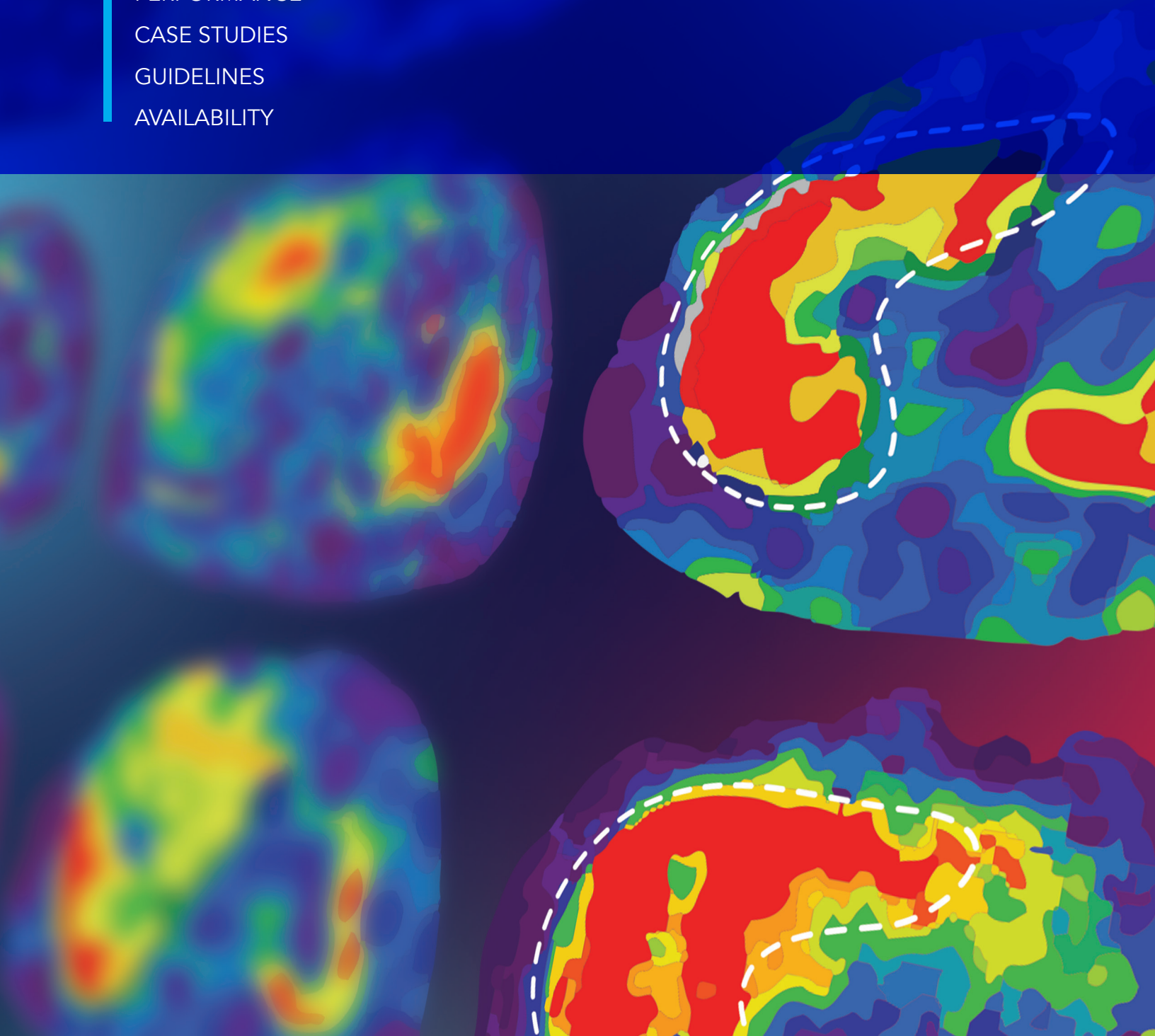
