Orthopedic Biomechanics Laboratory Room Gu 1-28

Dr Ehman

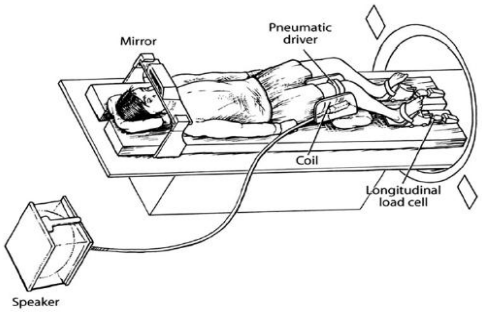
Dr An

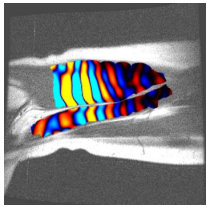
Dr Amadio

Dr Spelsberg (retired)

Dr Hawse

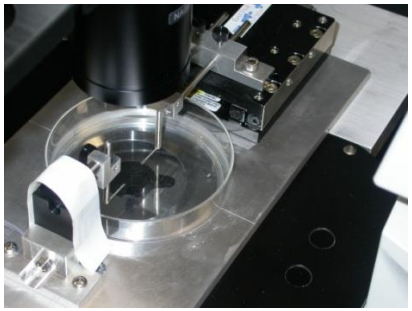
Elastography development for muscle → thigh

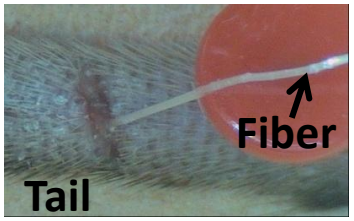




Role of TIEG1 in tendon

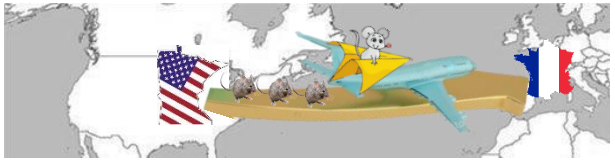
Development mechanical test





Set up of elastography plateform Muscle and liver applications

New role of TIEG1 in muscle



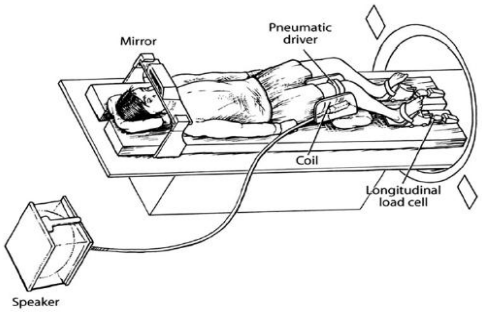
Orthopedic Biomechanics Laboratory
Room Gu 1-28

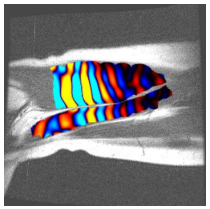
Dr Ehman

Dr An

Dr Amadio

Elastography development for muscle → thigh

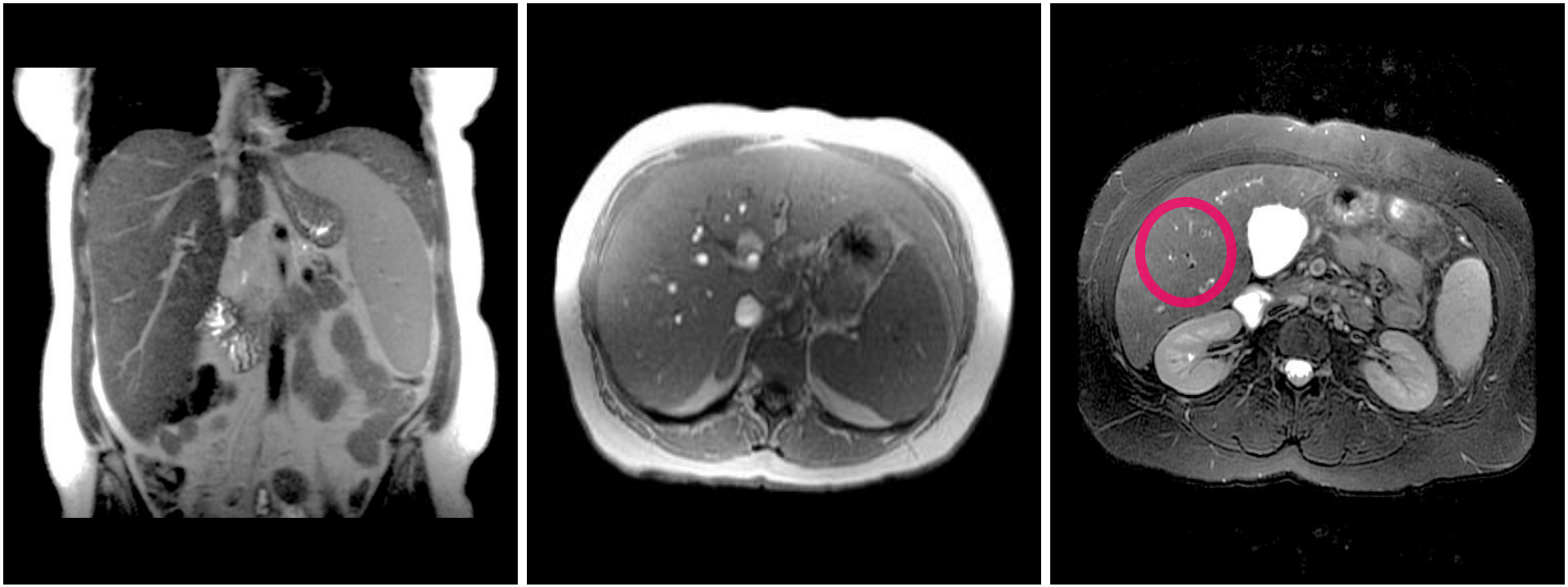




Set up of elastography plateform Muscle and liver applications

Richard L. Ehman, MD
Mayo Clinic Center for Advanced Imaging Research
ehman.richard@mayo.edu

Magnetic Resonance Imaging (MRI)

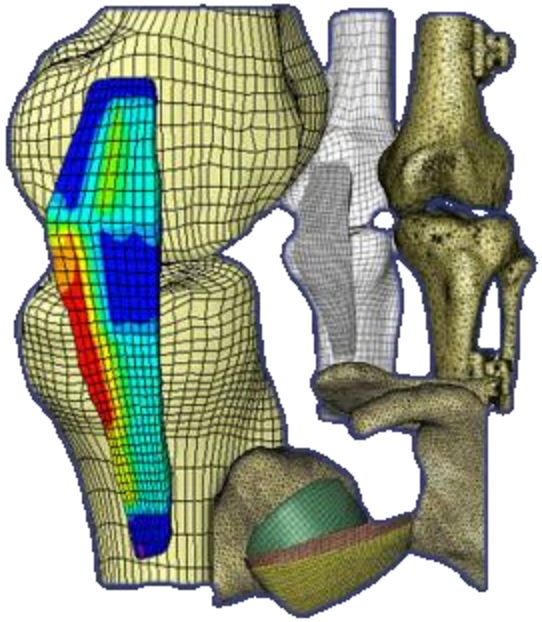


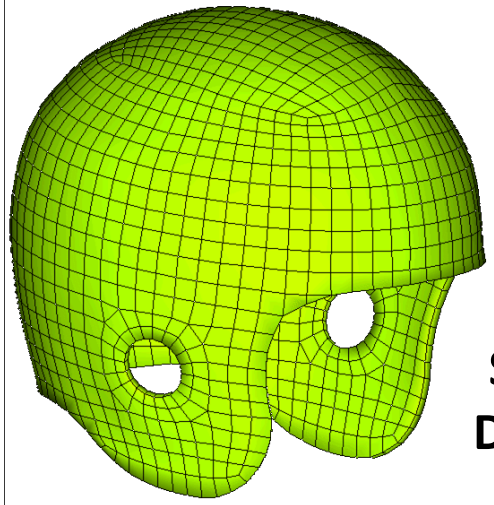
Liver Stiffness:
6.5 kPa
(~3 x normal)

Relevance of Tissue Mechanical Properties

Musculoskeletal Physiology

Biomechanics Of Injury

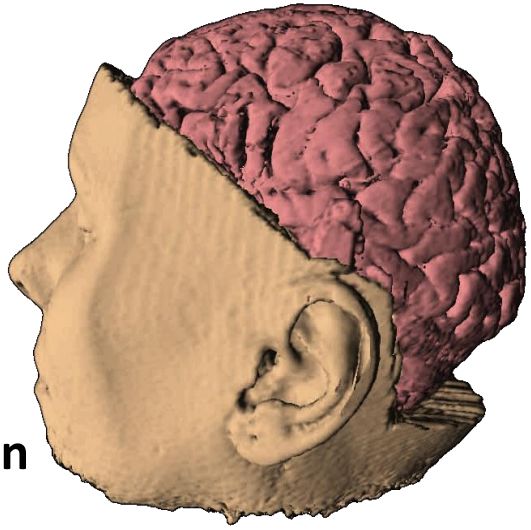




Prosthetics

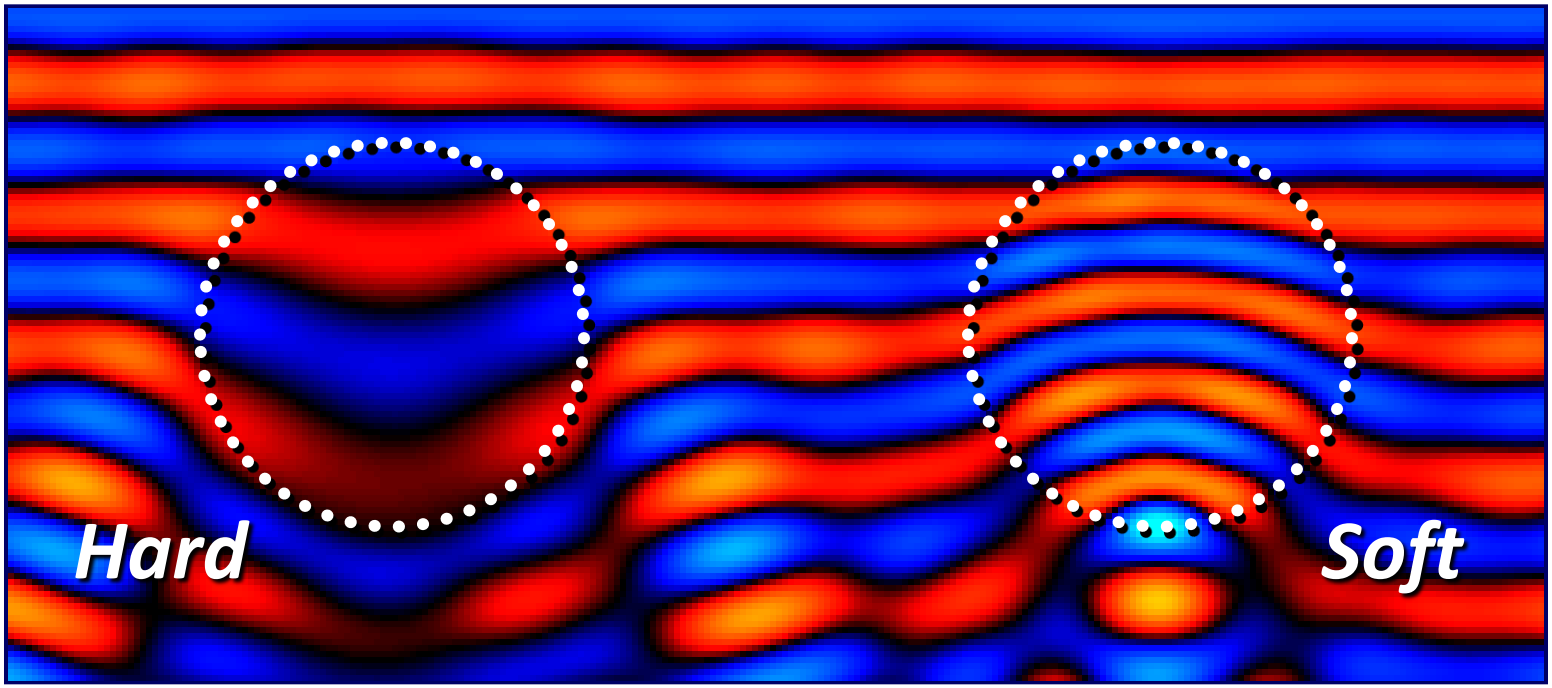
Safety Devices

Surgical Simulation



1993

Using shear waves to assess the stiffness of materials

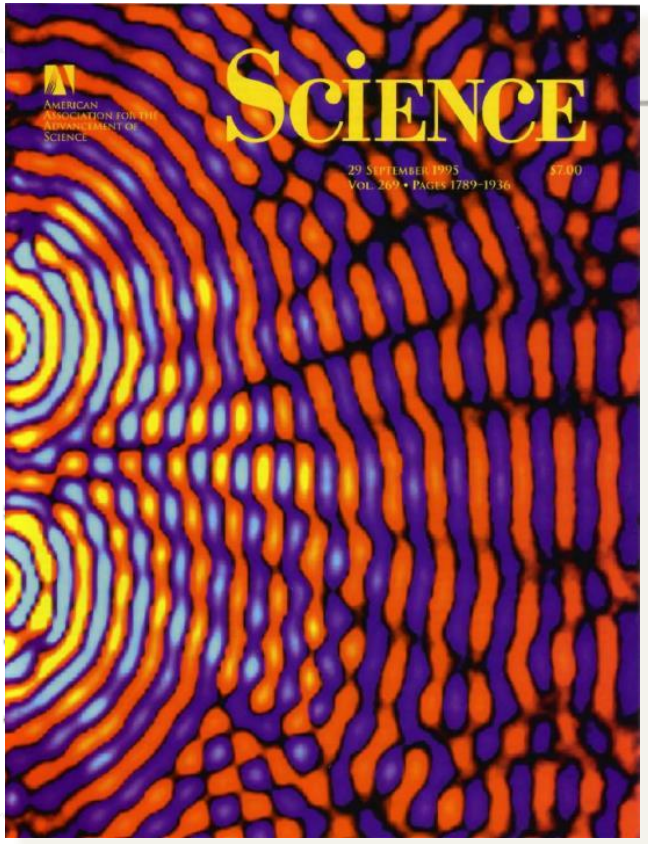


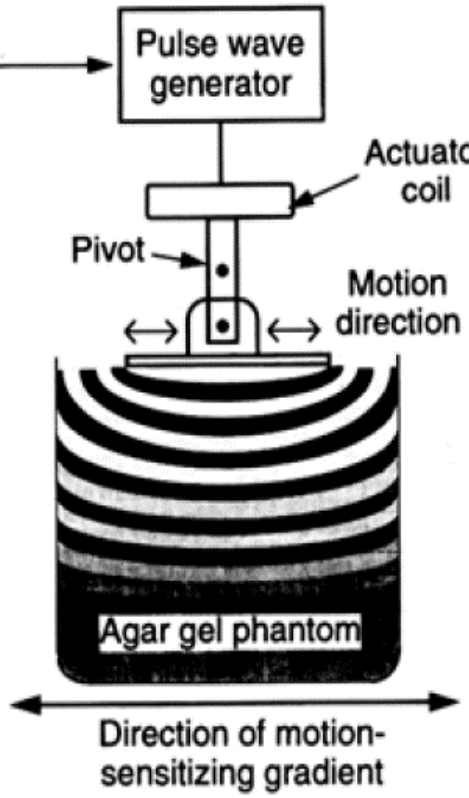
Magnetic Resonance Elastography

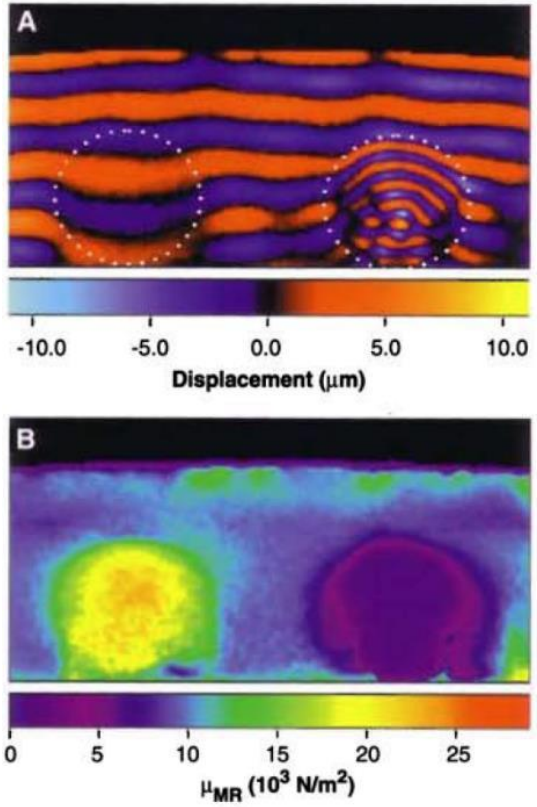
SCIENCE • VOL. 269 • 29 SEPTEMBER 1995

Magnetic Resonance Elastography by Direct Visualization of Propagating Acoustic Strain Waves

