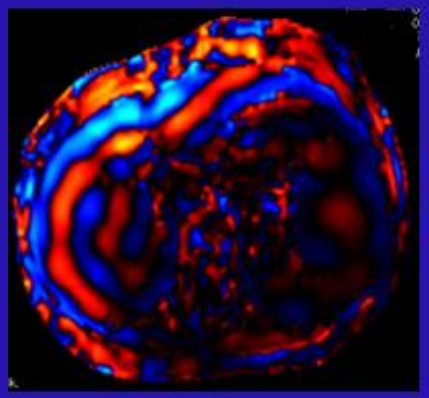
Nevertheless, there are some specific circumstances in which the final results should be interpreted with caution, either due to specific patient characteristics or technical particularities.

The technical failure rate of MRE is described to be around 6%.

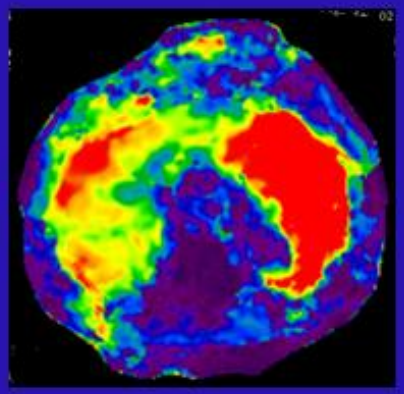
MRE PROTOCOL

PROTOCOL
axial MR touch
axial T2w frFSE (breath hold or respiratory triggered)
axial T2w frFSE fat sat
DWI (b=0, 800)
axial T2*multi-gradient-echo (16 and 8 echoes)
axial T1w SPGR in and out of phase

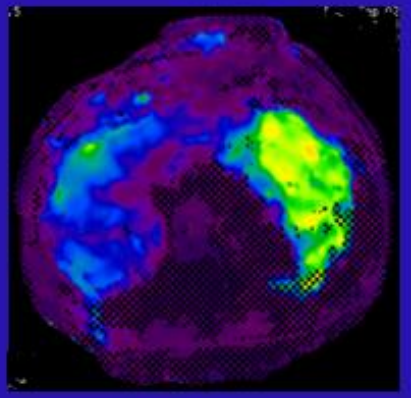
1.5T scanner , Signa HDxt, General Electric Medical Systems, Milwaukee, WI, USA.



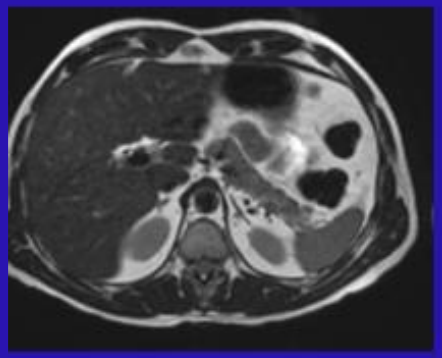
wave image



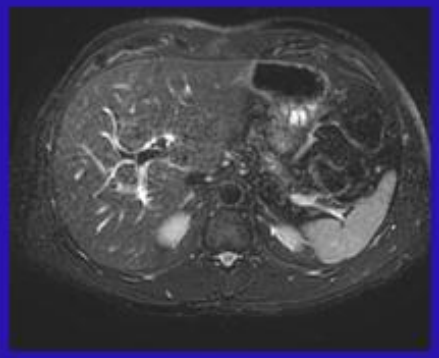
elastogram



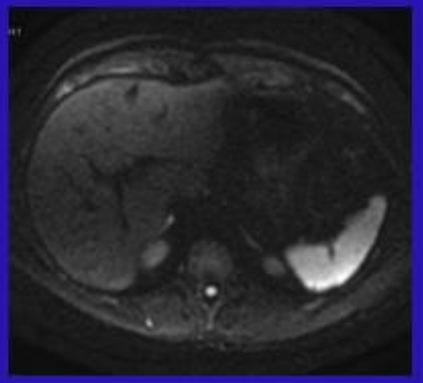
confidence map



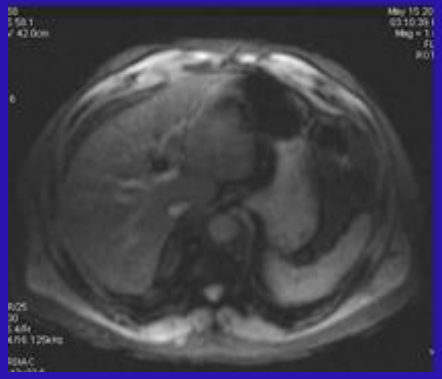
T2



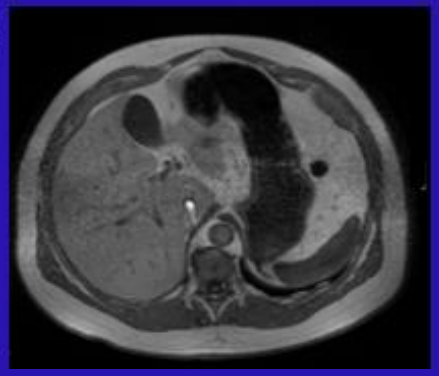
T2 fat sat



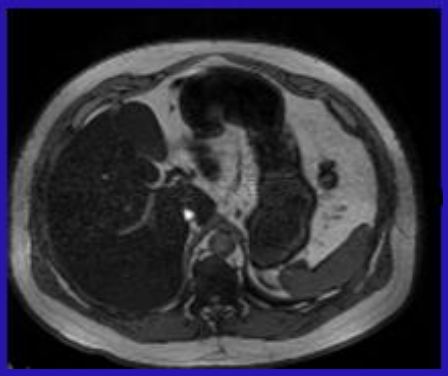
DWI (800)