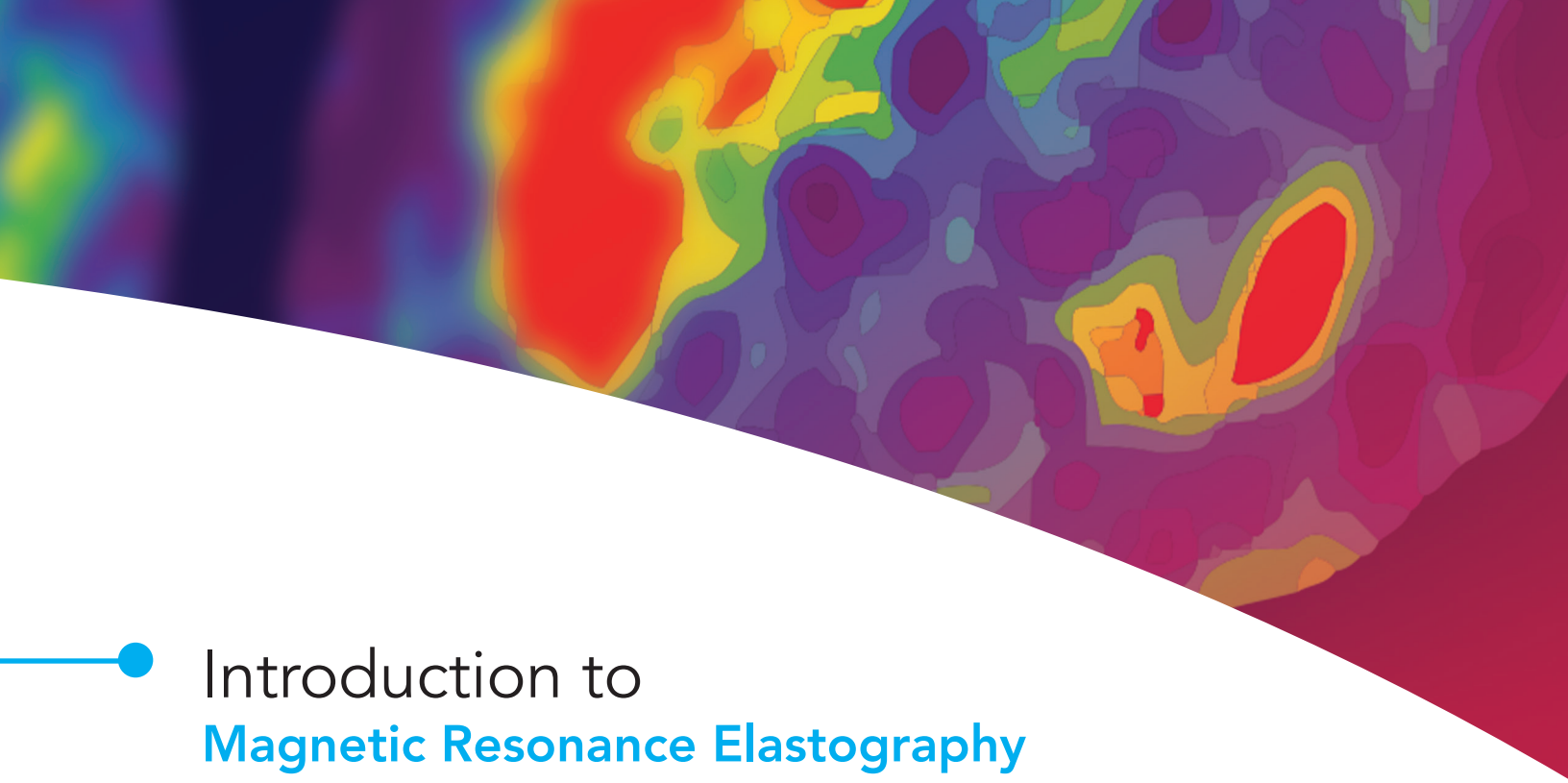
MAGNETIC RESONANCE **ELASTOGRAPHY**