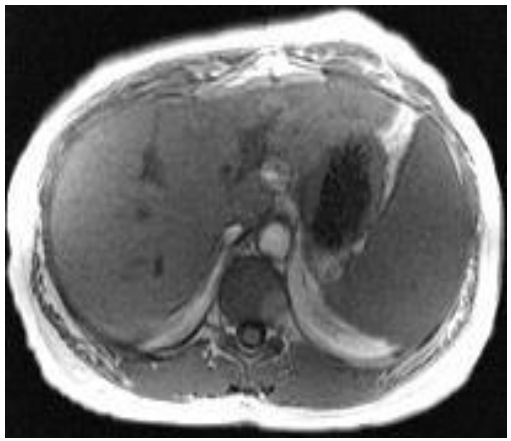
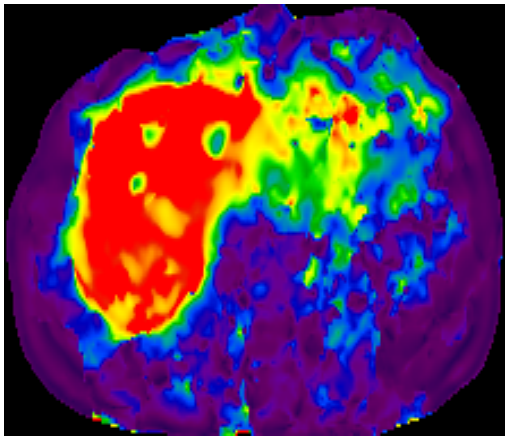
R. Muthupillai, D. J. Lomas, P. J. Rossman, J. F. Greenleaf,
A. Manduca, R. L. Ehman*





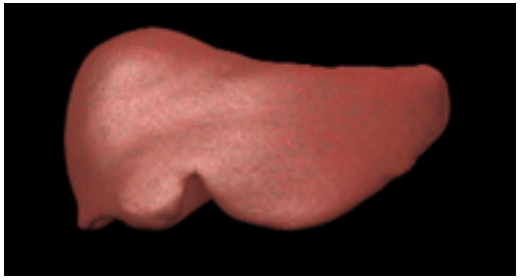


Magnetic Resonance Elastography


- **Main current application: Assessing liver fibrosis**
- **Acquisition time: ~ 1 minute**
- **FDA-cleared since 2009**
- **Installed clinical base ~ 1300 clinical systems**

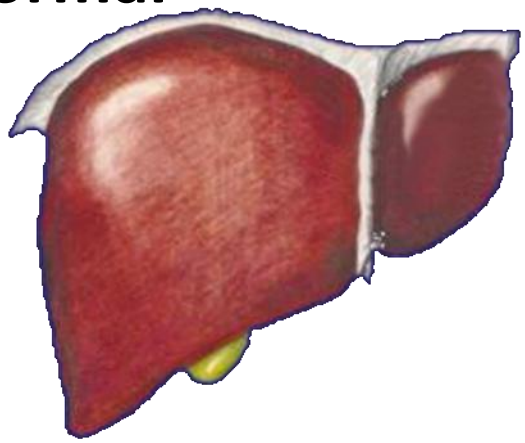
Importance of Chronic Liver Disease, Fibrosis, Cirrhosis



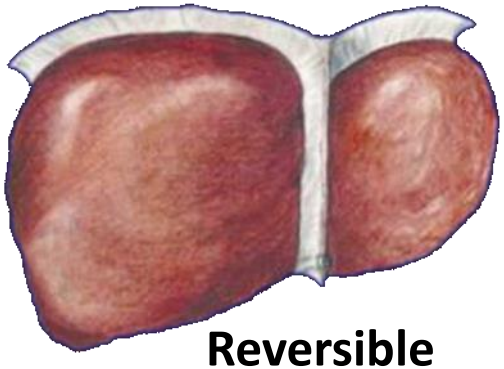
- A leading cause of death world-wide
- Increasing prevalence of conditions that cause hepatic fibrosis
  - Hepatitis C - 170 M people globally
  - Hepatitis B
  - Obesity / Fatty liver disease
- Fibrosis can be reversed, if diagnosed early and treated

Progression of Liver Disease

Normal

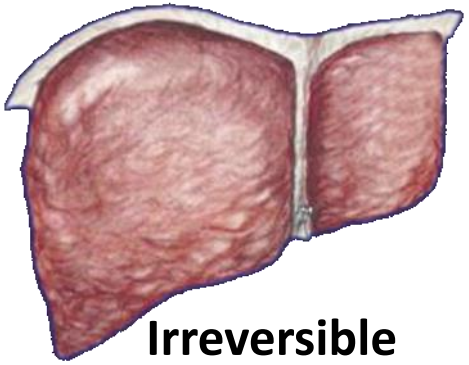


Fibrosis

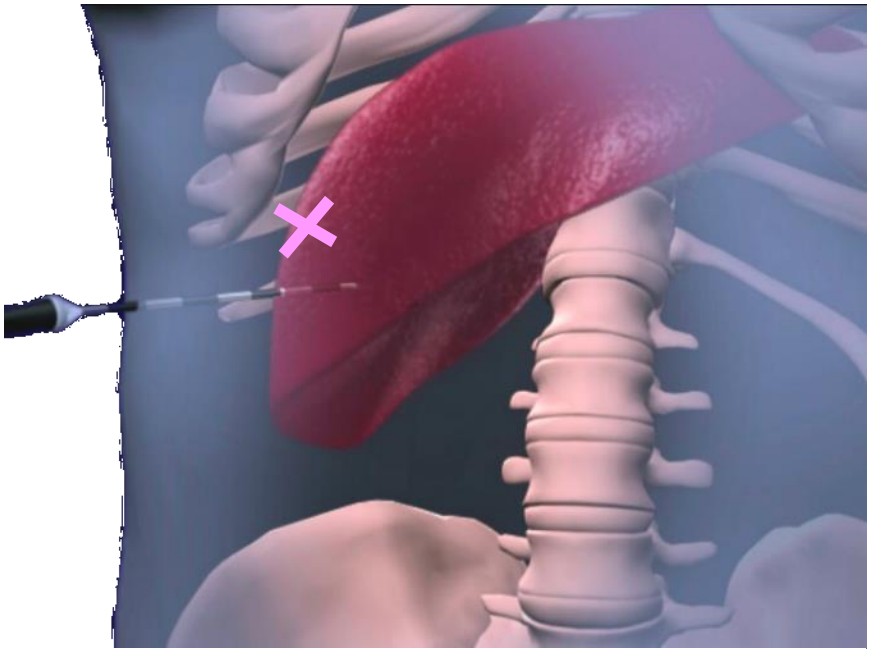


Reversible
Silent

Cirrhosis

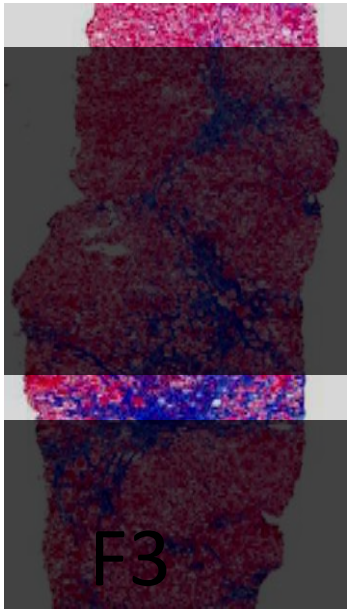


Irreversible
High mortality

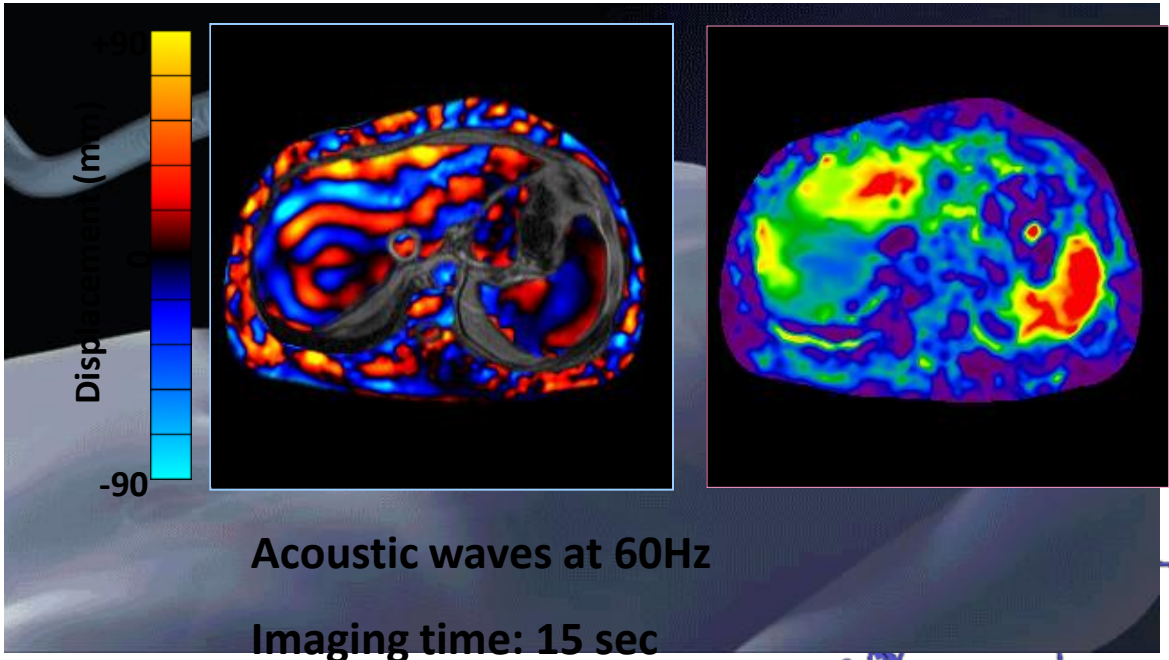


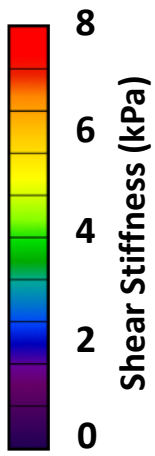
Liver Biopsy

- Invasive
  - Pain
  - Complications
- Expensive
- Poor repeatability
  - Sampling error