T2*(16)

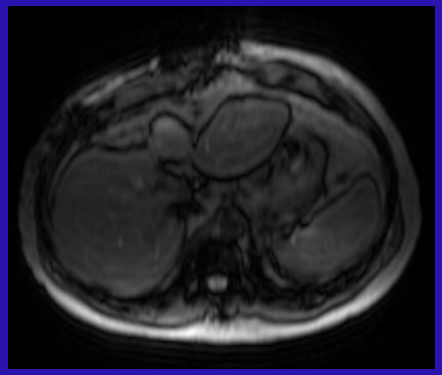


T1 in phase

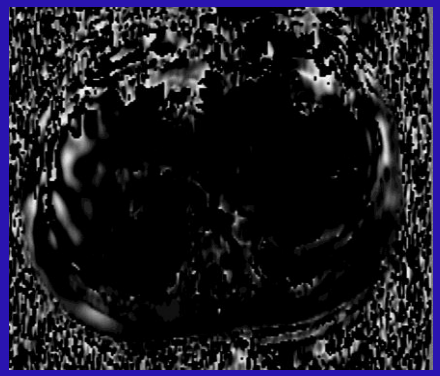


T1 out of phase

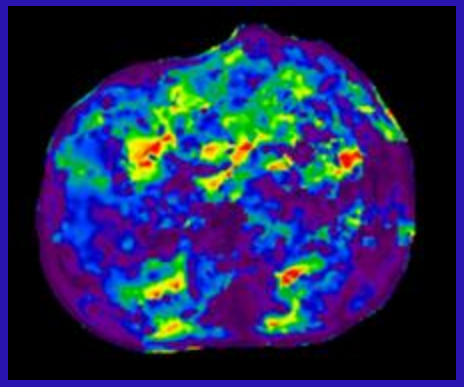
MR Elastography



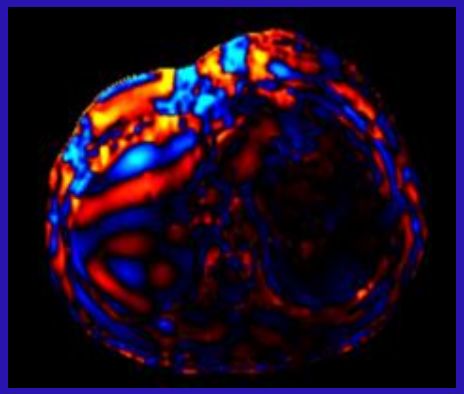
Magnitude image



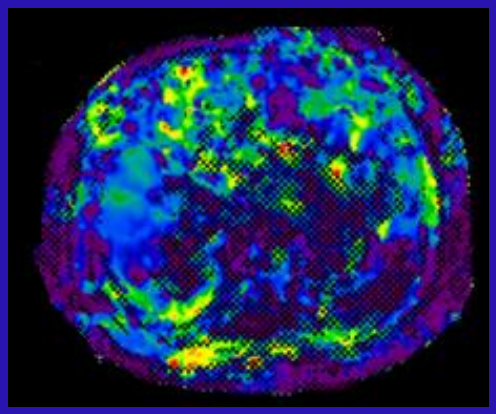
Phase image



Elastogram



Wave image

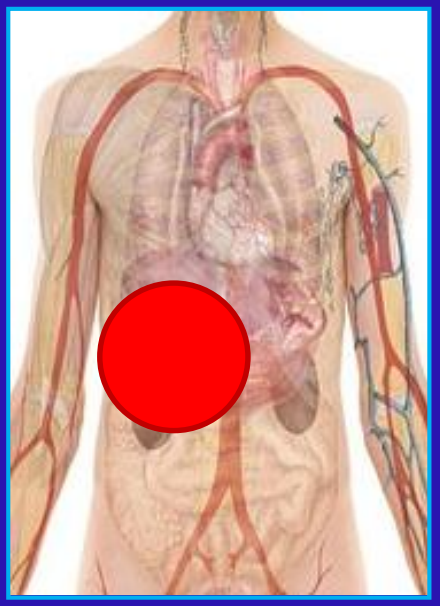


Confidence map

Low amplitude mechanical waves at 60 Hz are generated through the liver during imaging, using a passive driver device in contact with the anterior body wall. A two-dimensional gradient-echo sequence using motion-encoding gradients is used to map the shear waves traveling through the liver. 4 MR elastography sections are obtained in each patient during a breath-hold at the end of expiration. 4 quantitative images displaying shear stiffness (elastograms) are then generated by processing the acquired raw-data images of propagating shear waves using the direct inversion method with a commercially available software (MR Touch; GE Healthcare). An additional confidence algorithm generates confidence maps overlayed on the elastograms, to indicate the highest regions of statistical confidence in which is possible to place the regions of interest (ROIs) to calculate the liver stiffness.