RESOUNDANT®

- TECHNICAL INFORMATION
- PERFORMANCE
- CASE STUDIES
- GUIDELINES
- AVAILABILITY



> I was happy to learn that my liver is healthy — and to find that out **without experiencing any pain.**



Introduction to
Magnetic Resonance Elastography

Many disease processes cause profound changes in the mechanical properties of tissues. MR Elastography (MRE) is an MRI-based technique for quantitatively assessing tissue stiffness[1,6]. It was first introduced as an FDA-cleared product in the US in 2009 and since then it has been made available by several manufacturers as an upgrade to their MRI systems. The main application of MRE at this time is non-invasive assessment of liver fibrosis[2-6]. As of 2025, over 2,800 MRI systems around the world had been equipped for MRE.

MRE is based on the physical principle that the propagation characteristics of mechanical waves within various materials are determined by their mechanical properties.

The technique consists of three steps:

1. Generating mechanical waves in the region of interest
2. Imaging propagating mechanical waves
3. Processing the information to calculate the mechanical properties

For assessing liver disease, mechanical waves are typically generated at 60 Hz in the upper abdomen using a comfortable, flexible driver that is placed against the body wall. During imaging, synchronous cyclic motion-sensitizing gradients are used with a modified phase-contrast MRI pulse sequence to acquire snapshots of the propagating waves, depicting displacements as small as fractions of microns. The acquired data are then automatically processed with an inversion algorithm to generate cross-sectional images showing the mechanical properties of tissues (i.e., shear stiffness) on a color scale.

HOW **Liver MRE is Performed**

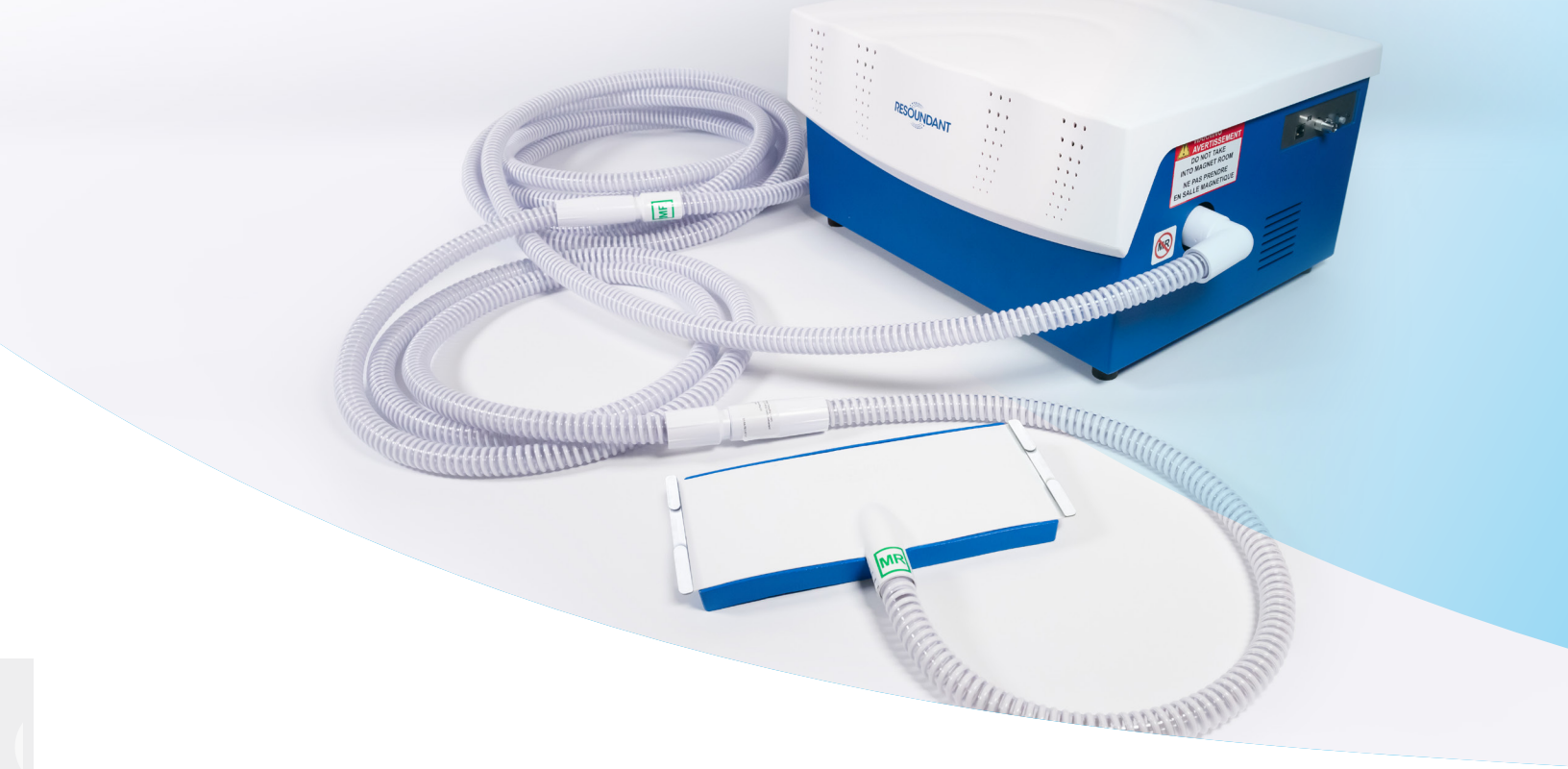
The MRE acquisition is performed during breath-holding at end expiration and takes 12-15 seconds for each slice. This acquisition is typically repeated four times, for a total acquisition time of less than one minute. MRE is usually added to a conventional abdominal MRI protocol (either full or limited) and adds little additional time to the overall examination. Another option is to perform a very limited exam consisting only of MRE (using CPT code 76391) and a ~30 second proton density fat fraction sequence, which would provide quantitative estimates of fat fraction, iron content, and liver stiffness in an exam that could be accomplished in less than 10 minutes of scanner time and at a very low cost.