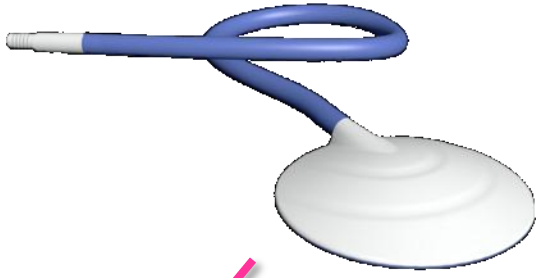


MR Elastography



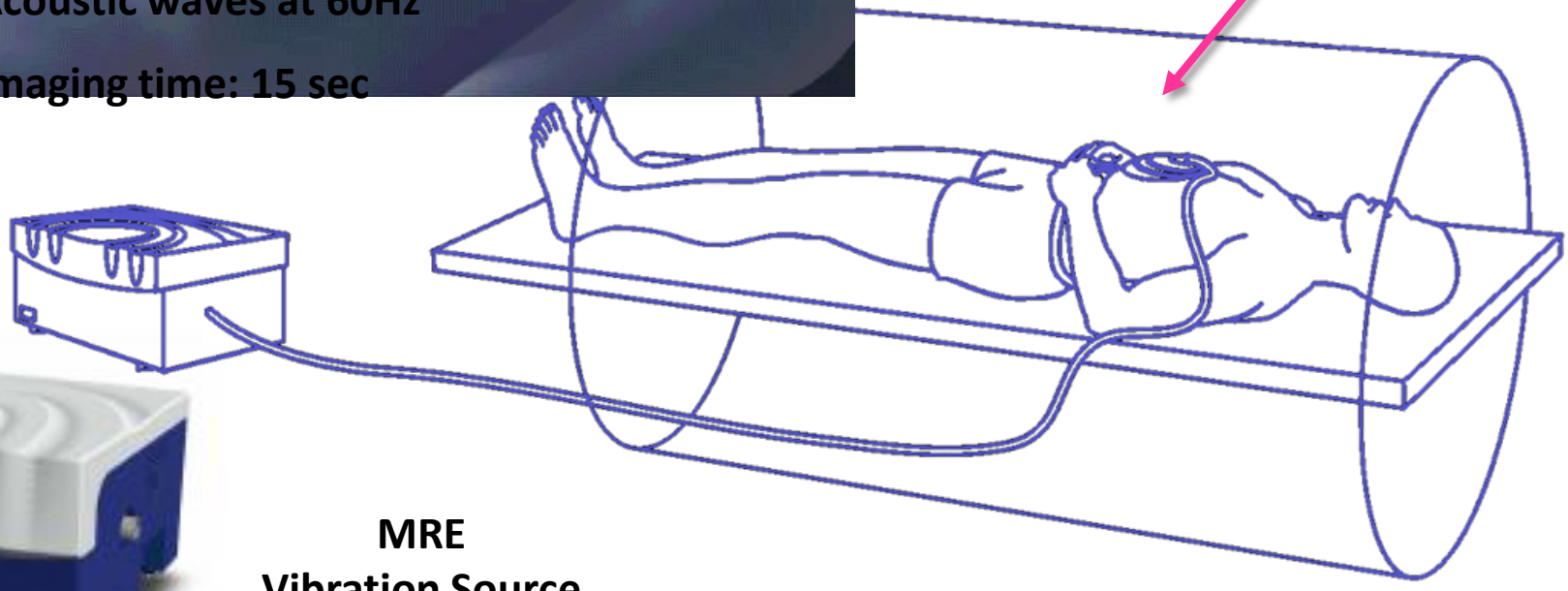


MRE Abdominal Driver



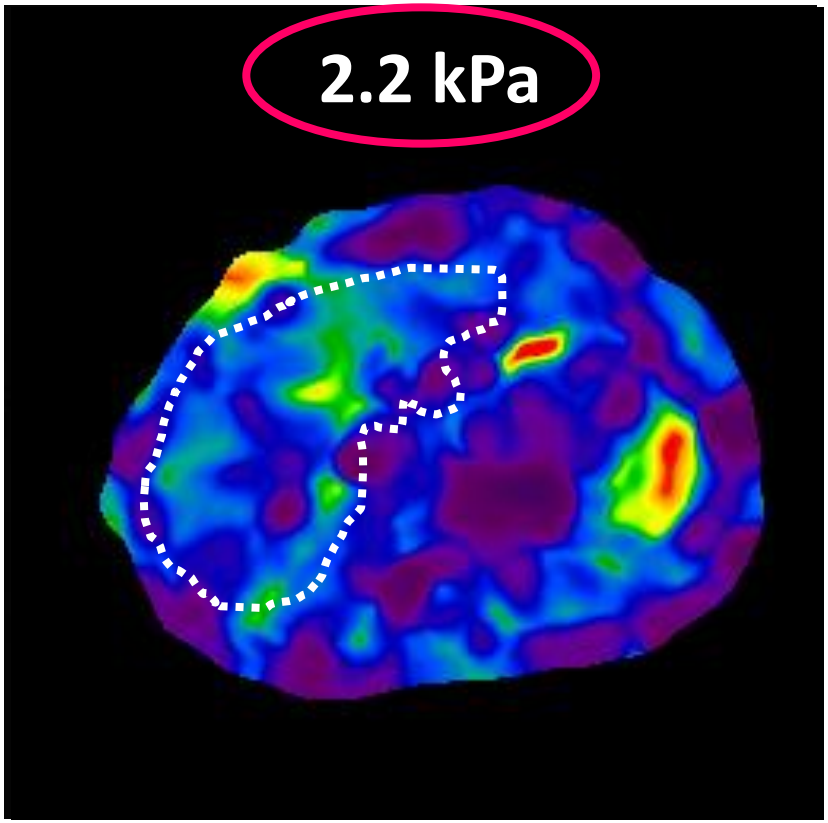
Acoustic waves at 60Hz

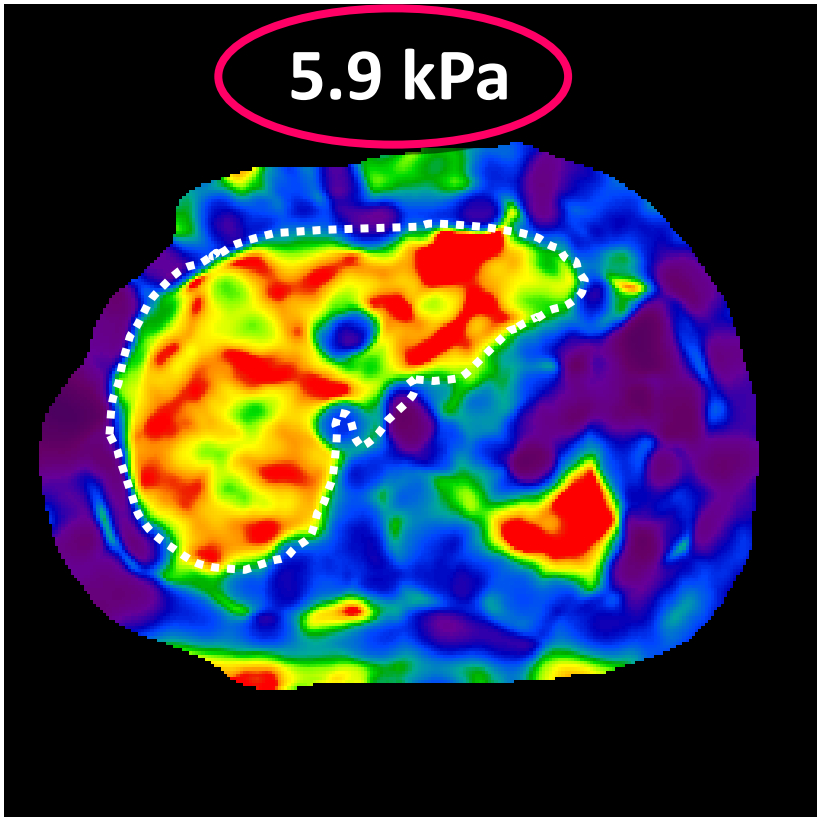
Imaging time: 15 sec



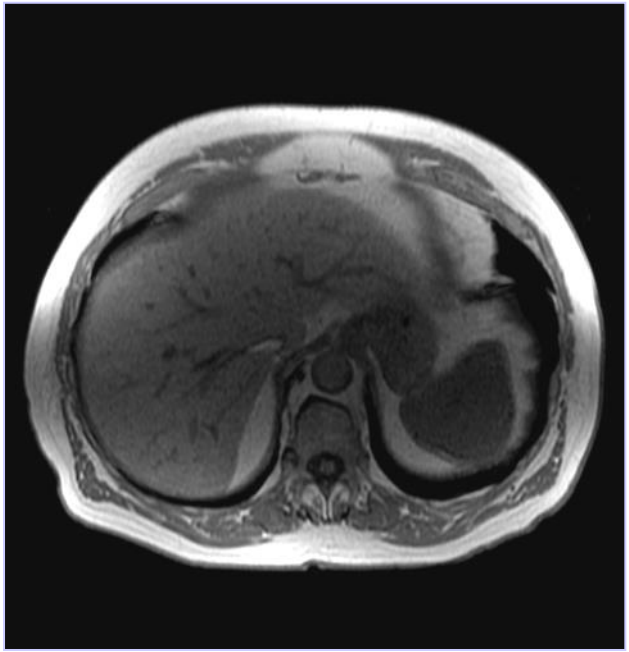
MRE Vibration Source

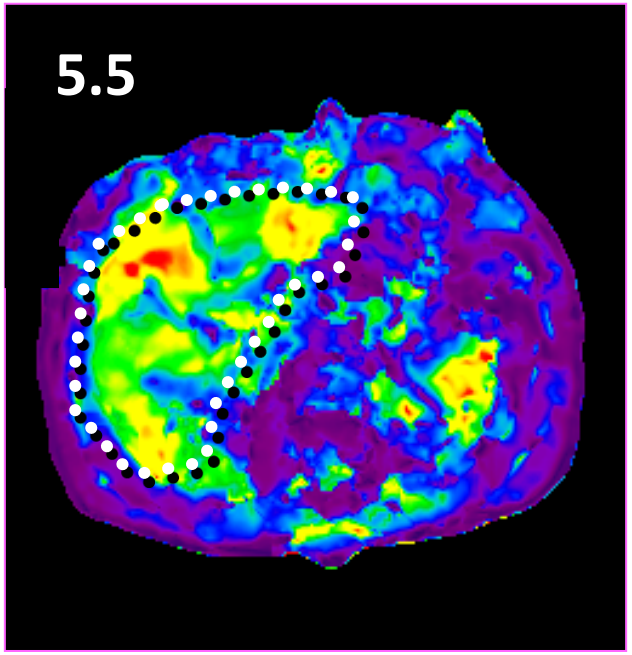
Two Patients with Chronic Liver Disease: Is Hepatic Fibrosis Present?

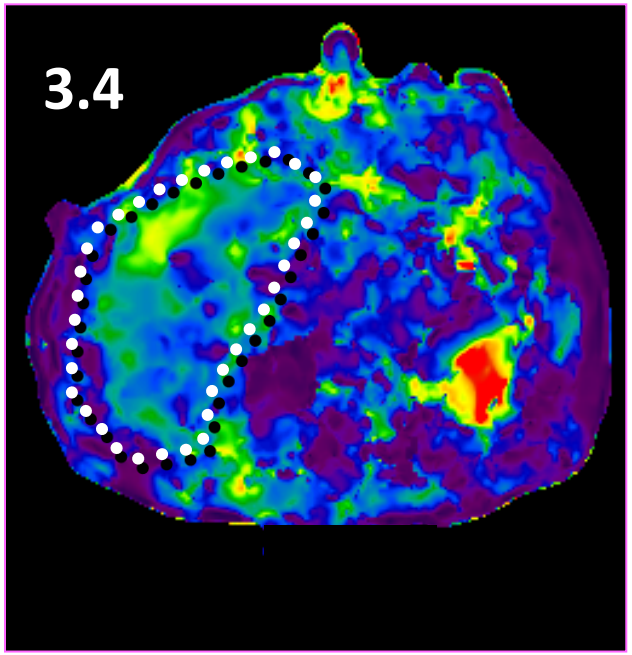


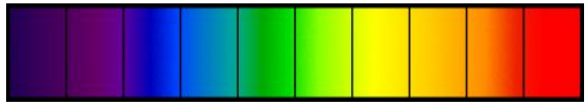


76 yo Patient - Alcohol









Abstinent

9 months later

Liver Magnetic Resonance Elastography (MRE)

ALCOHOLISM CLINICAL & EXPERIMENTAL RESEARCH

Original Article | Full Access

Cutoff Values for Alcoholic Liver Fibrosis Using Magnetic Resonance Elastography Technique

Sabine F. Bensamoun, Gwladys E. Leclerc, Laëtitia Debernard, Xiaobin Cheng, Ludovic Robert, Fabrice Charleux, Colette Rhein, Jean-Paul Latrive

First published: 06 December 2012 | https://doi.org/10.1111/acer.12025 | Cited by: 16

JMRI Journal of Magnetic Resonance Imaging ISMRM ONE

Technical Note | Free Access

Measurement of liver stiffness with two imaging techniques: Magnetic resonance elastography and ultrasound elastometry

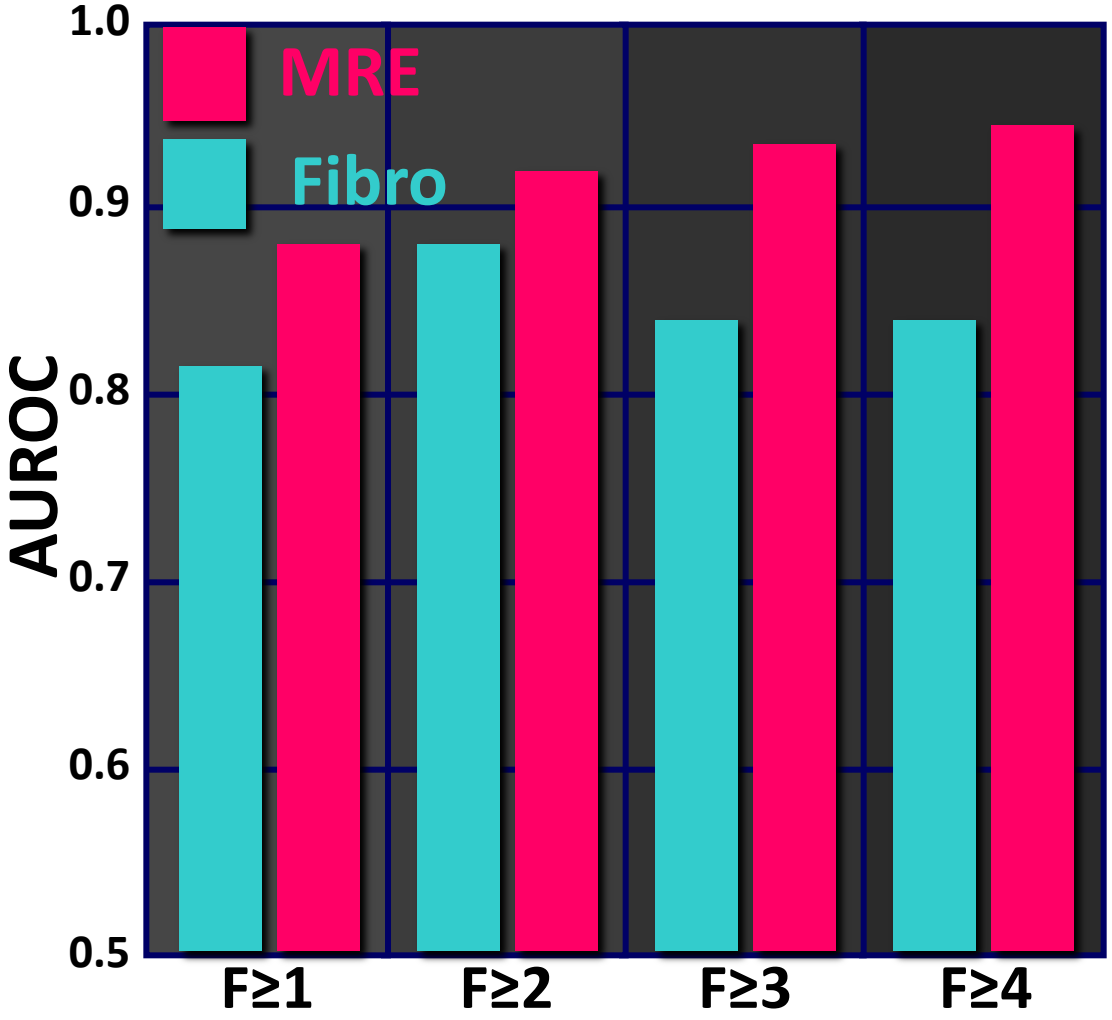
Sabine F. Bensamoun PhD, Lu Wang MS, Ludovic Robert Mr, Fabrice Charleux MD, Jean-Paul Latrive MD, Marie-Christine Ho Ba Tho PhD

First published: 28 October 2008 | https://doi.org/10.1002/jmri.21523 | Cited by: 48

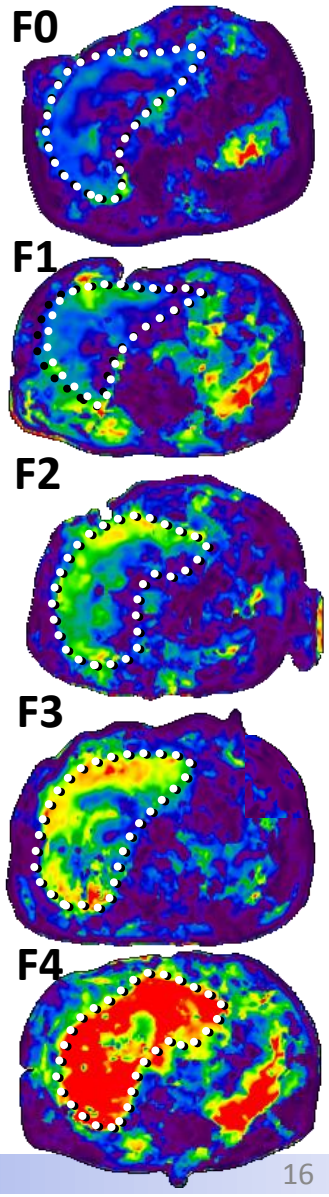
Diagnostic Performance: MRE vs Fibroscan