How to position the drive

The passive driver must firmly positioned directly over the liver on the upper abdomen with an elastic belt. The driver is placed along the right midclavicular line.
Inform your Patient that during the exam he will perceive small compressions generated by the drive.



1. Position the drive

2. Tighten the elastic band

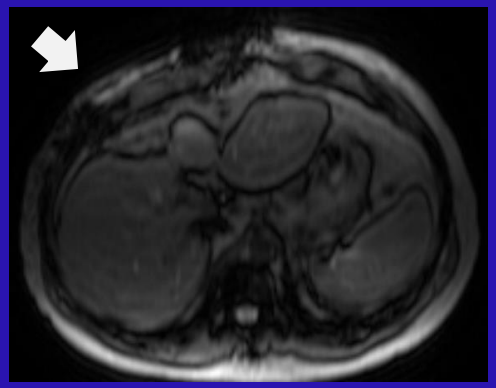
3. Place the coil

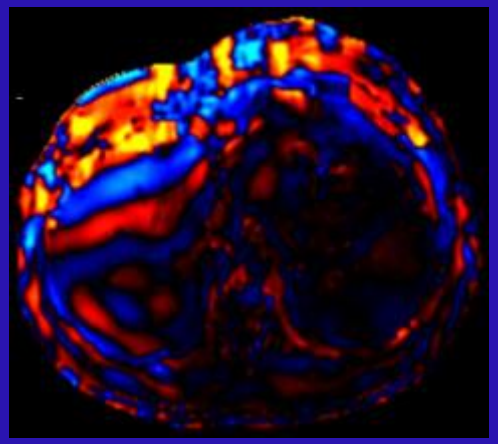
Quality control

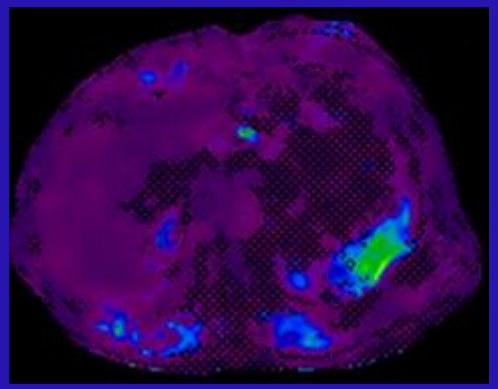
1. Check the magnitude images to look for the focal subcutaneous artifact within the subcutaneous fat (arrow) which indicates that the driver is correctly positioned and is transmitting pressure waves.

1. Check the wave images to assess correct and uniform wave propagation through the liver. Regions of wave interference may create artifactually increased stiffness values.