A simple, flexible driver generates acoustic waves within the tissue of interest.

A special MRI technique images tiny displacements of the tissue that result from wave propagation.

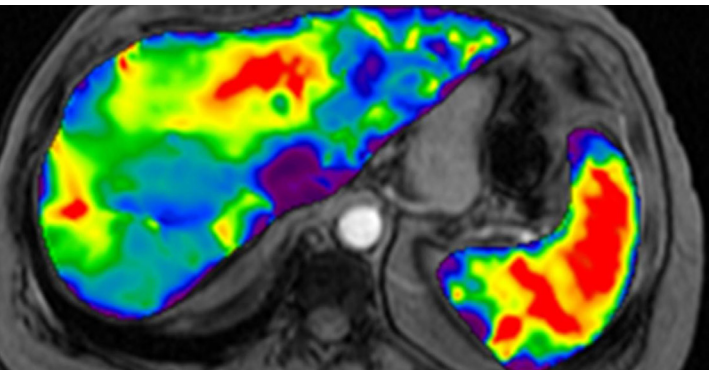
An advanced mathematical algorithm generates maps of tissue stiffness, known as "elastograms."

After 1-3 minutes of automatic processing, the scanner produces color-scaled quantitative images ("elastograms") depicting tissue shear stiffness in units of kiloPascals (kPa). In addition, the algorithm provides anatomic images corresponding to each of the elastograms and "confidence images" that provide a measure of the reliability of the tissue stiffness measurement at each image location.



Rarely seen, but always heard.

Sitting in the room adjacent to the MRI suite, the Resoundant system's Active Driver safely produces the 60Hz vibrations that work with the proprietary MRE software to uncover even the most subtle changes in tissue stiffness.



"Seeing my liver and the state of disease for the first time was a very powerful, emotional moment - it left me speechless," recalls Deb Sobel.

"MRE painted a true picture of the PBC progression. I used to be mad at my liver, but then I felt bad for it and decided to protect and take care of it as much as possible."

Global partnerships with
LEADERS IN IMAGING

Resoundant, Inc. is proud to collaborate with leading imaging manufacturers to make MRE available around the world. With more than 2,800 units installed worldwide (2025), MRE is widely available for patients and providers.

Canon · GE · PHILIPS · SIEMENS Healthineers · UNITED IMAGING

MRE is an add-on option for most new MR scanner purchases, or MRE can be added to nearly any existing 1.5T or 3T MR scanner by contacting one of our partners.

CLINICAL Indications

1 **LIVER FIBROSIS STAGING**

2 **TREATMENT MONITORING**

3 **POST-TREATMENT SURVEILLANCE**

MRE has emerged as a cornerstone imaging tool for the noninvasive assessment of liver fibrosis, addressing the long-standing limitations of biopsy. Unlike biopsy—which carries risks of morbidity, sampling variability, and subjective interpretation—MRE offers reproducible, quantitative, and whole-liver evaluation at a fraction of the cost of invasive testing.

The most rapidly expanding indication for MRE is in the evaluation of patients with metabolic dysfunction–associated steatotic liver disease (MASLD) and metabolic dysfunction–associated steatohepatitis (MASH). With the approval of antifibrotic and metabolic therapies such as resmetirom and semaglutide, precise fibrosis staging has become clinically essential. These therapies are indicated specifically in patients with moderate to advanced fibrosis (F2–F3), a population notoriously difficult to accurately identify with ultrasound-based elastography or serum biomarkers alone. Radiologists are therefore playing an increasingly central role in determining treatment eligibility through MRE.

Beyond therapy selection, MRE is increasingly applied to longitudinal monitoring—tracking fibrosis regression or progression under treatment—an application poised to grow rapidly as new MASH drugs reach the clinic. Other established indications include staging in chronic viral hepatitis, risk stratification in cirrhosis, and evaluation of patients with portal hypertension.

Importantly, MRE can be seamlessly integrated into a standard abdominal MRI exam, requiring minimal additional scan time. This efficiency means that MRE can be incorporated broadly into protocols, even in the absence of a strong pretest suspicion, ensuring that radiologists are well positioned to identify at-risk patients earlier and more accurately than ever before.