Fibro

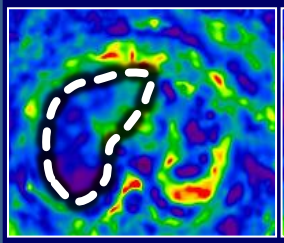
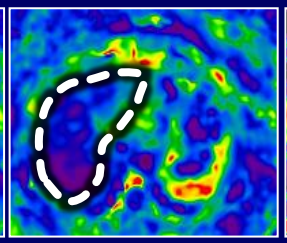
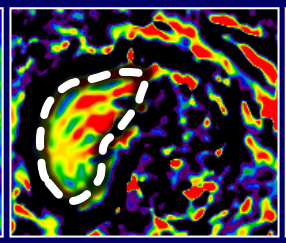
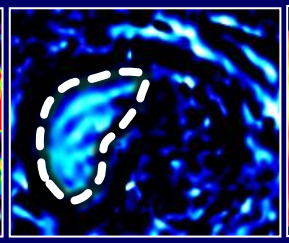
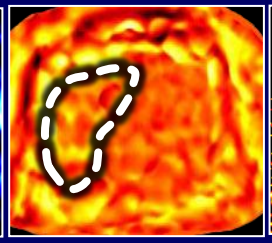
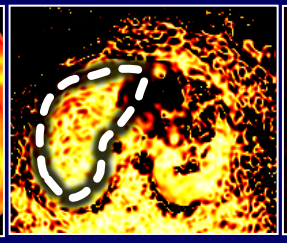
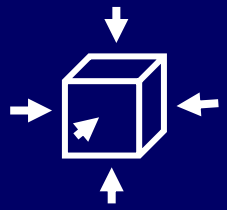
Hsu, Clin Gastro Hepatol. 2018
Pooled Analysis, n=230



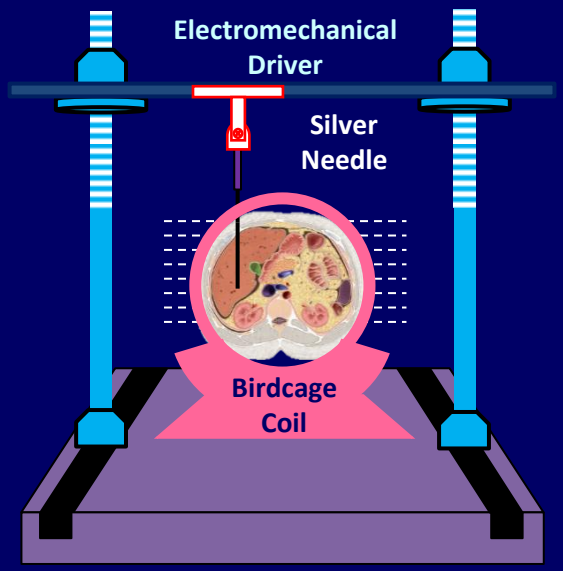
MRE

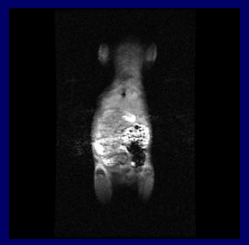


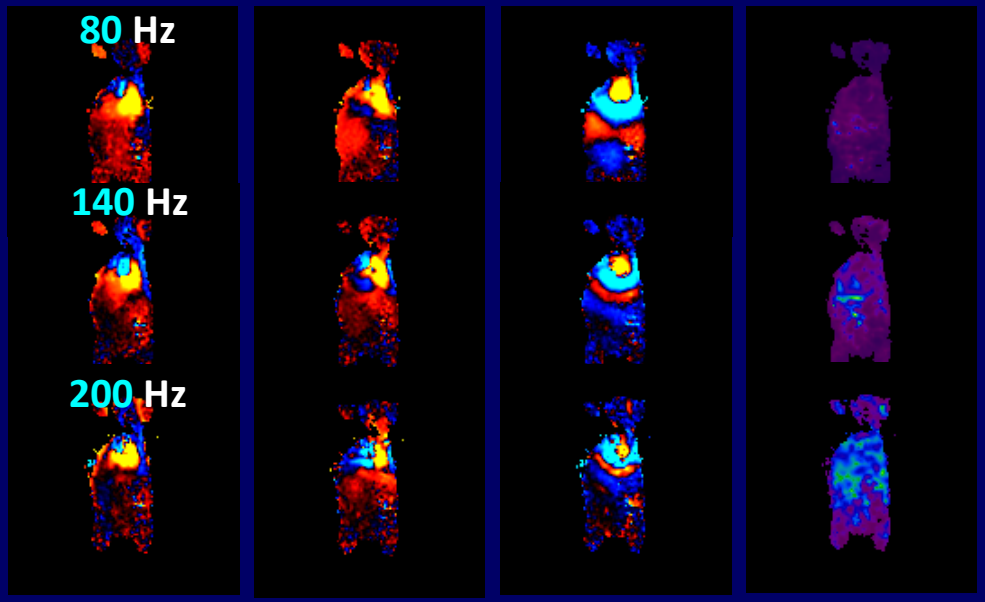
Advanced Multiparametric 3D MRE

$\lvert G^* \rvert$	G'	G''	$\zeta = \frac{G''}{2G'}$	m	ΔV	OSS
						
2.49 kPa	2.31 kPa	0.72 kPa	0.16	22.5 m^{-1}	0.7%	0.02%
"Stiffness"	Storage Modulus	Loss Modulus	Damping Ratio	Attenuation	Volumetric Strain	Shear Strain
						

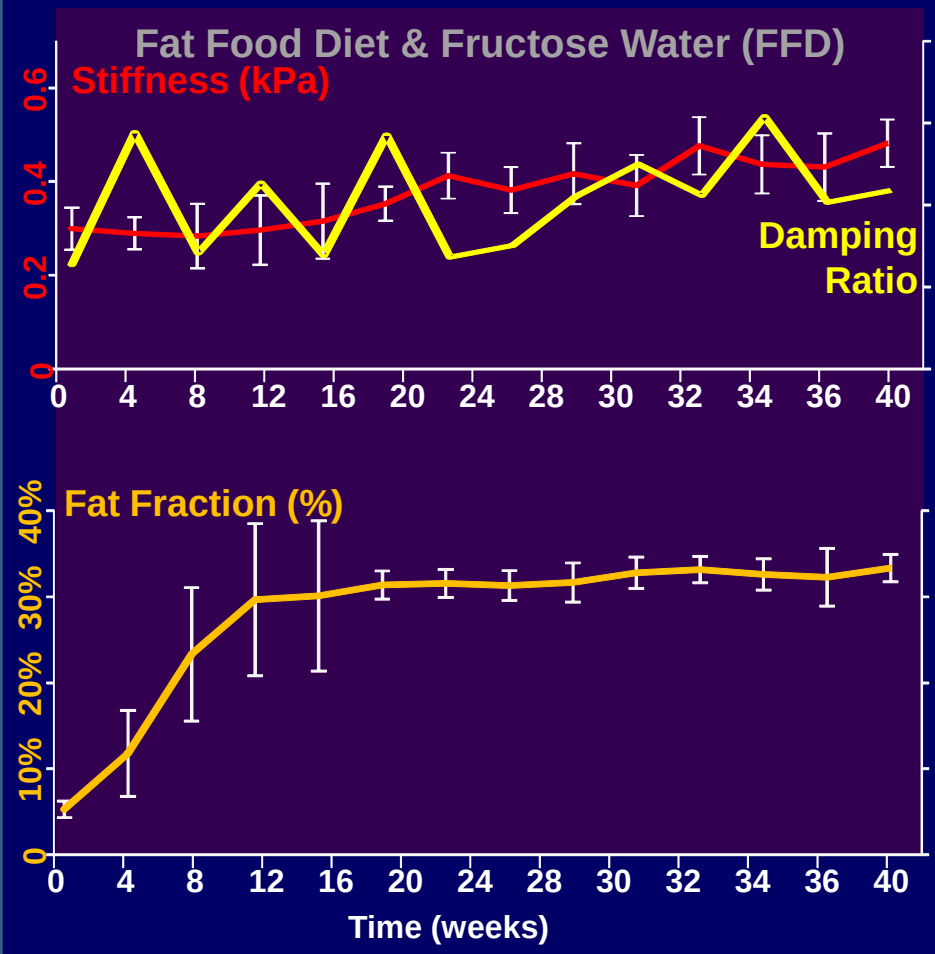
Hepatic MRE in Mouse Models of Fatty Liver Disease