1. Check the confidence map to ensure that there is an acceptable area of liver parenchyma with evaluable pixel values

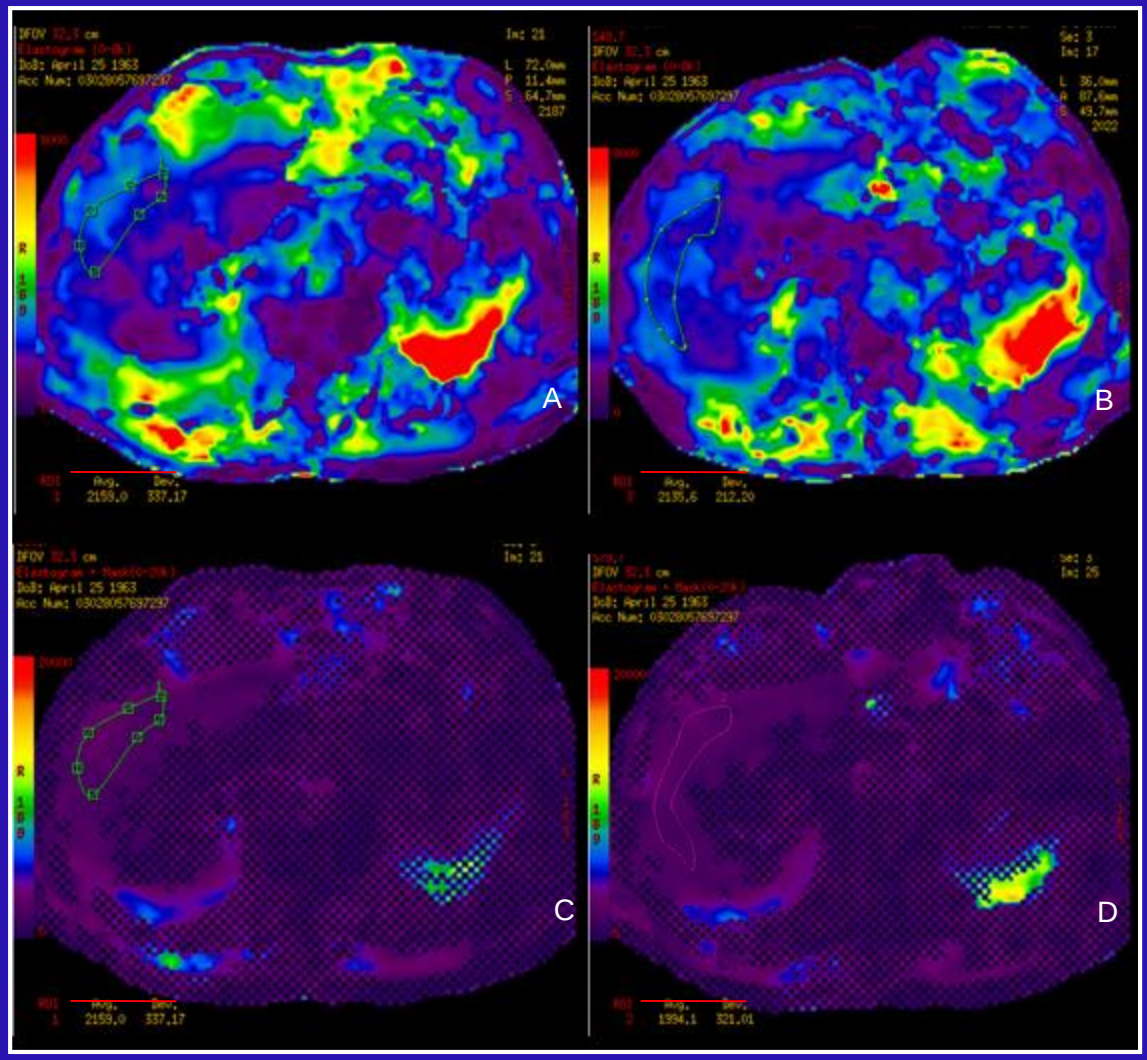






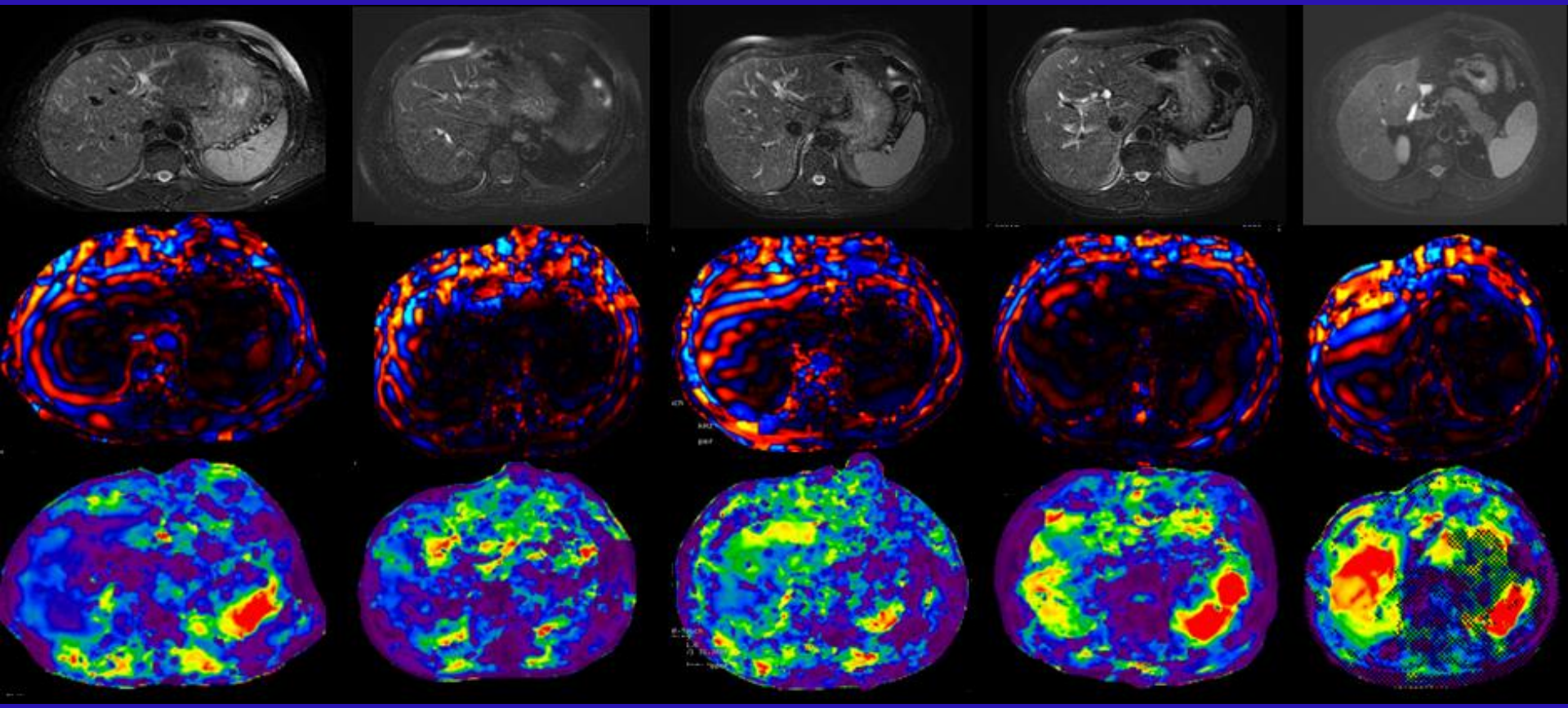
How to position the ROI

Liver stiffness values (expressed in kPa) are obtained placing four ROIs (one for each elastogram) in the hepatic parenchyma; ROIs are placed avoiding focal lesions, large blood vessels and large biliary ducts. The mean value is then converted into the corresponding METAVIR stage according to validated cut-off values.