DIAGNOSTIC **Performance**

Since 2006, there have been dozens of published studies assessing the diagnostic performance of MRE in detecting and staging hepatic fibrosis, using biopsy as the reference standard. An MRE-based measurement of hepatic stiffness that is in the normal range (< 2.5 kPa) has a very high negative predictive value for ruling out hepatic fibrosis of any stage. Excellent diagnostic performance for staging hepatic fibrosis has been reported in multiple studies.

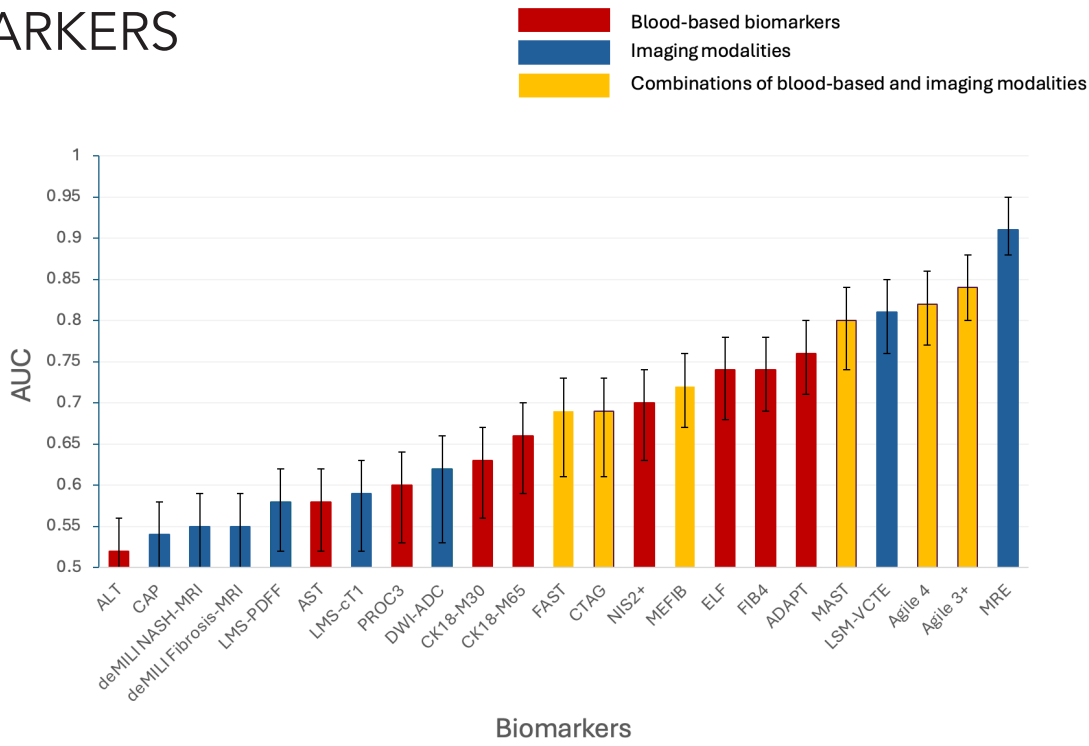
For instance, a recent meta-analysis concluded that the sensitivity, specificity, and AUROC of MRE for diagnosing advanced hepatic fibrosis and cirrhosis (≥F3) from less-advanced disease are 0.92, 0.96, and 0.98, respectively[7]. These metrics are probably at the limit of what is realistic to achieve, given the known limitations of using biopsy as a "gold standard." Another pooled meta-analysis of 12 published studies[8] encompassing 697 patients found that the sensitivity, specificity, and AUROC diagnostic performance for diagnosing stage F3 fibrosis and higher are 0.85, 0.85, and 0.93 respectively.

Meta-Analysis:
MRE for Distinguishing Advanced from Mild Fibrosis

Sensitivity | Specificity | AUROC

Performance compared to
OTHER BIOMARKERS

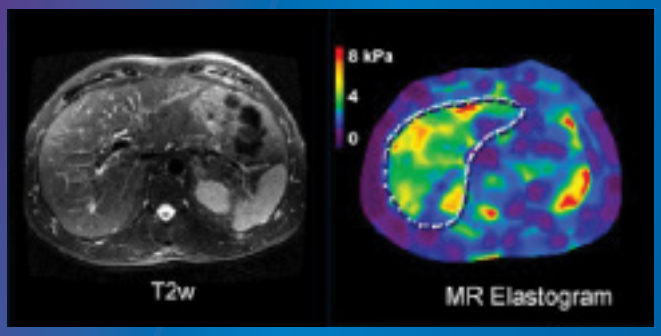
In the seminal LITMUS study[8], MRE was the highest performing biomarker for both Advanced Fibrosis (shown right) and cirrhosis. This is critical for ruling-in patients for novel therapeutics in the vulnerable F2-F3 population.