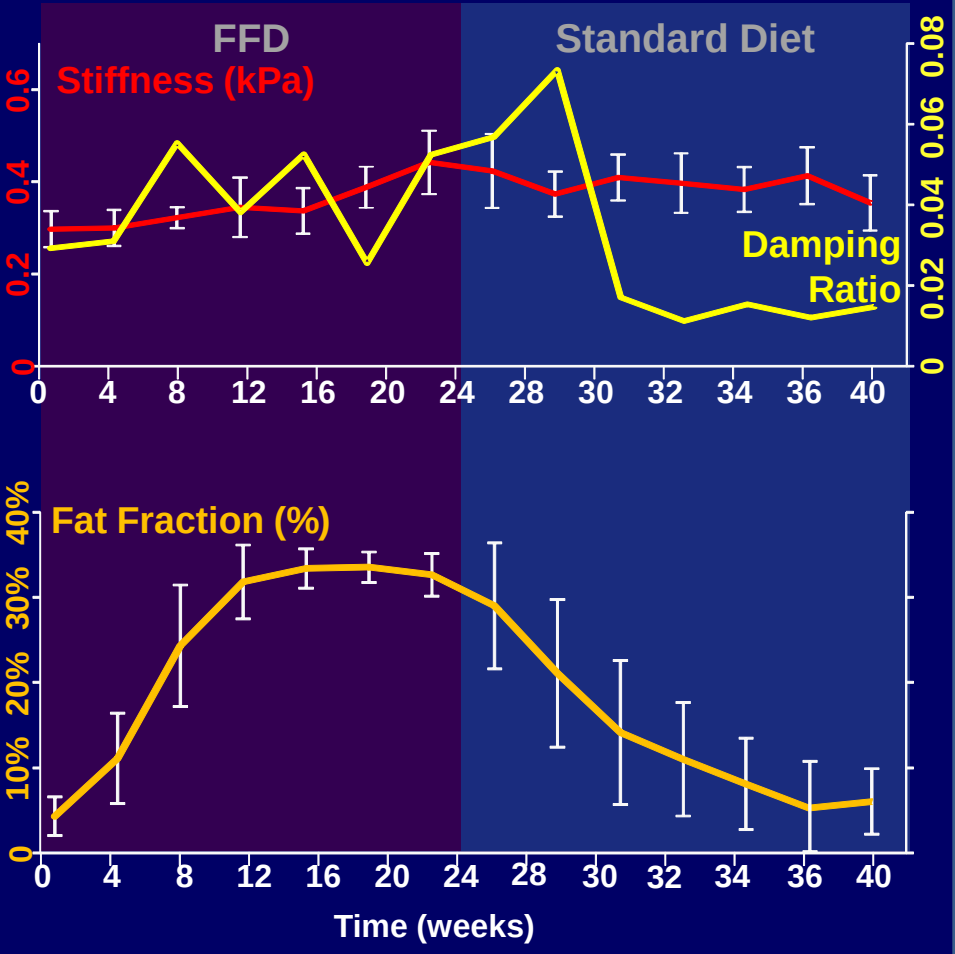




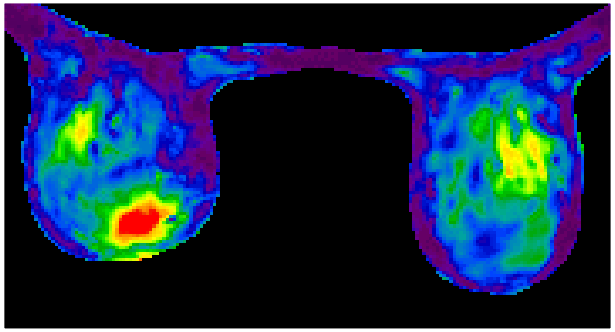


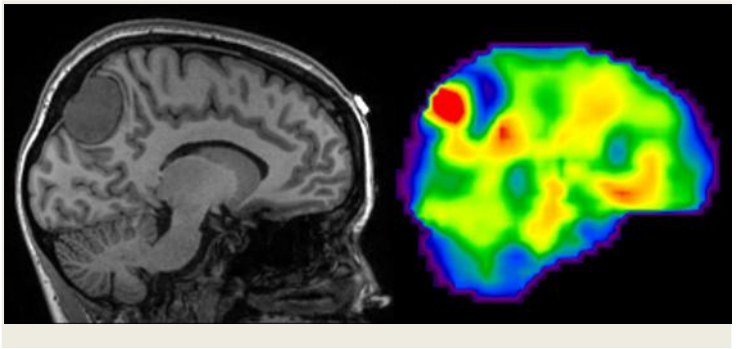
Value of Damping Ratio as Biomarker

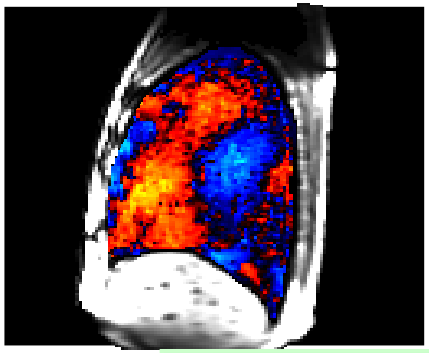


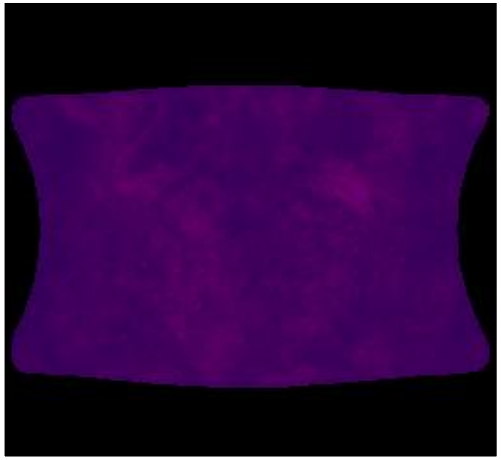


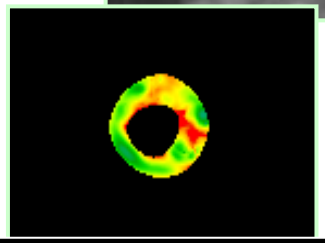
MR Elastography

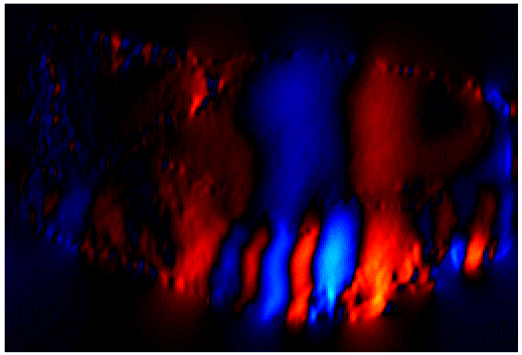


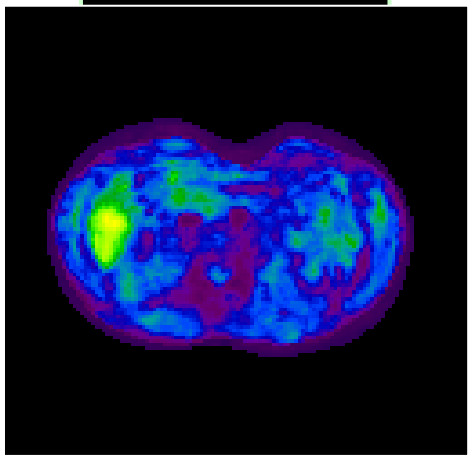




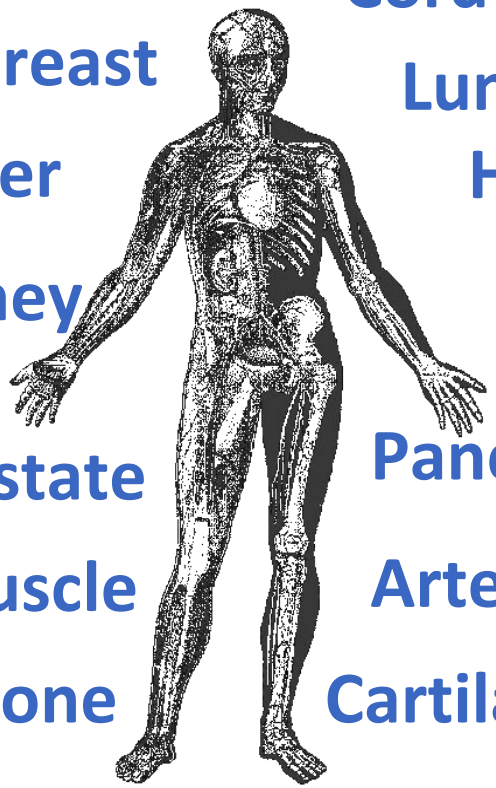




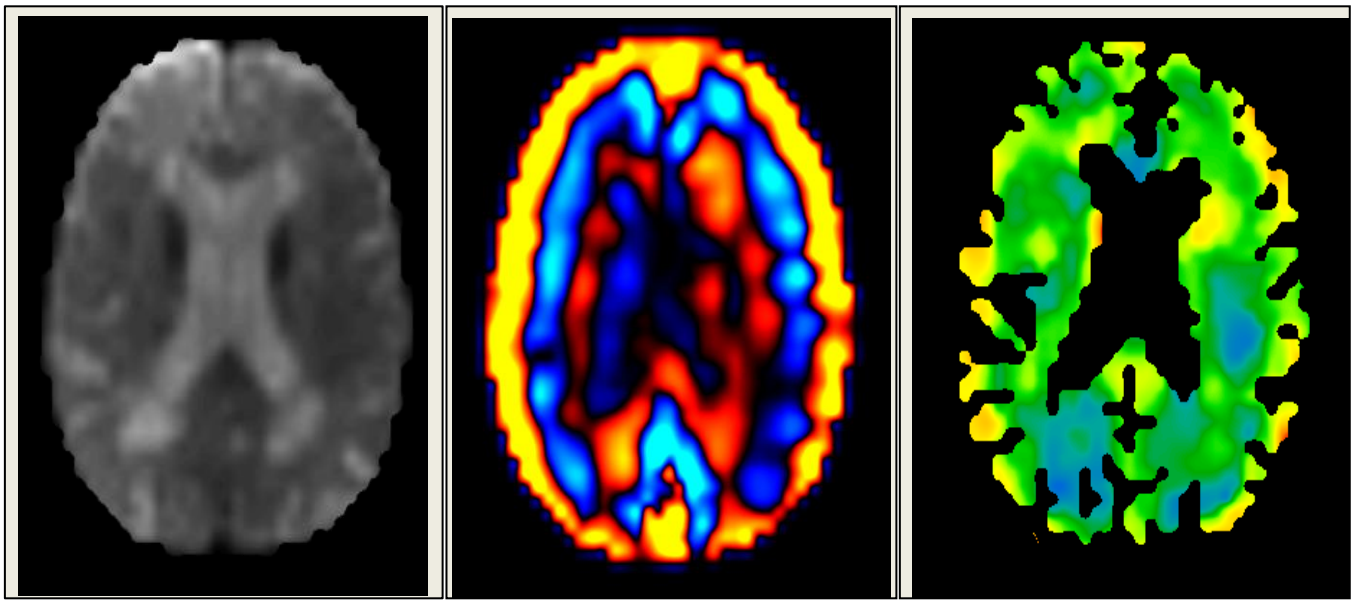




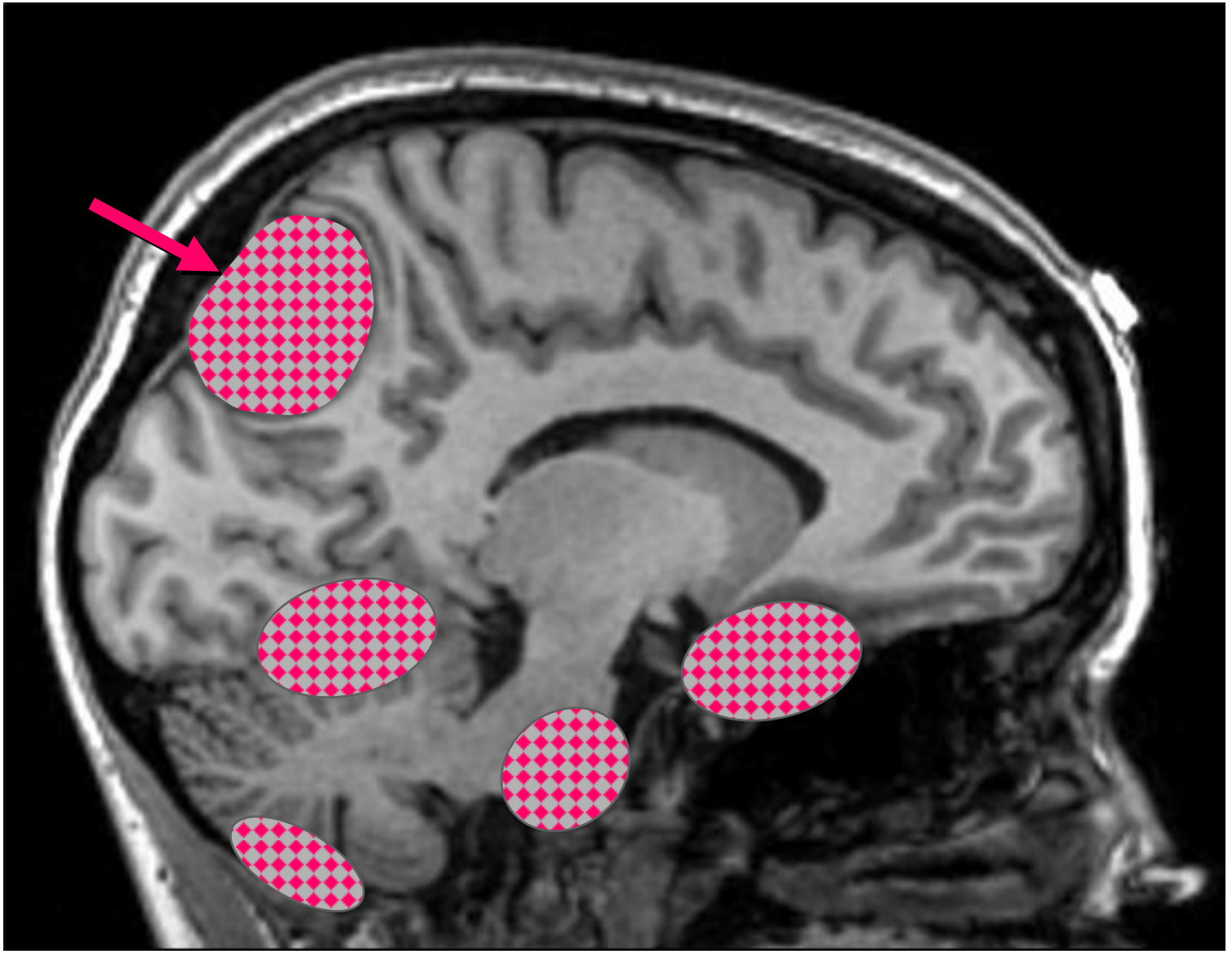
Brain
Cord
Breast
Lung
Liver
Heart
Kidney
Disc
Prostate
Pancreas
Muscle
Artery
Bone
Cartilage

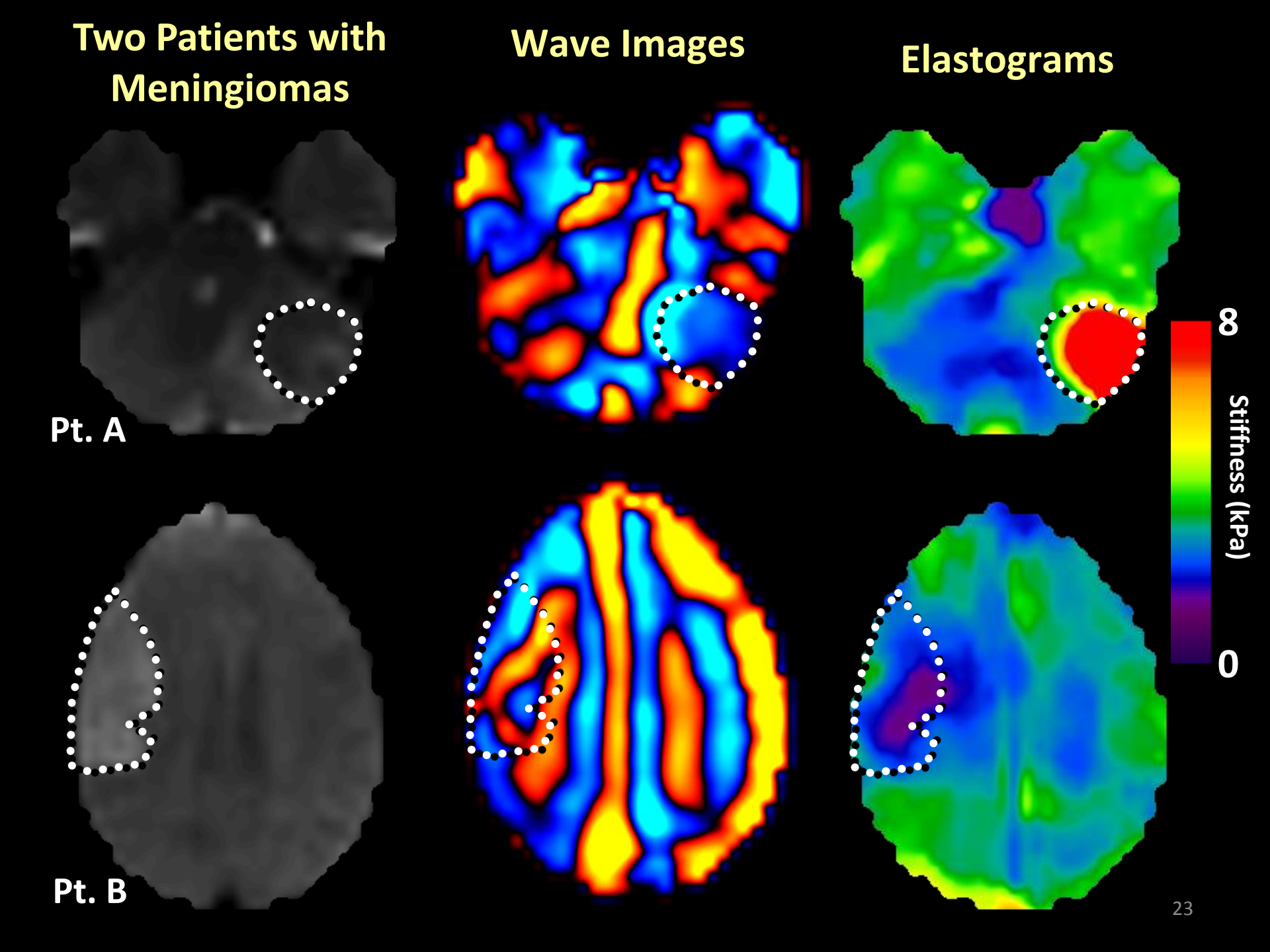


Assessing the Biomechanical Properties of the Brain



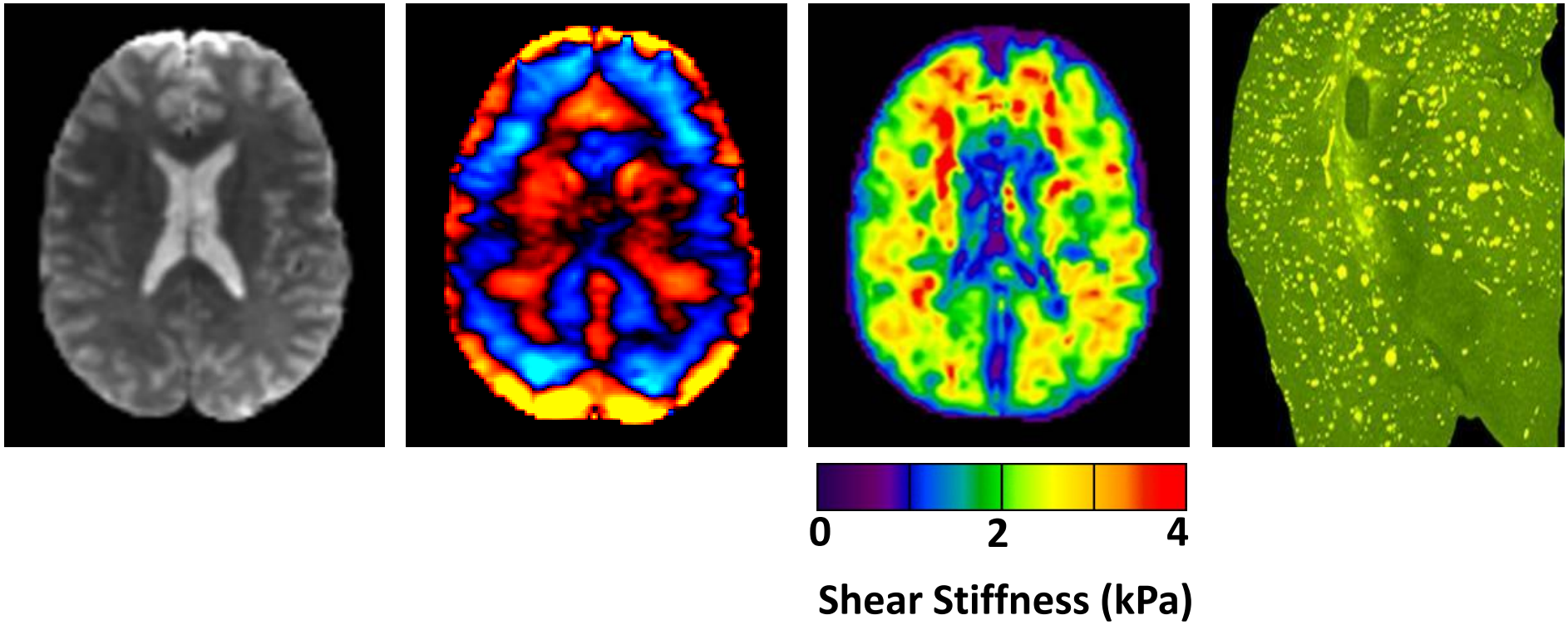
Meningioma




Two Patients with Meningiomas
Wave Images
Elastograms
Pt. A
Pt. B
8
Stiffness (kPa)
0