Exemple of two ROIs. A and B elastrogram. C and D confidence maps. Liver stiffness values expressed in Kpa underlined

METAVIR stage



F0	F1	F2	F3	F4
<2,5	2.5–2.9	2.9–3.5	3.5–4.0	4.0–5.0	> 5

Stiffness (kPa) and the stage of fibrosis (F) correlation

MRE Failure

Factor	Outcome	Comments
Incorrect driver position		We recommend to perform the sequence for elastography first, check the outcome during the remaining of the MR exam; if MRE fails replace the driver and repeat the sequence.
Iron overload		Iron deposition can determine MRE failure. In our experience hepatic iron deposition with T2* <10 ms predicts MRE technical failure.
Colon interposition		Colon interposition may cause MRE failure due to the lack of propagating waves in the liver.
Massive ascite		Massive ascites may cause MRE failure .

Some circumstances can be responsible for technical failure.
Technical failure is determined as no pixel value in the confidence map or disorganized wave pattern on wave image

MRE Success

Factor	Outcome	Comments
Intravenous contrast agent		Intravenous contrast agent does not alter liver stiffness.
Hepatic steatosis		Hepatic steatosis does not alter liver stiffness.
Body mass index		Patient size does not alter liver stiffness.
Age and race		Patient's age and race do not alter liver stiffness.