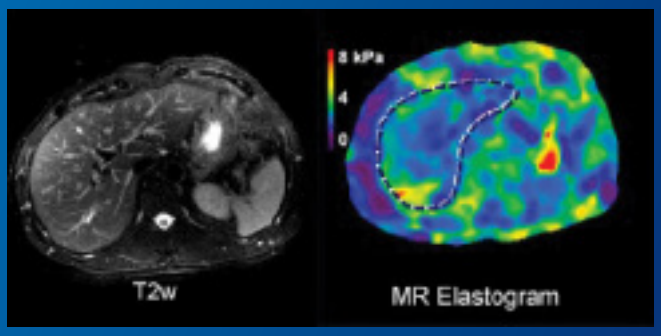
CASE STUDY

MRE provides highly sensitive and comprehensive assessment to treatment response, something previously not possible with traditional MR imaging.

A 57-YEAR-OLD MALE PATIENT WITH CHRONIC HEPATITIS C



Baseline liver stiffness = 4.2 kPa ± 0.88



3-year follow-up liver stiffness = 2.80 kPa ± 0.69

Decreasing liver stiffness indicating response to treatment

PRECISION and Accuracy

The FDA-cleared MRE products from Canon, GE, Siemens, Philips, and United Imaging all use the same hardware, the same default shear wave frequency of 60 Hz, comparable pulse sequences, and the same data processing algorithm to compute tissue stiffness. They all report the magnitude of the complex shear modulus (i.e., tissue stiffness), use the same color scale in the images, and a default 0-8 kPa display. Testing in phantoms and human volunteers has provided confirmation that liver stiffness data obtained on systems from these three vendors can be compared on a valid basis. MRE-based measurements of phantom stiffness have also been demonstrated to compare favorably with TE-based measurements.[10]

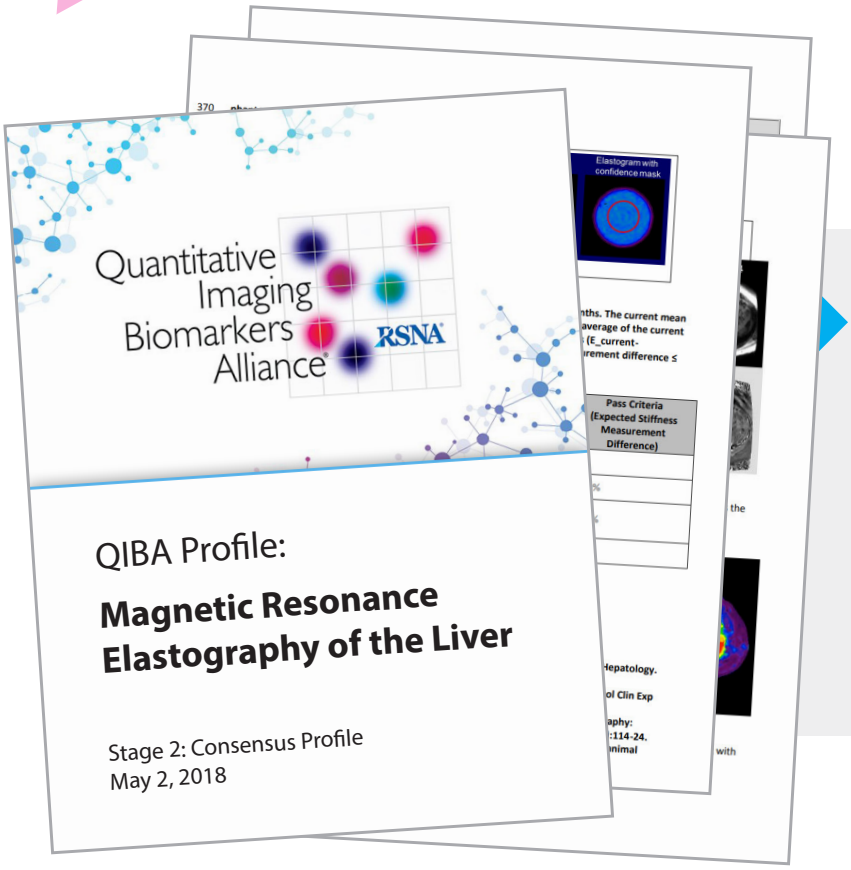
More than 10 published studies have assessed the test-retest repeatability of clinical MRE for liver fibrosis assessment. Stress-testing the most extreme clinical variability (differernt scanners, fasting status, field strength, etc), they have shown that differences in MRE-derived liver stiffness of greater than 19% represent meaningful longitudinal changes[11-13]. This is a useful level of repeatability because the difference in mean stiffness between normal liver and significant fibrosis is approximately 100% and for advanced fibrosis it is approximately 200%. For clinical trial use, MRE's Coefficient of Variability has been shown to be around 11% for determine the efficacy of therapeutic candidates.