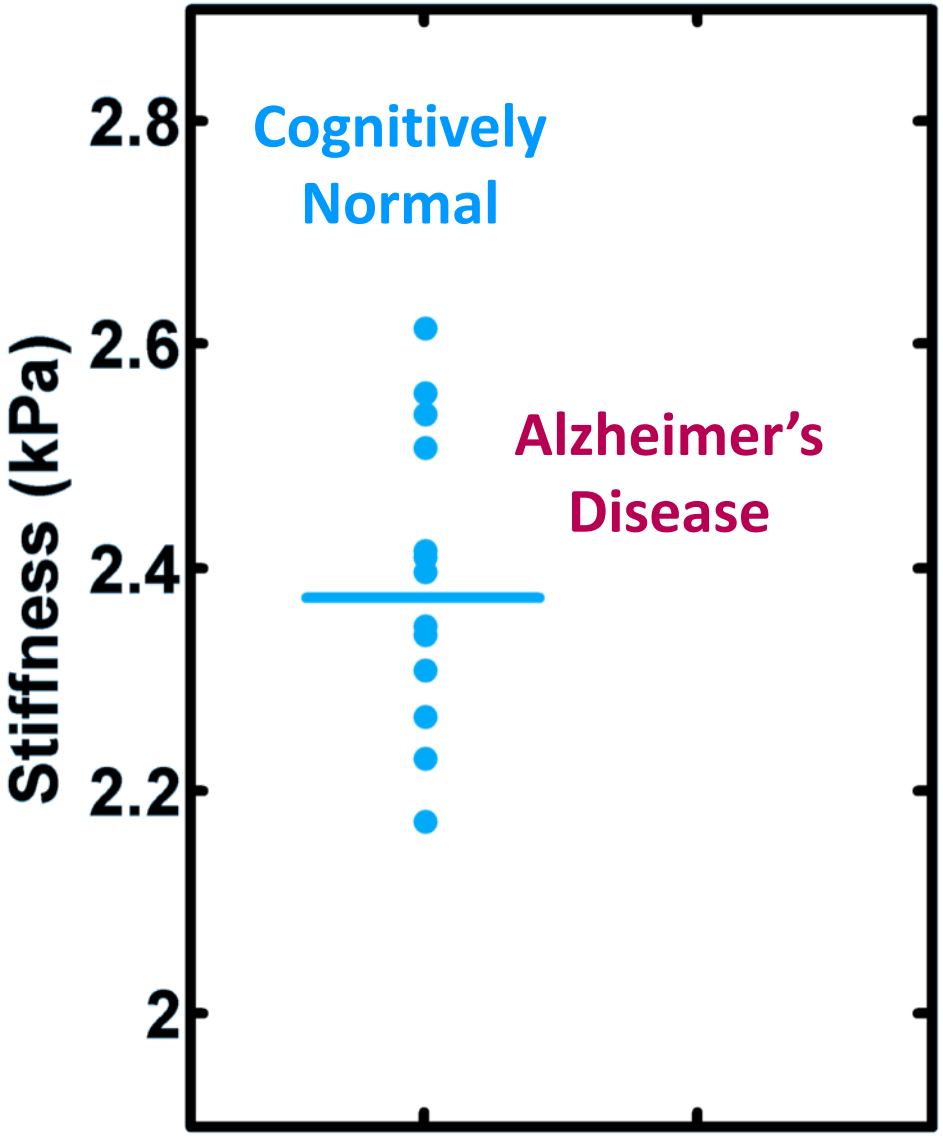
Characterizing Neurodegenerative Disease?

Elastogram



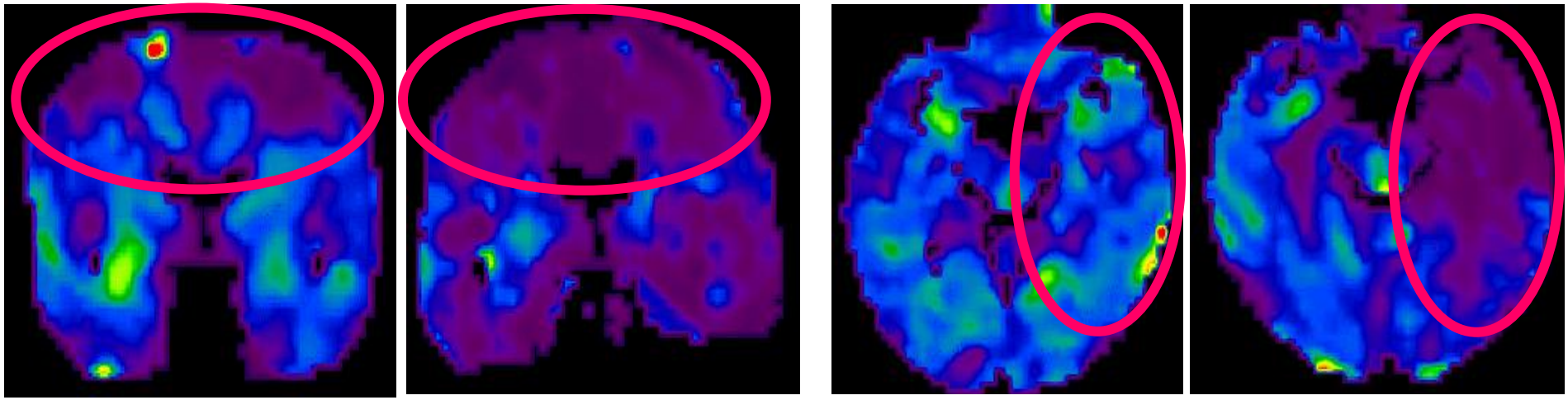
Characterizing Neurodegenerative Disease?

Patients with Alzheimer's disease have significantly decreased brain stiffness, compared with age-matched, cognitively-normal subjects.



Murphy M, J Magn Reson Imaging. 2011 Sep;34(3):494-8.

MRE in Neurodegenerative Disease

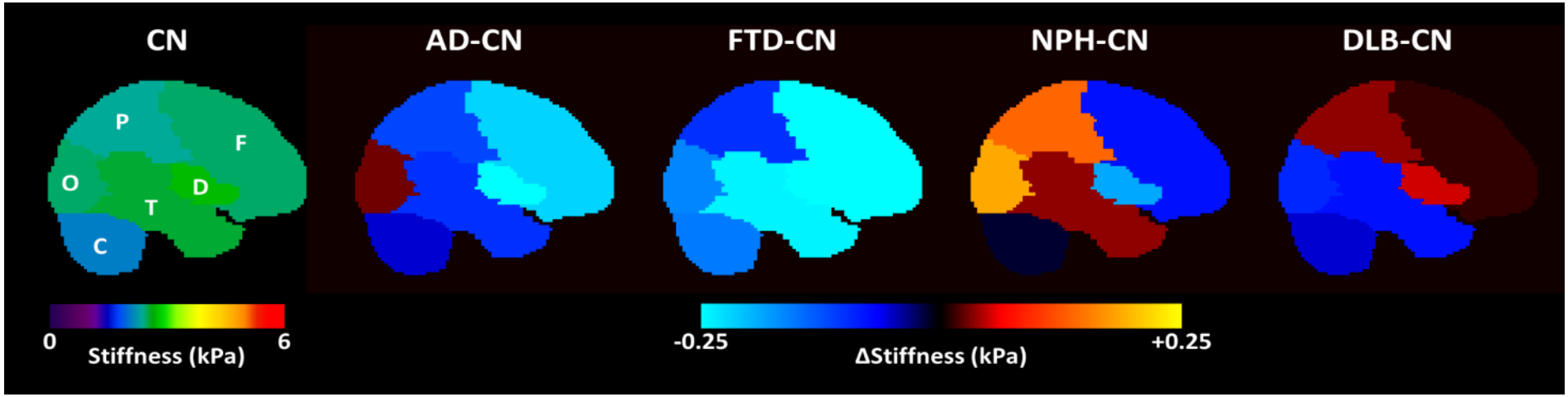


Normal Control
87 y female

AD Patient
87 y female

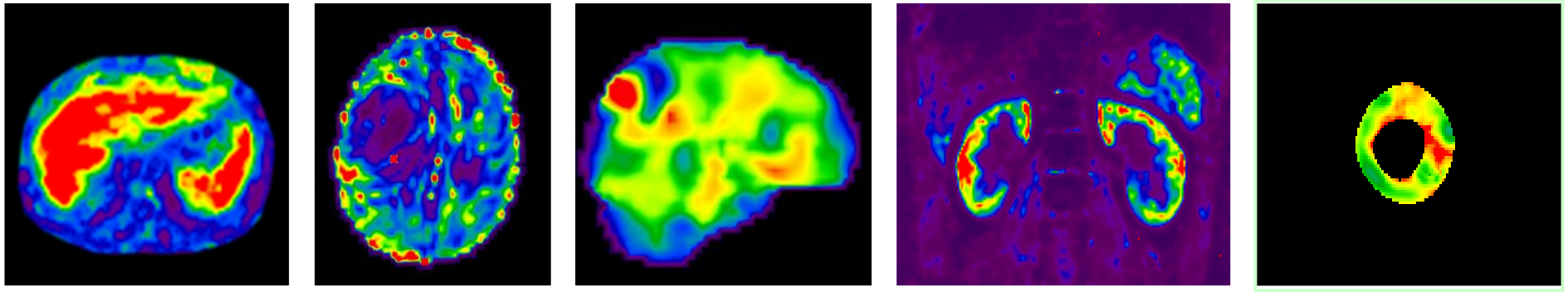
Normal Control
65 y male

FTD Patient
65 yr male

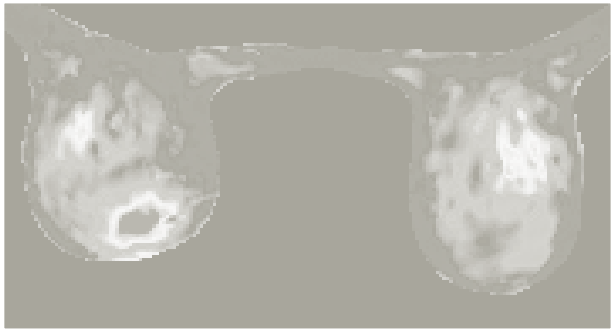


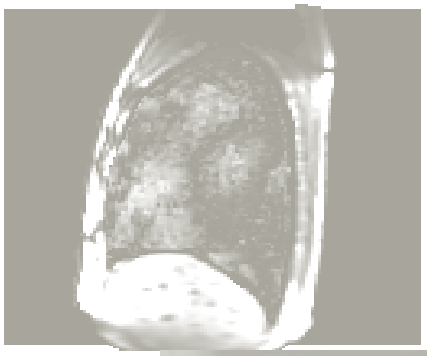
Magnetic Resonance Elastography

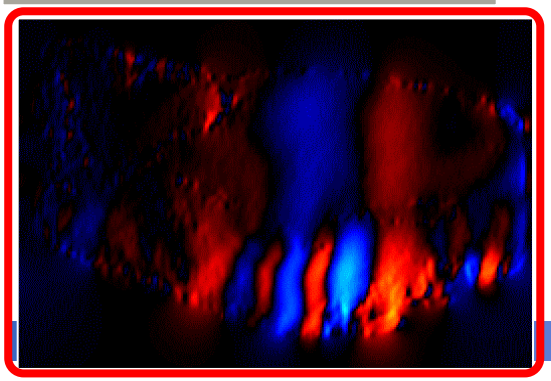
- **Provides an array of new quantitative imaging biomarkers**
- **Basic technology platform now widely deployed worldwide**
- **Established as a reliable, comfortable, and less costly alternative to liver biopsy for assessing hepatic fibrosis**
- **Brain imaging is likely to be the next well-established clinical application of MRE**
- **Unique tool for studying musculoskeletal biomechanics…**



MR Elastography







Brain
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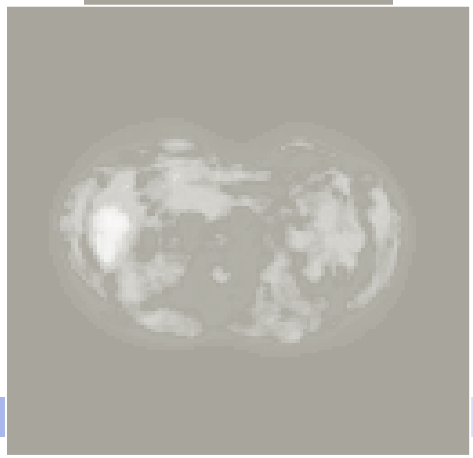

Thigh muscle Magnetic Resonance Elastography (MRE)

JMRI Journal of Magnetic Resonance Imaging | ISMRM ONE COMMUNITY FOR CLINICIANS AND SCIENTISTS

Technical Note | Free Access

Determination of thigh muscle stiffness using magnetic resonance elastography

Sabine F. Bensamoun PhD, Stacie I. Ringleb PhD, Laurel Littrell MD, Qingshan Chen PhD, Michael Brennan MD, Richard L. Ehman MD, Kai-Nan An PhD

First published: 22 December 2005 | https://doi.org/10.1002/jmri.20487 | Cited by: 95

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Archives of Physical Medicine and Rehabilitation
Volume 88, Issue 12, December 2007, Pages 1658-1661

Original article

Identification and Quantification of Myofascial Taut Bands With Magnetic Resonance Elastography

Qingshan Chen MS [a], Sabine Bensamoun PhD [a], Jeffrey R. Basford MD, PhD [b], Jeffrey M. Thompson MD [b], Kai-Nan An PhD [b]