Some factors that do not alter liver stiffness

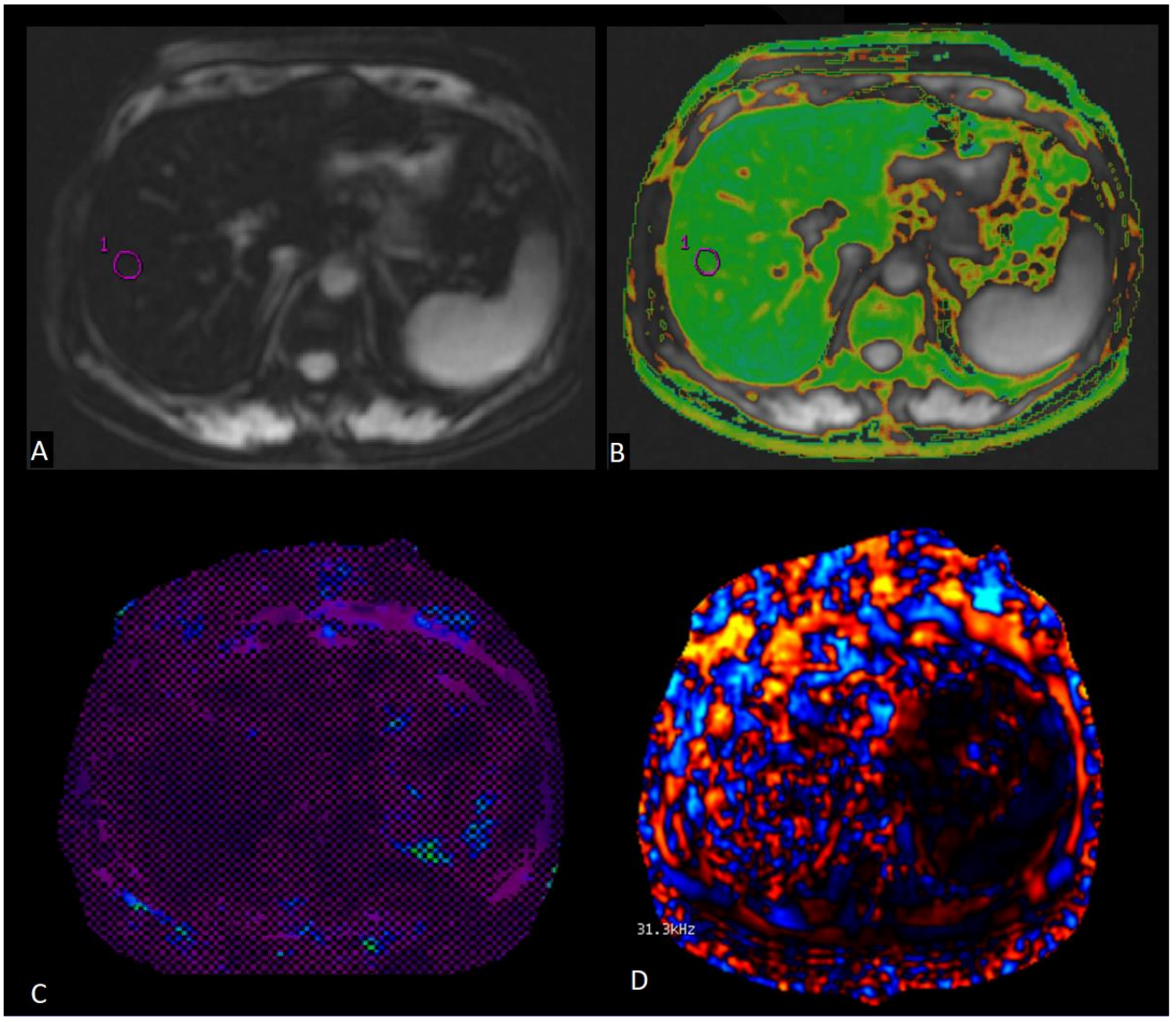
MRE Failure

Factor	Outcome	Comments
Lack of fasting		Lack of fasting can reduce the accuracy of the result. In the setting of liver fibrosis, liver stiffness increases after a meal. The patient must be fasting.
Acquisition in forced inspiratory phase		Forced inspiratory phase can reduce the accuracy of the result. Ideally, sequence should be performed in a breath hold during gentle normal expiration
Prone decubitus		Prone decubitus can reduce the accuracy of the result: in the setting of liver fibrosis, liver stiffness increases, minimal to no effect in normal liver.

Factors that influence liver stiffness

Iron overload

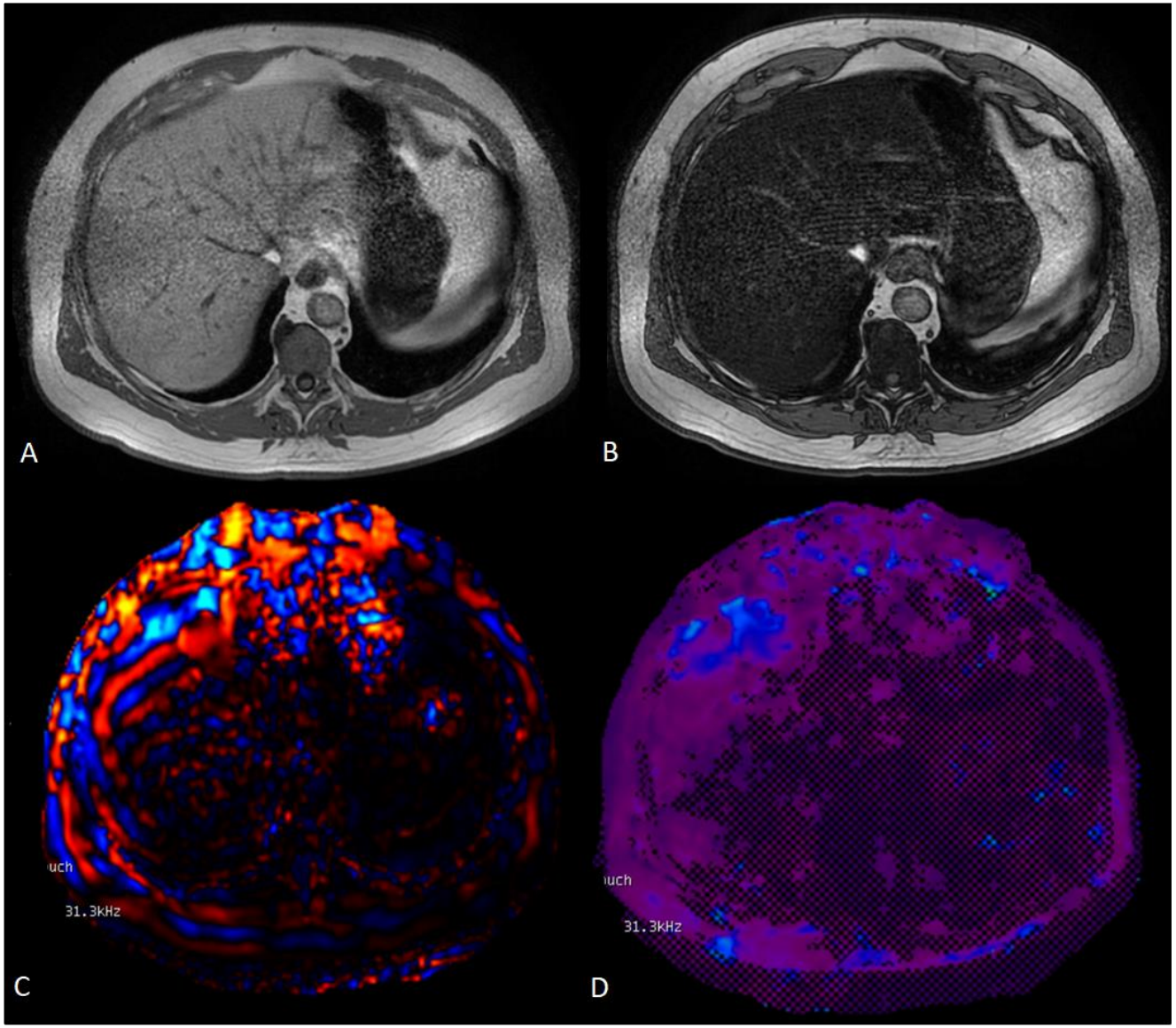
MRE FAILED!