Confounding FACTORS

MRE has the same potential confounding factors as quantitative ultrasound-based elastography. Liver stiffness is affected by chronic and acute inflammation in very early stages of fibrogenesis (F0-F1), which can cause overlap in stiffness values between patients with stage F0 and stage F1 fibrosis. Acute hepatitis can be associated with very high liver stiffness values without any degree of fibrosis. Portal hypertension, hepatic venous congestion, and malignant cellular infiltrates can elevate liver stiffness independent of the presence of fibrosis.

The most common reason for technical failure of MRE has been hepatic iron overload, which is not uncommon in patients with liver disease. With conventional gradient echo MRE sequences, very high liver iron content may cause the signal intensity of the liver to be too low to visualize the mechanical waves, resulting in a failure rate of ~4% in clinical populations. The newly-introduced SE-EPI MRE sequences are much less sensitive to iron overload, making these technical failures much less common.

Clinical experience has shown that the technical success of MRE is not affected by obesity[14], unless the patient cannot fit in the scanner. The presence of ascites, common in patients with liver disease, does not affect the technical success rate of MRE.



For clinical use or clinical trial design, a comprehensive image acquisition and analysis profile can be found on the RSNA QIBA website.

https://qibawiki.rsna.org/images/a/a5/MRE-QIBAProfile-2018-05-02-CONSENSUS.pdf

Recommended in
CLINICAL GUIDELINES

Resmetirom can be considered for treatment of adults with MASH [using] noninvasive liver disease assessment—preferably VCTE or MRE—consistent with MASH with F2-F3. In persons whose treatment candidacy was determined by liver stiffness measurements (VCTE or MRE), a repeat measurement at 12 months of therapy is recommended.

Resmetirom therapy for metabolic dysfunction-associated steatotic liver disease: October 2024 updates to AASLD Practice Guidance [15]

aga

"We further recommend referring these high-risk patients (>12.0 kPa) to a hepatologist, if not already in hepatology care, for consideration of liver biopsy or MRE"

AGA Clinical Care Pathway for the Risk Stratification and Management of Patients With Nonalcoholic Fatty Liver Disease (2021)[16]

AASLD
AMERICAN ASSOCIATION FOR THE STUDY OF LIVER DISEASES

"MRE is more sensitive than VCTE in the detection of fibrosis stage ≥2 and is considered to be the most accurate noninvasive, imaging-based biomarker of fibrosis in NAFLD."

AASLD Practice Guidance on the Clinical Assessment and Management of Nonalcoholic Fatty Liver Disease (2023)[17]

ACR®
AMERICAN COLLEGE OF RADIOLOGY

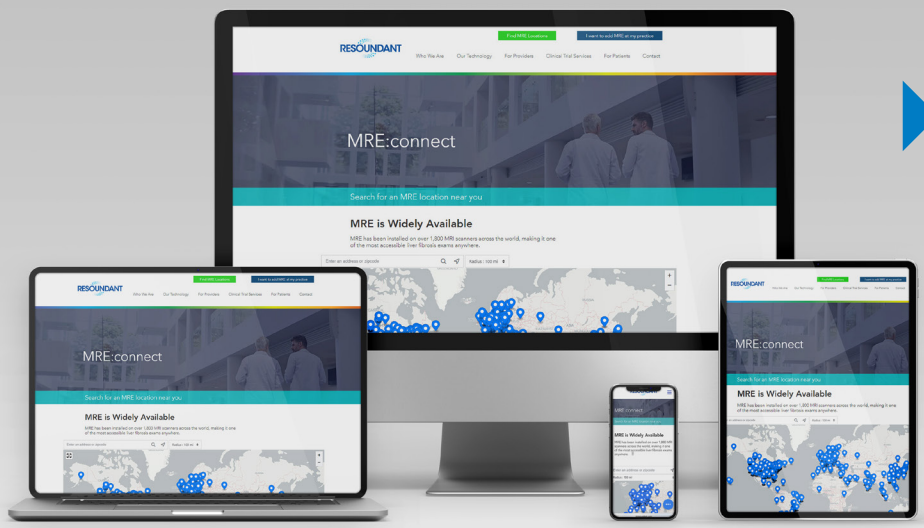
"MR elastography is the most accurate method for diagnosing liver fibrosis non-invasively because it assesses the whole liver and can stage liver fibrosis."