Cited by: 108

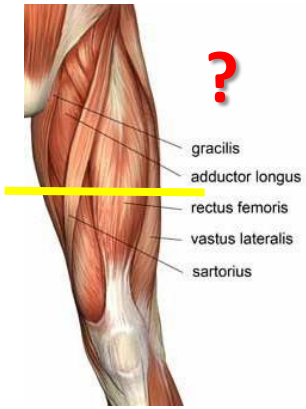
Purpose

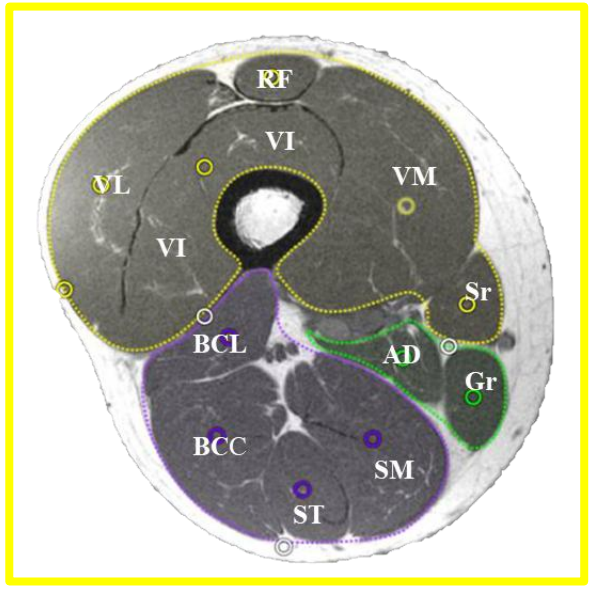
Characterize the mechanical properties of soft tissue (muscle and liver) to provide quantitative measurements to the clinician

Assess the degree of disease severity

Follow treatment effects

Improve knowledge of the behavior, the mechanism of the tissue : personalized treatments

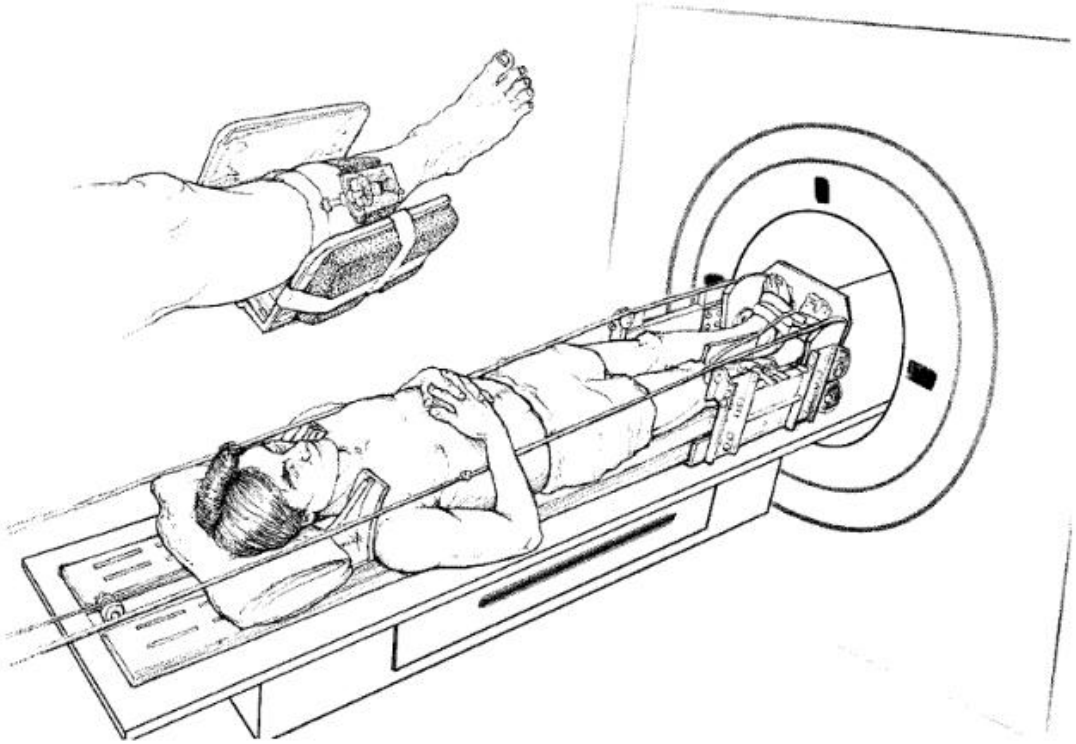




Context

2002: The first MRE muscle study → Calf muscle

“ To investigate whether a new tissue-imaging technique, magnetic resonance elastography (MRE), offers a viable, noninvasive way to study healthy and diseased muscle ”



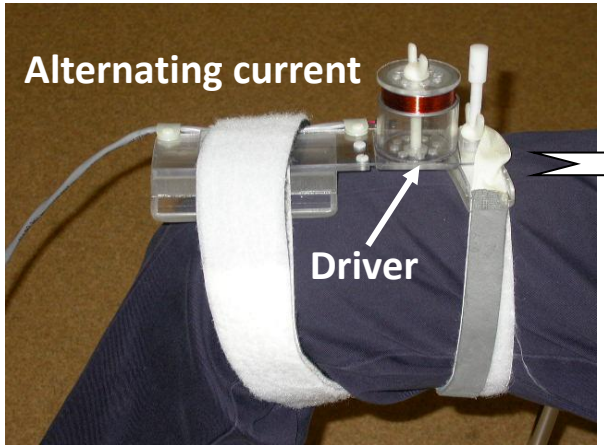
Basford et al., 2002

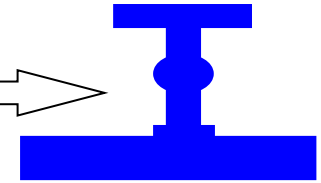
Nothing on thigh muscle

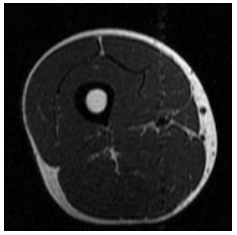
Objective: characterization of the mechanical properties of healthy and pathological thigh muscles

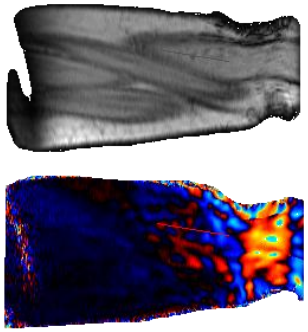
How to induce the waves inside the muscle ?

Mechanical driver (low frequency: 120Hz)

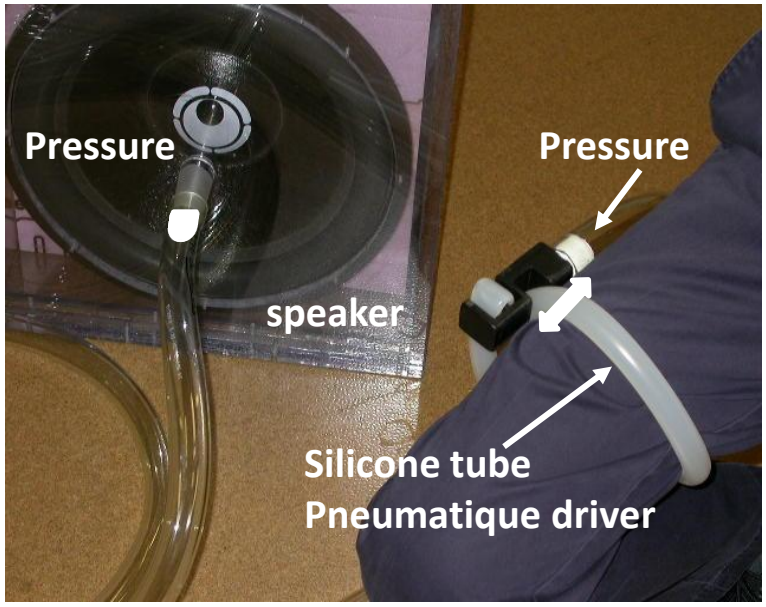




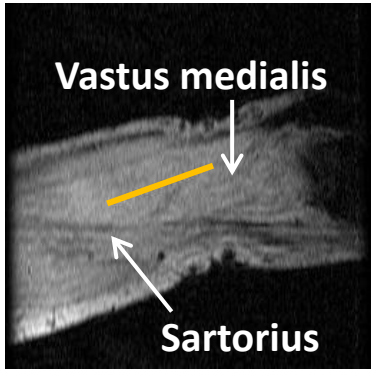


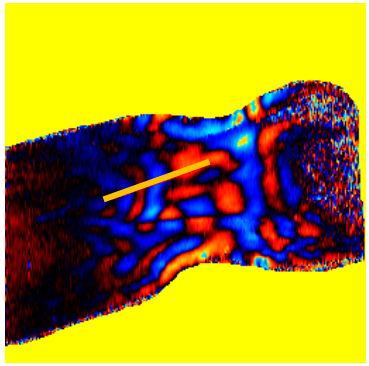


Difficult to see the waves
II
subcutaneous adipose tissue



6 months after

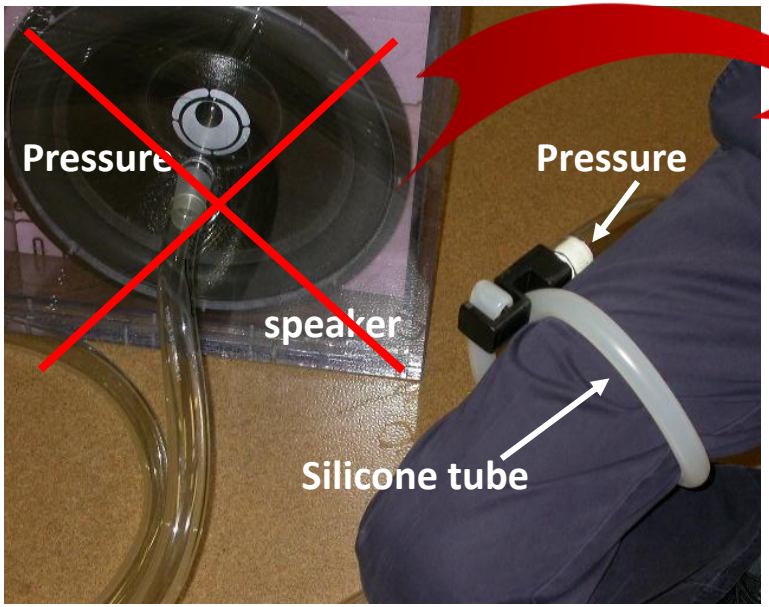




Waves are propagated with and without Subcutaneous tissues

How to induce the waves inside the muscle ?

2004 – 2006 Mayo Clinic

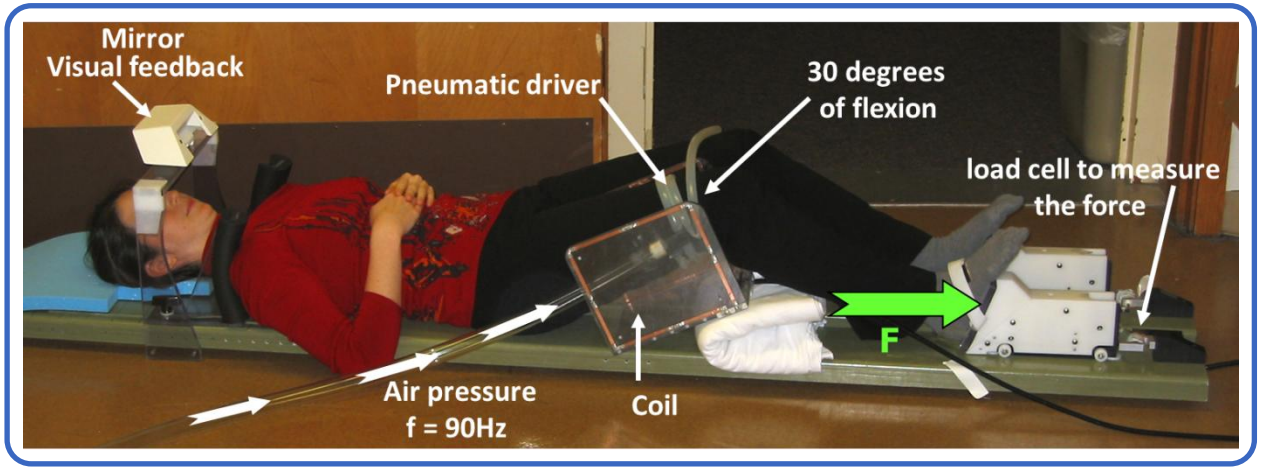


2007

RESOUNDANT

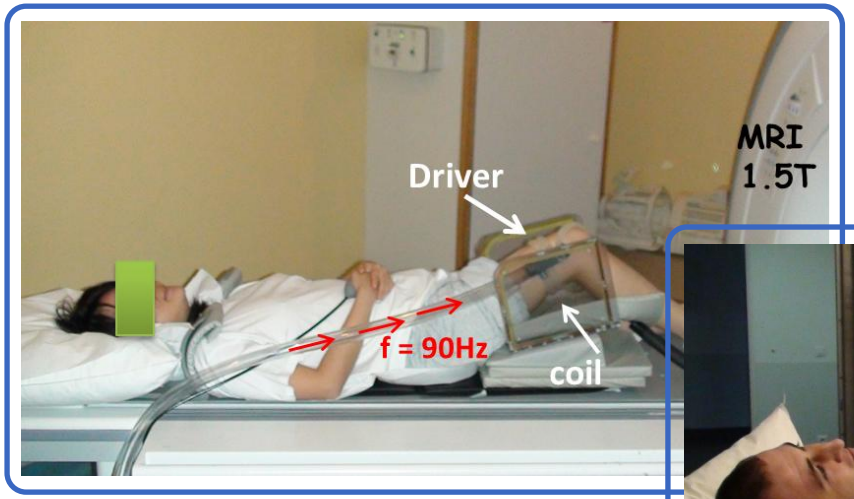
2013

Experimental Set-up to analyze the muscle in passive and active condition

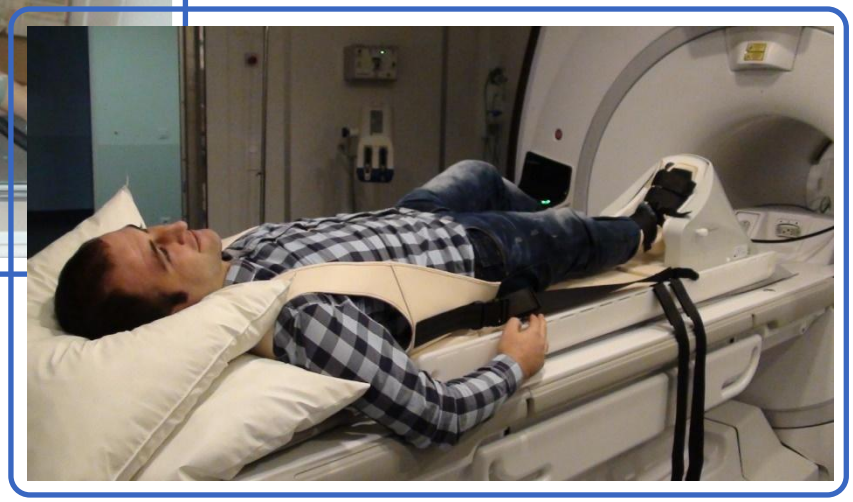


Muscle is characterized: passive (relaxed) and active (contracted) conditions

2006



2008



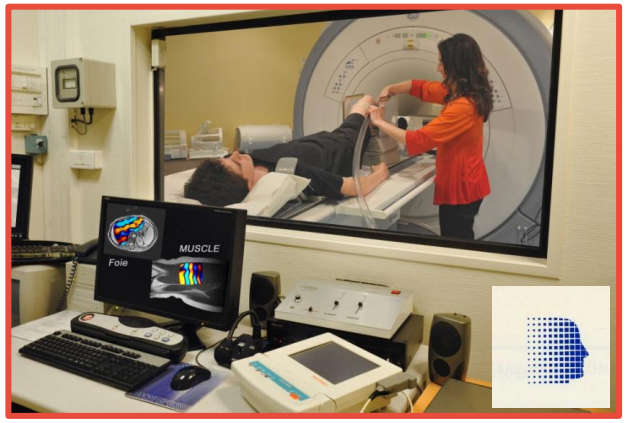
2012

MR Elastography Platforms

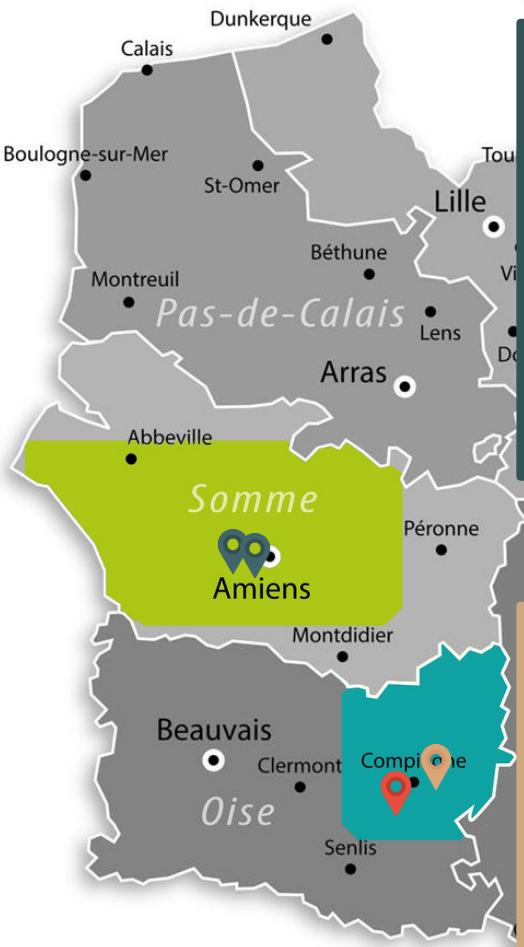
2018: Third platform

Institut Faire Faces (IFF)