A 59 -year-old woman with beta thalassemia major. A and B: T2* sequence and T2*map show diffuse iron deposition with T2* of 5,7 msec; C and D: no pixel value with confidence index higher than 95% on the confidence map and no wave propagation (disorganized pattern) on the wave image show MRE failure.

Steatosis

MRE SUCCESS!!

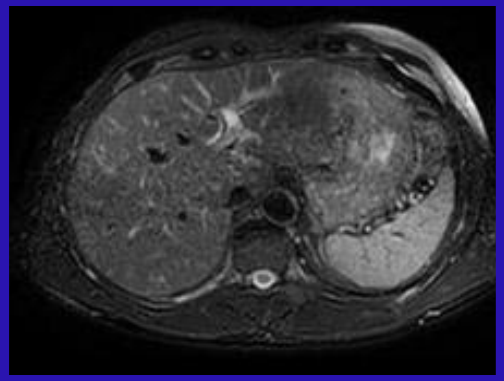


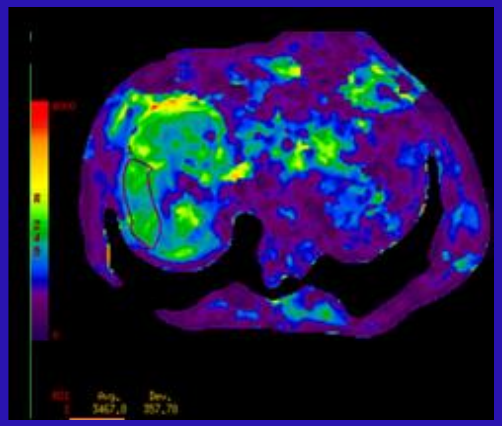
A 46- year-old man with HCV chronic infection and severe steatosis (38% fat percentage). A and B: T1- weighted in and out of phase images show severe steatosis; C and D: acceptable wave propagation on wave image and acceptable coverage by pixel values on the confidence map demonstrate MRE success.