American College of Radiology Appropriateness Criteria®: Chronic Liver Disease (2017)[18]

AVAILABILITY

Figures listed are estimates for illustrative purposes only.
Please refer to **resoundant.com/mre-connect** for up to date listings.

resoundant.com/mre-connect



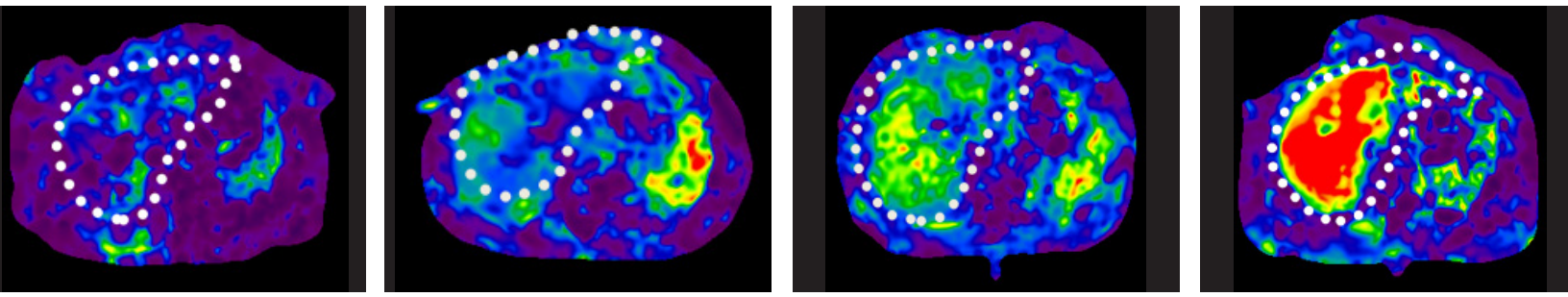
MR Elastography is widely available. To find a location near you, go to: **resoundant.com/mre-connect.**

If you don't yet have a local imaging center equipped with MRE, you can go to **resoundant.com/mrenearme** to help us bring MRE to your area.

CONCLUSION

The well-documented value of MR elastography as an alternative to liver biopsy in diagnosing hepatic fibrosis has prompted the transition of MR elastography from the laboratory to a widely-available clinical diagnostic tool. Further technical developments, especially advances in pulse sequences and processing algorithms for 3D MRE are opening up new applications, such as pancreatic, lung, and kidney disease.

The application that is most likely to become the next well-documented indication for MRE is preoperative assessment of meningiomas and skull base tumors.[19-20] MRE provides a range of novel quantitative imaging biomarkers that will merit exploration for many years to come.



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About Resoundant, Inc.

Resoundant, Inc. was founded by Mayo Clinic and is the developer and manufacturer of Magnetic Resonance Elastography (MRE), a revolutionary imaging technology that quantitatively maps the mechanical properties of tissue almost anywhere in the body. With MRE, physicians can assess changes in these novel biomarkers that occur in conditions like fibrosis, inflammation, and cancer, obtaining information painlessly and noninvasively that previously may have required a biopsy.

The software and hardware needed for MRE is available as an upgrade for many 1.5T or 3T MRI systems from Canon, GE Healthcare, Philips Healthcare, Siemens Healthineers, or United Imaging. MRE was invented by Mayo Clinic physicians and researchers in a program continuously funded by the National Institutes of Health since 1995. MRE has been commercially-available as an FDA-cleared diagnostic technology since 2009 and is used in clinical practice on over 2,800 MRI systems around the world. MRE has been recognized as a standard of clinical care for liver fibrosis staging by a number of professional medical societies and serves as a key biomarker for liver fibrosis for numerous MASLD/MASH clinical trials. In the United States, a new Current Procedural Terminology (CPT) code (76391) was approved in 2019, advancing its role as a standalone, rapid and cost-effective diagnostic test of liver health.

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