2007: First platform



Centre d'Imagerie Medicale Avancée de Compiègne (CIMA)



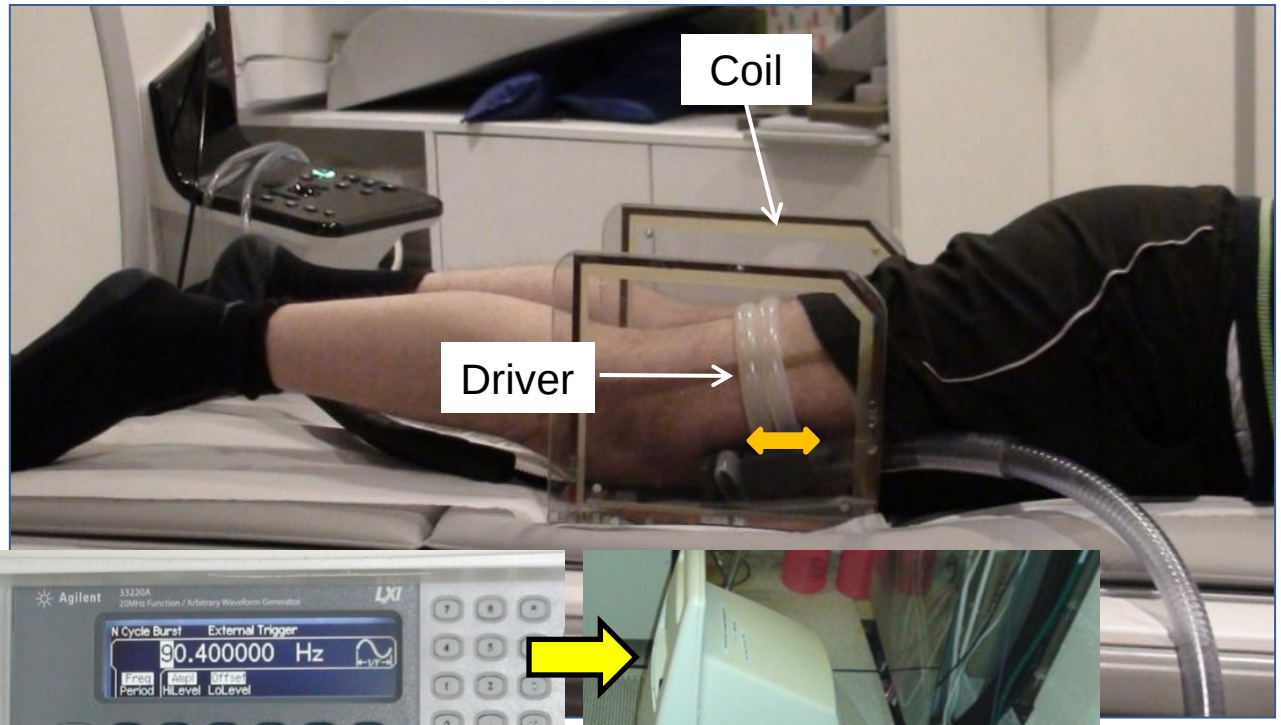
2021: Forth platform

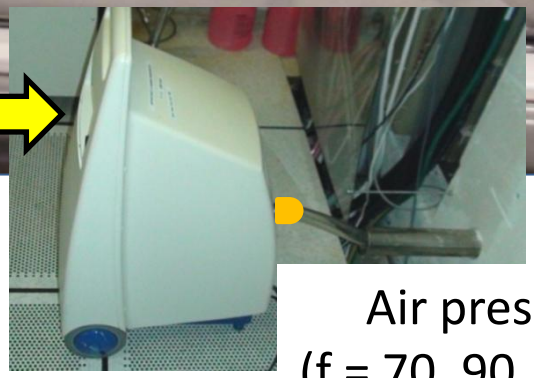
2013: Second platform

Polyclinique St Côme

Thigh muscle MRE tests

1.5T MRI machine (GE), Gradient echo sequence, field of view : 24 cm, 256x64 acquisition matrix

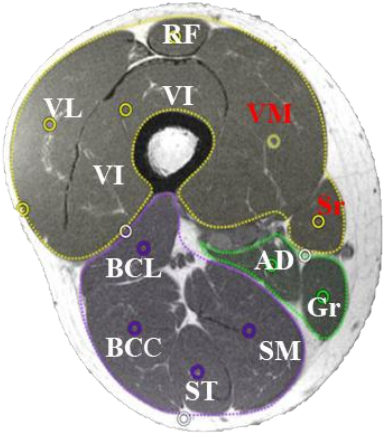




Air pressure
(f = 70, 90, 110Hz)

The total scan time was about 38 s

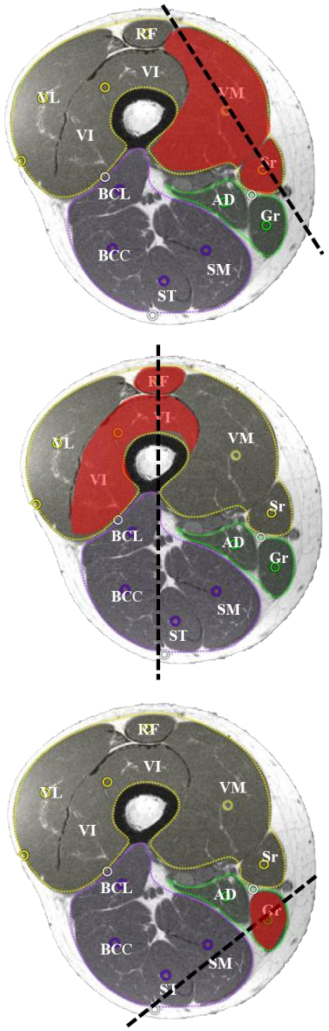
Development of MRE protocols to visualize the displacement of the waves in all the thigh muscles



Quantify the viscoelastic properties of all the thigh muscles

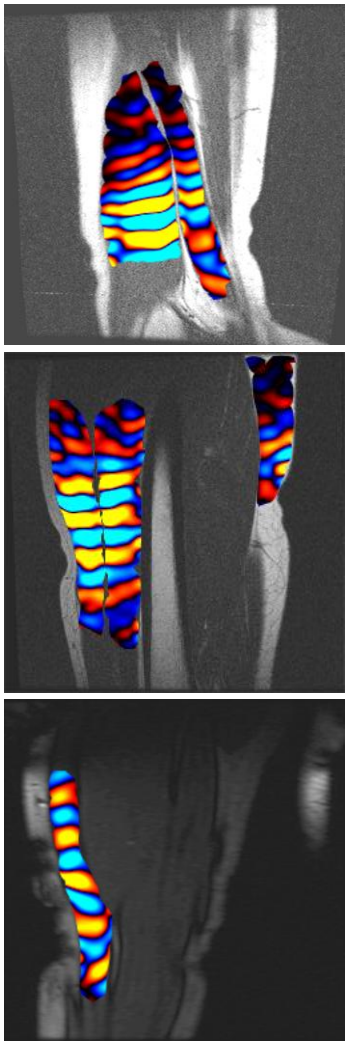
Protocols for the different acquisitions of the phase images

Axial anatomical image



Coronal anatomical image

Phase image superimposed on the anatomical image



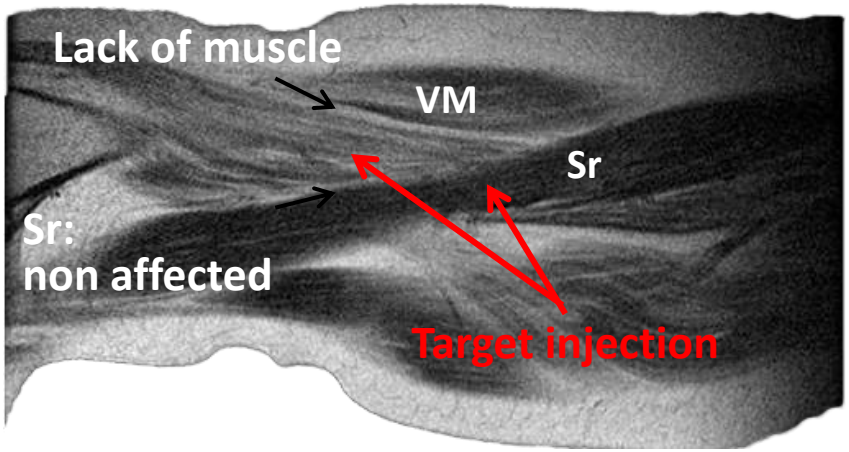
Valorizations

Sabine Bensamoun

Dystrophy Muscular Duchenne (DMD)

- Measurement of the mechanical properties
- Development of the MRE protocols

→ Development of a non invasive tool to follow the treatment



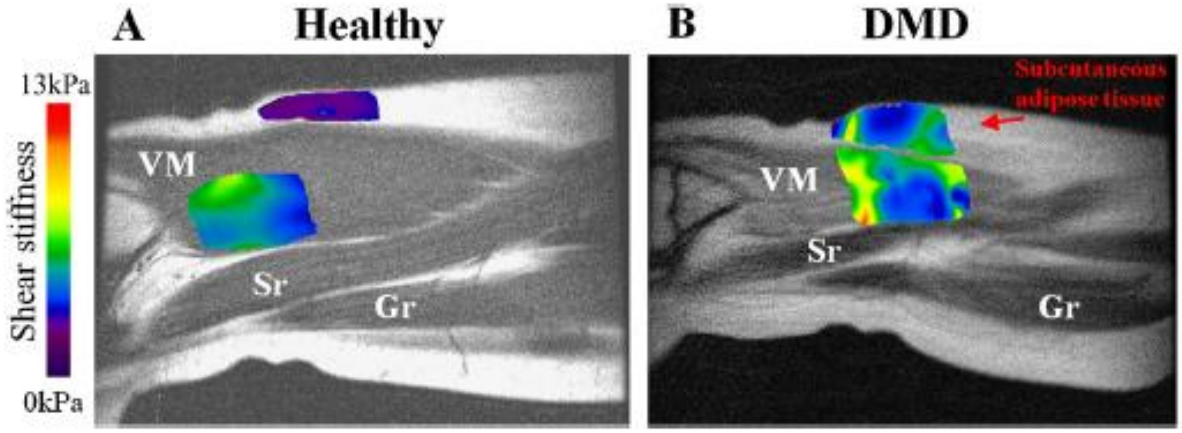
SORBONNE UNIVERSITÉS

INVESTISSEMENTS D'AVENIR

IUIS 2015

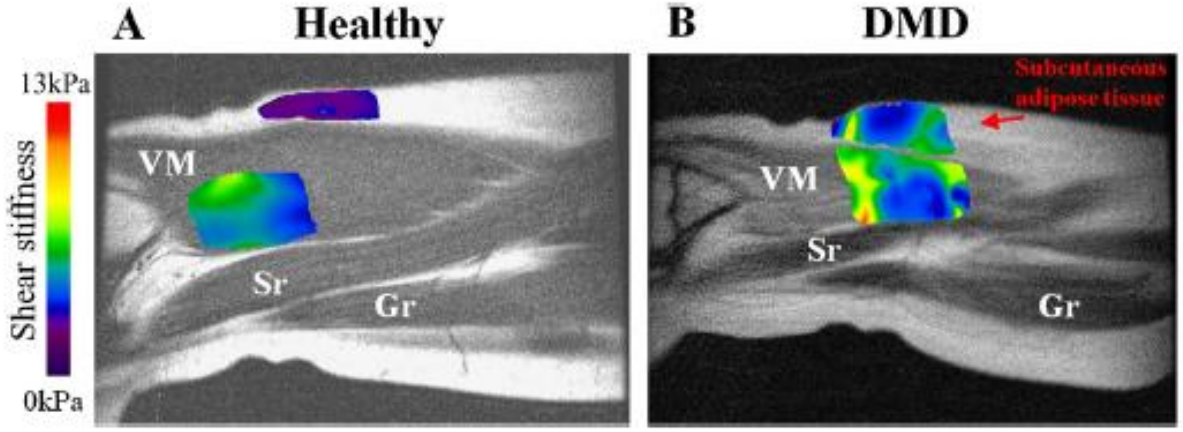
To evaluate the functional properties of individual muscle before and after treatment

Dystrophy Muscular Duchenne (DMD)



- **The present protocol is capable to measure the elastic properties (μ) for DMD**
- **Adipous tissu μ DMD > μ Sain : new observation, must be confirm with more patients**
- **Relax Muscle μ DMD > μ Sain : fatty infiltration**
- **Contracted Muscle μ DMD < μ Sain : decrease of contractibility**

Dystrophy Muscular Duchenne (DMD)



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IRBM
IRBM 36 (2015) 4–9

Technical note

Elastic properties of skeletal muscle and subcutaneous tissues in Duchenne muscular dystrophy by magnetic resonance elastography (MRE): A feasibility study

S.F. Bensamoun [a,*,1], F. Charleux [b,2], L. Debernard [a,1], C. Themar-Noel [c,2], T. Voit [c,d,2]

Animal Research and Alternatives

Despite the difference in appearance between humans and animals they have a very similar genetic → 99% between Mice and Men