Decubitus position

Increase of stiffness

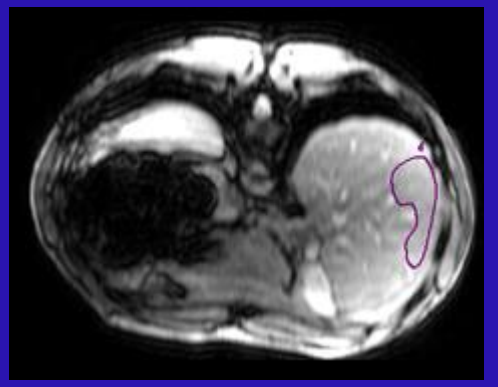
A

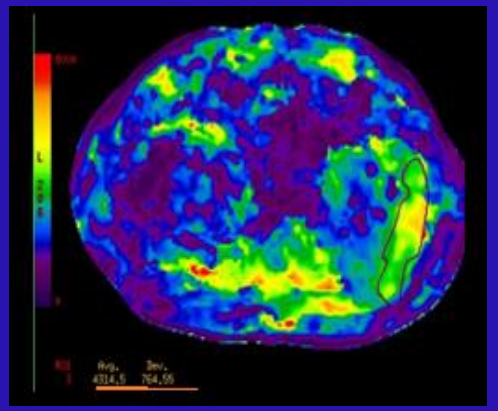




Metavir F2

B

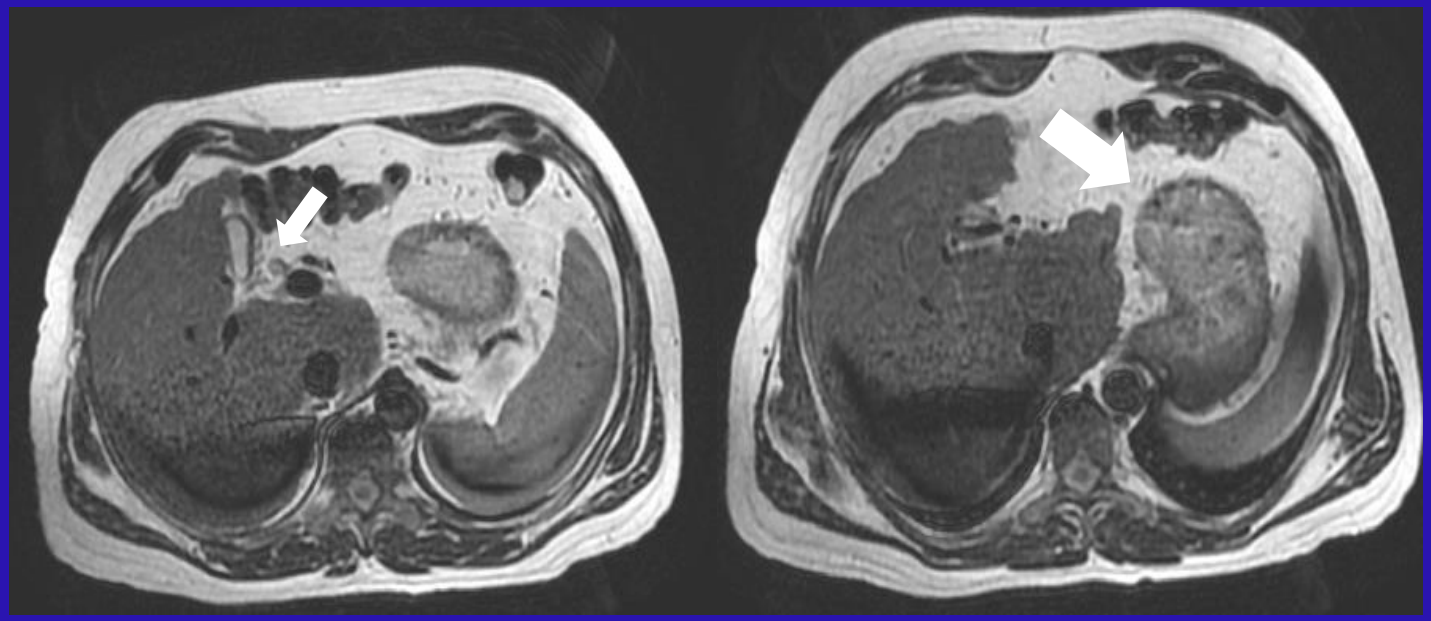




Metavir F3

A 58 year-old man with HCV chronic infection was examined in both supine (A) and prone (B) decubitus. The liver stiffness value calculated in the prone decubitus was higher than in the supine decubitus.

Lack of fasting



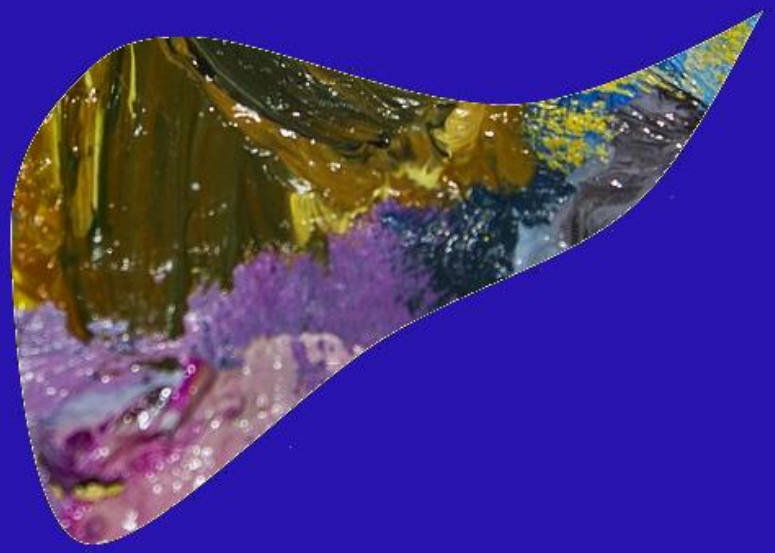
The patient must be fasting. Check for gastric contents and the gallbladder contraction.

It is possible to find water inside the tube that connects the driver to the compressor.
Check for water and if present removes it.

Conclusion

MR Elastography of the liver is a non-invasive, safe, fast, and highly accurate technique able to evaluate a large area of liver parenchyma, with good reproducibility.

Knowing MR Elastography limitations and avoiding procedural errors reduces the technical failure rate and increases the accuracy for evaluating liver stiffness using this technique.



References

1. A. S. Babu, M. L. Wells, O. M. Teytelboym et al. “Elastography in Chronic Liver Disease: Modalities, Techniques, Limitations, and Future Directions” Radiographics (2016) 36:1987–2006.

2. S. Venkatesh, M. Yin, R. L. Ehman Magnetic. “Resonanc e Elastography of Liver: Technique, Analysis, and Clinical Applications” Journal of Magnetic Resonance Imaging (2013) 37: 544–555.

3. M. Wagner, I. Corcuera-Solano, G. Lo et al. “Technical Failure of Mr elastography examinations of the liver: Experience from a Large Single-Center Study” Radiology (2017) 284:401-412.

4. J. Yoon, J. Min Lee, J Joo, et al. “Hepatic Fibrosis: Prospective Comparison of MR Elastography and US Shear-Wave Elastography for Evaluation” Radiology (2014) 273:772-82 .

5. Hepatic Mr elastography: Clinical Performance in a Series of 1377 Consecutive Examinations. Radiology (2016) 278:114-24.

Authors Information

Ilaria Mussetto MD, *University of Genoa, Department of Health Sciences DISSAL, Via Antonio Pastore 1, 16132 Genova, Italy*

Joao Matos MD and Matteo De Cesari MD: *University of Genoa, Department of Health Sciences DISSAL, Via Antonio Pastore 1, 16132 Genova, Italy*

Lorenzo Bacigalupo MD, Francesco Paparo MD, Luca Cevasco, S. Perugin Bernardi and Gianandrea Rollandi MD: *Radiology unit, Department of Diagnostic Imaging, E.O. Ospedali Galliera, Mura delle Cappuccine 14, 16128 Genoa, Italy*

University of Genoa

E.O. Ospedali Galliera